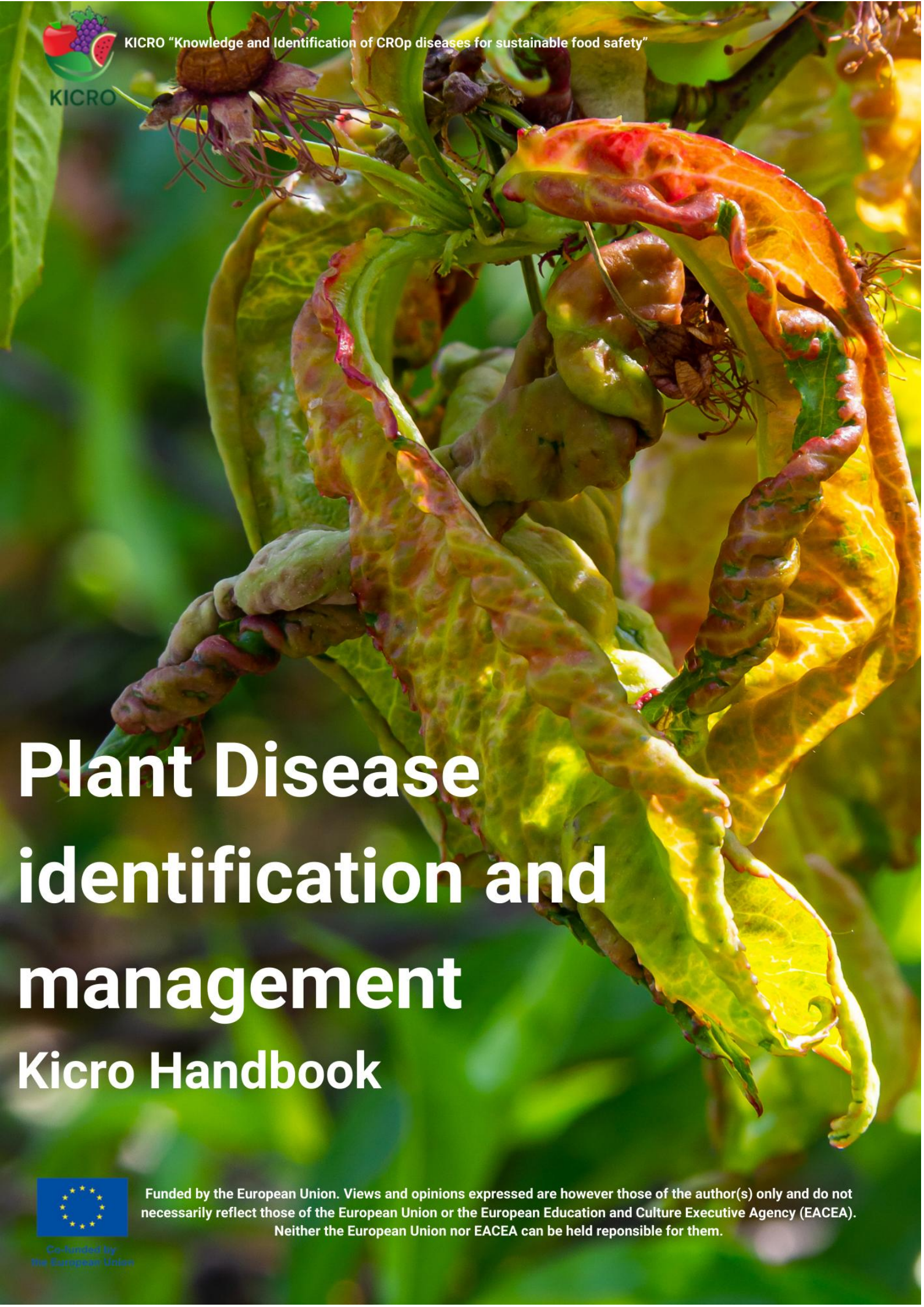
KICRO "Knowledge and Identification of CROp diseases for sustainable food safety"



Plant Disease identification and management

Kicro Handbook

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Summary

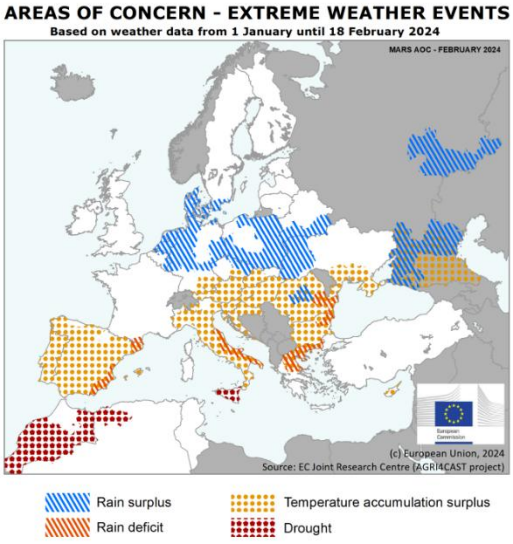
CHAPTER 1

Introduction

In the constantly evolving landscape of European agriculture, weather patterns play a crucial role in shaping crop conditions and productivity. The continent's diverse geography and climatic zones contribute to a wide range of agricultural practices and challenges faced by farmers. Over the past few years, it has become increasingly evident that European crop conditions exhibit significant regional disparities, largely influenced by extreme weather patterns. Specifically, as of May 2024, these disparities were pronounced, with most of Europe experiencing warmer-than-usual weather, while the north-western, northern-central, and eastern regions encountered above-average rainfall. Additionally, several areas around the Mediterranean and Black Sea faced substantial deficits in rainfall.

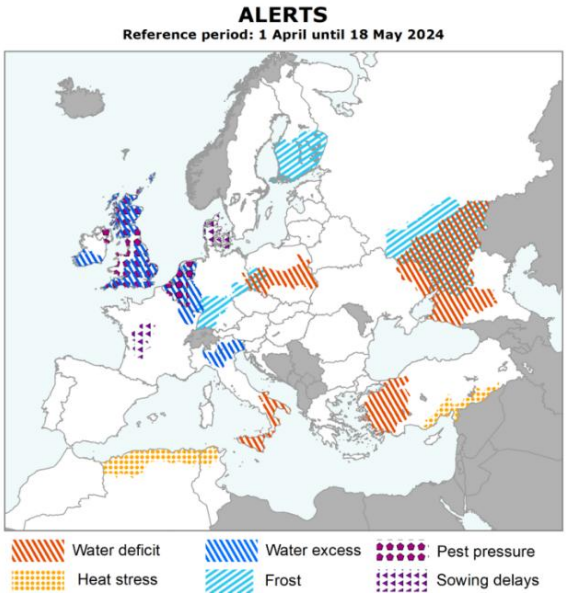
The Benelux countries and north-western Germany faced continuous heavy rains, leading to waterlogging and localized flooding, which hindered crop growth and delayed fertilization. Similar challenges were observed in Denmark and southeastern Sweden, exacerbated by intense rainfall in early February. On the other hand, eastern Germany, Czechia, Poland, Belarus, western Ukraine, central Romania, and European Russia experienced precipitation surpluses, primarily from heavy February rains, which fortunately did not threaten crops. However, southeastern Romania and northeastern Bulgaria encountered significant rain deficits, adversely affecting winter crops. Additionally, coastal Mediterranean areas in Spain experienced worsening rain shortages, impacting crops and water reserves. Despite these adversities, Greece's agricultural regions managed to maintain adequate soil moisture levels.

Italy witnessed one of its driest periods since 1991, while southeastern Germany, Austria, Czechia, and Slovakia saw unusually mild temperatures, benefiting late-sown crops but making winter crops more vulnerable to cold snaps. Meanwhile, Portugal, Spain, and Greece recorded high temperatures without significant concerns regarding crop growth. In Cyprus, above-average temperatures and normal rainfall potentially benefited winter barley growth (Joint Research Centre, 2024, February).



Throughout the winter season, adverse weather conditions affected winter crop areas in various regions. Northern areas anticipate resowing fields with spring or summer crops, while southern regions faced decreased yield potential. Extensive parts of western, northern, and eastern Europe encountered overly wet conditions, hindering winter crop development. Severe frost events in northern and eastern Europe caused further damage, compounded by persistently wet soils, making fieldwork challenging. In eastern Romania, eastern Bulgaria and Sicily winter crop growth was hampered by a persistent lack of rainfall or drought conditions (Joint Research Centre, 2024, March).

Overall, these diverse weather patterns led to slight downward adjustments in EU yield forecasts, with challenges such as waterlogging, pest pressure, and water deficits affecting crop yields in various regions. Additionally, a cold spell in April caused considerable damage to fruits and vineyards across Europe, particularly in southern and eastern Germany, Czechia, Poland, and southern Finland, while water deficits in regions like eastern Germany and Poland highlight the ongoing need for more rainfall to sustain crop outlooks (Joint Research Centre, 2024, May).



Source: EC Joint Research Centre, 2024.

Climate change, which leads to the aforementioned weather patterns, profoundly impacts plant diseases through complex interactions involving pathogens, hosts, and environmental factors. Elevated temperatures enhance pathogen survival and virulence, accelerating diseases like coffee leaf rust, while simultaneously weakening plant immunity and facilitating rapid pathogen spread. Increased carbon dioxide levels variably affect disease dynamics; while some diseases worsen, such as powdery mildew in vineyards, others like downy mildew in soybeans diminish. Changes in humidity and soil moisture further complicate predictions: high humidity fosters fungal diseases, whereas drought can stress hosts or inhibit pathogen activity.

Climate change also drives pathogen evolution, enhancing their global infectivity, exacerbated by agricultural practices and international trade. Soil and plant microbiomes play pivotal roles: diverse microbial communities bolster plant immunity, whereas degraded soils increase vulnerability to pathogens. Climate-induced shifts in plant physiology and root exudates alter the plant microbiome, influencing pathogen interactions. Beneficial microorganisms can mitigate disease incidence, but instability in plant immunity may aid pathogen invasion (Singh et al., 2023).

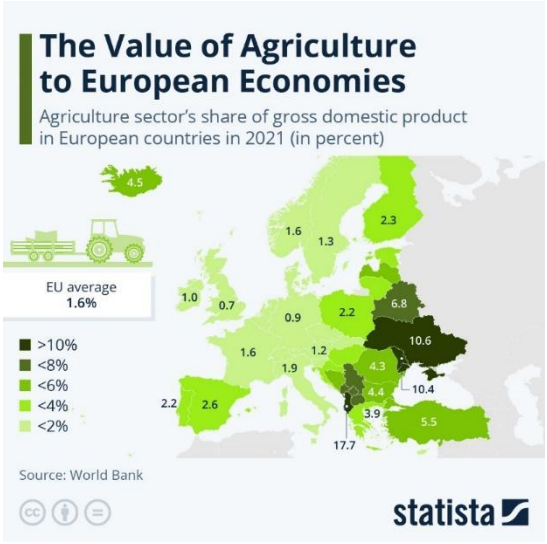
The impacts on fruit crop production are stark and varied. For instance, apple yields in Himachal Pradesh dropped from 10.8 to 5.8 tons per hectare due to climate shifts, demonstrating vulnerability to erratic weather. Similarly, mango orchards in Gujarat experience 80-90% yield losses from unseasonal rains and heavy dew, underscoring climate change's detrimental effects. High temperatures above 38ºC significantly hinder banana production through bunch choking, while Cape

gooseberry plants suffer 10-40% yield losses from prolonged water stress. Strawberries see up to 35% yield decreases under varying nitrogen levels, reflecting intricate environmental interactions affecting productivity (Chawla, Mohit, Sadawarti, & Sheokand, 2021).

Furthermore, climate change disrupts fruit crop phenology, physiological responses, and quality parameters. Changes in phenology affect optimal fruit production cycles, with physiological stressors like reduced water efficiency and increased heat further jeopardizing crop health. Quality parameters such as fruit ripening and susceptibility to sunburn are altered, impacting marketability. Geographical suitability for fruit cultivation shifts, necessitating resilient crop varieties and optimized practices. Pest and disease dynamics escalate with warmer temperatures and altered rainfall, favoring pathogens like powdery mildew and bacterial blight (Bhattacharjee, Warang, Das, & Das, 2022). As a result, understanding these complex interactions is crucial for mitigating the far-reaching effects of crop loss on food security, economic stability, and societal well-being.

More specifically, crop loss has far-reaching effects across multiple dimensions. Firstly, it contributes to food insecurity, particularly in developing nations where agriculture serves as the primary source of sustenance and income. With failed crops, farmers not only struggle to feed their families but also face challenges in supplying local markets. This predicament exacerbates malnutrition and hunger, especially among vulnerable demographics such as children and the elderly.

Secondly, the economic repercussions of crop loss are significant. Farmers bear the brunt of financial hardship as they lose their primary source of income. Moreover, the ripple effects extend to consumers through increased food prices, impacting their purchasing power and potentially triggering inflation. Additionally, agricultural exports may suffer, consequently affecting a country's balance of trade and overall economic growth.



Lastly, crop loss contributes to adverse environmental outcomes. In response to failed crops, farmers may resort to clearing more land for cultivation, thereby accelerating deforestation and habitat destruction. Furthermore, the use of chemical pesticides and fertilizers to safeguard crops not only harms soil and water quality but also poses risks to wildlife and ecosystem integrity.

To mitigate the impact of crop losses, Integrated Pest Management (IPM) practices are essential. These practices include the use of disease-resistant crop varieties, cultural practices, and chemical control measures (Erlee S, 2023). IPM focuses on fostering healthy crop growth with minimal disruption to agro-ecosystems, thereby encouraging natural pest control processes. For instance, key strategies for preventing or controlling harmful organisms include crop rotation and employing suitable cultivation techniques such as the stale seedbed technique, optimal sowing dates and densities, under-sowing, conservation tillage, pruning, and direct sowing. Furthermore, it involves using resistant or tolerant cultivars and certified seeds and planting materials when appropriate. Additionally, IPM includes applying balanced fertilization, liming, and irrigation/drainage practices, as well as implementing hygiene measures to prevent the spread of harmful organisms, such as regular cleaning of machinery and equipment. Moreover, IPM emphasizes protecting and promoting beneficial organisms through appropriate plant protection measures or by utilizing ecological infrastructures within and around production sites.

Monitoring harmful organisms through effective methods and tools, including field observations and scientifically-based warning, forecasting, and early diagnosis systems, is crucial. To complement these efforts, professional advice should also be sought when necessary. Consequently, decisions on

plant protection measures must be based on monitoring results, using robust and scientifically valid threshold values tailored to the region, specific areas, crops, and climatic conditions.

Furthermore, non-chemical methods must be prioritized for pest control if they are effective. However, when pesticides are necessary, they should be target-specific and have minimal side effects on human health, non-target organisms, and the environment. To ensure this, professional users should minimize pesticide use and other interventions, applying reduced doses, less frequent applications, or partial applications. This approach helps in ensuring acceptable vegetation risk levels and prevents resistance development in pest populations.

In cases where resistance risks are known and repeated pesticide applications are required, anti-resistance strategies, such as using multiple pesticides with different modes of action, should be implemented. Finally, professional users must evaluate the success of plant protection measures based on pesticide use records and pest monitoring data. This continuous assessment ensures the ongoing effectiveness and sustainability of the IPM approach (European Commission, n.d.).

Stages of Integrated Pest Management (IPM)

1. Prevention Implement practices to reduce pest establishment, reproduction, and survival.
2. Monitoring and Identification Regularly monitor for pest presence and accurately identify pests.
3. Setting Action Thresholds Determine the level at which pests become an economic threat.
4. Control Methods Apply the effectiveness of the pest management strategy and make adjustments.

5. Evaluation

Assess the effectiveness of the pest management strategy and make adjustments.

This educational material explores the diseases affecting specific fruits in the field, detailing their symptoms, signs, management tips, identification strategies, and potential physiological disorders. Additionally, it examines post-harvest diseases and provides practical management tips. A key focus is also on disease management strategies and best practices essential for maximizing cultivation and ensuring optimal production. Before delving into the specifics of each fruit's diseases and physiological disorders, it is crucial to acknowledge the commonalities in post-harvest guidelines across various fruits. While each fruit may present unique challenges, the principles governing post-harvest management often overlap, providing a foundational understanding that can be applied broadly.

In terms of post-harvest management, fruits such as lemons, grapes, cherries, strawberries, oranges, apples, raspberries, plums, peaches, and watermelon share several common practices aimed at minimizing losses and preserving quality. Central to these practices is the careful handling of harvested fruit to prevent physical damage, which can lead to fungal infections. For instance, maintaining proper temperature and humidity levels is crucial across all these fruits. Grapes and strawberries benefit from rapid cooling and storage at low temperatures with controlled humidity to inhibit pathogen growth, while proper temperature management is also vital for cherries, oranges, and watermelons to slow down the growth and spread of pathogens.

Furthermore, sanitation plays a key role in post-harvest management. Regular cleaning of harvesting equipment, containers, and storage facilities helps prevent the spread of diseases. For lemons, regularly cleaning packing line equipment prevents dirt and wax buildup that can cause fruit abrasion, while cherries benefit from keeping harvest and storage areas clean and free of plant debris. Apples also require meticulous cleaning of storage areas to prevent the spread of pathogens.

In addition to these practices, the use of fungicides is a common approach across these fruits. However, it is essential to adhere to the recommended timing and pre-harvest intervals to ensure safe residue levels. For example, treating lemons with a registered fungicide within 24 hours of harvest helps prevent green and blue molds. Similarly, strawberries and cherries require judicious fungicide

use to manage post-harvest diseases effectively, ensuring that the fruits remain safe and high-quality for consumers. For apples, fungicide applications should consider weather conditions and the developmental stage of both the plant and pathogen to maximize effectiveness.

Moreover, sorting and grading to remove damaged or diseased fruit before storage or transportation is emphasized to maintain high quality. This practice is crucial for all fruits, including lemons, cherries, and strawberries, ensuring that only high-quality fruits are packed and marketed. Apples, for example, benefit from removing infested shoots early in the season to reduce the source of infections.

Packaging also plays a significant role, with the use of clean, sanitized materials to prevent contamination during storage and transport, thus preserving the integrity of the fruits. For example, lemons must avoid exposure to direct sunlight and cold, wet conditions to prevent oleocellosis. Meanwhile, grapes require materials that prevent infections and maintain low temperatures around 0°C. Oranges necessitate careful handling to avoid heat damage and proper storage temperatures (4-7°C) and humidity levels (85-90%), whereas strawberries require rapid and consistent cold storage with relative humidity between 90% and 95%. For apples, maintaining appropriate storage conditions, including temperature and humidity control, is essential to prevent diseases like apple scabs and grey mold.

Similarly, watermelons need to avoid direct sunlight exposure, use clean, smooth harvesting bins, and promptly remove old fruit from packing areas. Additionally, watermelons benefit from pre-harvest management practices such as planting in well-drained fields, using raised beds and drip irrigation, and rotating crops to reduce post-harvest losses.

By focusing on careful handling, maintaining proper environmental conditions, ensuring sanitation, judicious use of fungicides, and effective sorting and packaging, it is possible to minimize post-harvest losses and maintain the high quality of lemons, grapes, cherries, strawberries, oranges, watermelon, apples, and other fruits. This comprehensive approach to disease management and best practices is essential for maximizing cultivation and ensuring optimal production, which is one of the main objectives of the KICRO project. Integrating these specific guidelines for each fruit into the overall framework of post-harvest management allows growers to enhance the quality and longevity of their produce, achieving the goals of the project.

The KICRO project, co-funded by the EU under the Erasmus+ Programme, is committed to addressing significant policy priorities, particularly focusing on environmental sustainability and combating climate change. This initiative aims to empower the fruit growing sector, including farmers and packinghouse staff, by equipping them with advanced tools to better understand and identify diseases in fruits and vegetables. Addressing these issues is crucial, as they are key contributors to food loss along the supply chain, which has severe environmental impacts.

Food loss results in unnecessary greenhouse gas emissions and inefficient utilization of water and land, leading to the degradation of natural ecosystems. By mitigating food losses, the project enhances food availability and safety, thereby promoting environmental sustainability. Fruit decay, triggered by both abiotic factors like adverse climate conditions and biotic factors such as pathogens, is worsened by climate change. Rising temperatures and increased UV radiation foster the emergence of new pathogens, making it vital for the fruit growing sector to have effective tools to tackle these challenges.

The KICRO project directly supports the priority of 'Environment Actions and Fight Against Climate Change' by developing and sharing knowledge and skills to reduce the environmental footprint of fruit production. This initiative will enable farmers and packinghouse staff to more effectively identify and manage crop diseases, reducing the reliance on chemical treatments and storage interventions. Consequently, this promotes practices such as organic farming, soil protection, and natural resource management, aligning with the objectives of the European Green Deal.

Furthermore, the project aligns with the priority of adapting vocational education and training (VET) to labor market needs. By enhancing skills and creating work-based learning opportunities for stakeholders in the fruit growing sector, the KICRO project supports evolving job roles and methodologies. The improved competencies in crop disease identification and management contribute to a sustainable, green, and digital transition within the industry, fostering economic resilience and growth.

In conclusion, climate change contributes significantly to European crop losses by exacerbating outbreaks of pathogens, which directly lead to reduced agricultural yields. This educational material aims to explore these specific challenges, detailing the symptoms, signs, and management strategies for various crop diseases, alongside practical insights into post-harvest management. By addressing these issues, we not only enhance our understanding of agricultural sustainability but also equip

farmers and stakeholders with the tools and knowledge necessary to mitigate losses and ensure optimal production. Through initiatives like the KICRO project, supported by the EU under the Erasmus+ Programme, we can actively work towards environmental sustainability and the broader goals of the European Green Deal.

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CHAPTER 2

Plum [Prunus domestica L., 1753]

Author: Yordan Nikolov
Organisation: Balkan Bridge

WHAT WILL WE LEARN IN THIS CHAPTER?

We're going to learn about the intricacies of plum trees, their fruit-related diseases both in the field and post-harvest, along with the physiological disorders they may develop. This comprehensive exploration encompasses disease management strategies and best practices aimed at optimizing plum cultivation.

Keywords: Black Knot, Powdery mildew, Brown rot, Rhizopus Rot

Summary

1. Overview

Plum is a fruit that belongs to the genus *Prunus L.* in the Rosaceae family. It is a small, round or oval-shaped fruit that can range in colour from yellow to red to purple, depending on the variety. Plums are generally sweet and juicy, with a slightly tart flavour. Plum fruits are commonly consumed fresh or used to make jams or jellies. Plums may be dried to produce prunes.

2 Field Diseases and physiopathies

2.1 Black Knot *(Apiosporina morbosa)*

Black knot, caused by the fungus *Apiosporina morbosa*, is a very destructive disease of plum and prune. It is also quite common on wild plum and cherry as well as on *Prunus* species in the landscape. The disease affects only woody tissues and can develop on twigs, branches, and scaffold limbs. Losses result from extensive dieback of girdled limbs and stunting of growth beyond the knots. In extreme cases, whole trees can be killed. Symptoms are easily recognized as hard, black, elongate swellings or galls on twigs, branches, and trunks of trees. While knots are most outstanding on dormant trees, newly formed knots are greenish and soft but become hard and black with age. The fungus overwinters on infected twigs and produces spores in spring. New shoots are susceptible and can be infected soon after budbreak and throughout the period of active shoot elongation. However, most infections are thought to occur just before bloom or after petal-fall. Wet spring weather is favorable for disease since rain is important for discharging the spores from the knots. In addition, wind and rain help to spread these spores to the susceptible tissues. Spores of black knot are capable of penetrating unwounded tissues, so they do not require wounds in order to infect. Most infections occur in spring but symptoms are often not visible until fall when they appear as small swellings on the twigs. These knots gradually enlarge, mature, and take on their diagnostic rough, black appearance during the winter and the following spring.

Symptoms and signs

Initial Symptoms:

The first sign of infection is a small, light brown or olive-green swelling on the current year's growth of twigs and branches. This swelling may appear in late spring or early summer. As the fungus develops, the swelling darkens and becomes more noticeable. By late summer or early fall, it turns a dark brown or black colour.

Knots Formation:

The distinctive symptom of black knot is the formation of rough, black, elongated galls (knots) on the branches and twigs. These knots are often about 1/2 inch to 1 inch in diameter but can grow larger over time. The knots may grow around the entire circumference of a branch, effectively girdling it. This cuts off the flow of nutrients and water, leading to the death of the branch beyond the knot.

Management

Control is best achieved using a combination of pruning and sanitation, properly timed fungicide sprays, and resistant varieties. Pruning and sanitation are essential to any control

program since fungicide sprays are relatively ineffective unless old knots are pruned and removed from the vicinity of the tree. Infected tissues should be pruned before budbreak and cuts made at least 6-8" below any visible swellings or knots. In addition, any wild plum, cherry, or ornamental Prunus species with symptoms should be pruned or removed within 600 feet of the orchard. These trees can be important sources of inoculum. Resistance is an option for control since plum varieties differ in their susceptibility to black knot. The cultivars Stanley, Damson, Bluefree, and Shropshire are considered most susceptible; Fellenburg, Methley, Milton, Bradshaw, and Early Italian are moderately susceptible; Formosa, Shiro, and Santa Rose are slightly susceptible; and President is considered highly resistant. In general, Japanese varieties are less susceptible than most American varieties. In conjunction with pruning and sanitation, a fungicide spray program is necessary for effective black knot control. Properly selected and timed fungicide applications should be made to protect developing twigs (refer to Spray Guide below).

Black knot can be prevented from spreading by spraying trees with NEEM oil and also products containing chlorothalonil, captan, and thiophanate-methyl (it will not destroy fungus that is already present). As directed, spray trees immediately before the leaves and blossoms appear and, if possible, before it rains. Until the weather clears, keep going on a cycle according to the. It is believed that spore formation can be avoided by spraying trees with lime sulfur while they are dormant. During dormancy, copper sprays may also prevent the development of spores.

Identification tips

- Observe the Time of Year

Spring to Early Summer: Look for early signs of infection in the late spring to early summer. These are usually subtle and appear as small, light brown or olive-green swellings on new growth.

Late Summer to Fall: As the season progresses, these swellings will darken, making them easier to spot.

1.1 Examine Branches and Twigs

Check for any swollen areas on the branches and twigs. Early infections appear as small bumps or swollen sections on the current year's growth. Infected areas will start as light brown or green and then turn dark brown or black. The color change is a significant indicator of black knot.

- Look for Characteristic Knots

The most distinctive sign of black knot is the presence of hard, rough, black, knobby growths, or "knots," on the branches and twigs. These can range from 1/2 inch to several inches in diameter. The knots often have an elongated, spindle-like shape, and they tend to grow along the length of the branch rather than just around its circumference.

Figure 2: Elongated hard black swelling on twigs and branches are characteristics of black knot. https://www.birchtreecare.com/blog/black-knot-fungus

Figure 1: Black knot galls on an ornamental cherry (Prunus sp.) (N. Brazee, https://localgardener.net/black-knot-on-cherry-trees/)

2.2 Powdery mildew (*Sphaerotheca pannosa)*

Powdery mildew of plum attacks leaves, young shoots, and fruit. This fungal disease produces a characteristic white, powdery coating on the surface of affected leaves. Older leaves may show patchy areas of fungal growth, while shoots may become covered with the fungus. Diseased tissues are often deformed and stunted. Fruits first develop white circular spots, which may enlarge and coalesce to cover the entire fruit. Young fruit may be somewhat deformed, while older fruit may show scabby or dead areas. At this stage, the white fungal growth may not be visible. The fungus can overwinter on twigs and in infected buds. Powdery mildew is favored by high humidity, warm days, and cool nights.

Symptoms and signs

White, Powdery Spots:

The most characteristic sign of powdery mildew is the appearance of white or grayish powdery spots on the leaves, stems, and sometimes the flowers and fruits of the plant. These spots usually begin on the upper surface of leaves, but they can also appear on the undersides, stems, buds, and even flowers. The powdery spots can expand and coalesce, eventually covering large areas of the plant.

Leaf Symptoms:

As the infection progresses, affected leaves may become distorted, curled, or twisted. In some cases, the areas around the powdery spots may turn yellow or brown. Severe infections can cause leaves to wither and fall off the plant prematurely.

Stem and Bud Symptoms:

On some plants, powdery mildew may also infect stems, where it appears as white or gray powdery patches. In severe cases, stems may become stunted or deformed. If flower buds are infected, they may fail to open or produce distorted flowers.

Management

Prune for good air circulation and keep grass mowed to reduce humidity in the cultivation. This helps to promote rapid drying of the leaves, fruit, and twigs. Minimize infection by selecting planting sites that are not low-lying. You can also remove infected sprouts before full leaf occurs. Begin chemical control no later than petal fall and apply until harvest.
Fungicides can provide adequate control of this disease if applications are properly timed.
Three sprays are recommended at the following vegetative phases.

a) during petal fall
b) during calyx detachement (10 to 15 days after the 1st spaying)
c) 20 days after b

In areas with severe infection spraying is continued until shoot grow is completed.
Suitable chemicals for powdery mildew control are: dinocap, quinomethionate, benomyl, thiophanate-methyl, carbendazim, bupirimate, imazalil, pyrifenox, Tebuconazole etc.

Identification tips

- White, Powdery Spots

The most distinctive sign of powdery mildew is the presence of white, powdery spots or patches on the plant's leaves, stems, and sometimes flowers and fruits. Initially, these spots often appear on the upper surface of the leaves but can spread to the undersides, stems, and other parts of the plant. In the early stages, the spots may be small and scattered but can quickly grow and merge to cover large areas.

- Inspect the Leaves Closely

The white powdery coating has a dusty or talcum powder-like texture, which can be easily rubbed off with a finger. Surrounding the white spots, you might notice the leaf tissue turning yellow or brown, indicating the plant's reaction to the fungal infection. Infected leaves may curl, twist, or become distorted, especially as the disease progresses.

Figure 3: Epic Gardening. 15 Plum Tree Diseases to Watch Out For and How to Prevent Them. https://www.epicgardening.com/plum-tree-diseases/

Check the Stems and Buds

On some plants, powdery mildew also affects the stems, where it appears as white or gray powdery patches similar to those on the leaves. This can cause stunted or deformed stem growth. Powdery mildew can affect flower buds, leading to failure to open or resulting in distorted, less vibrant flowers.

Figure 4: Frontier Landscaping. (n.d.). Plant & insect pest profiles: Powdery mildew. https://frontierlandscaping.com/plant-insect-pest-profiles-powdery-mildew/

2.3 Cytospora Canker (*Leucocytospora cincta/L. leucostoma*)

Two related fungi (*Leucocytospora cincta/L. leucostoma*) that incite cytospora canker invade sites where damage has occurred due to mechanical injury, cold, poor pruning techniques, improper pruning time, borers, or other causes.

The first visible symptom is the oozing of gummy sap near the wound, beginning when temperatures warm in the spring. Because the fungus advances more rapidly up and down the branch than around the branch, cytospora cankers usually have an elongated shape.
In succeeding years, the bark becomes broken, disfigured, and covered with a black fungus overgrowth.

Symptoms and signs

The canker forms from a small necrotic center that slowly enlarges with the collapse of the inner bark tissue. Cankers enlarge more along the length than the width of the branch. Older cankers are therefore oval to elongated in outline.

New cankers often have complete outer bark, with the exception of gumming areas. The central bark of older cankers becomes torn. Alternate wetness and drying, as well as the presence of saprophytic fungi, cause the gum to turn black. A roll of callus tissue envelops older cankers. Because it repeatedly invades healthy tissue, the canker becomes larger every year. The tree defends itself by forming a callus ring around the canker with new growth in the spring. Until the lesser peach tree borer burrows through the callus ring and into good tissue, this can be a very effective protection.

Management

A tree infected with cytospora can live for many years after the initial infection, and the illness advances slowly. The first steps in management include removing wild or neglected plums and peaches from the area around the orchard and selecting planting locations away from existing peach and plum trees. Whitewashing trunks to reflect the winter sun can be beneficial because cold damage is frequently the main location of infection. Other management strategies focus on reducing tree damage by removing dead and diseased branches, managing borers, avoiding leaving pruning stubs, and pruning only in the early spring when temperatures have risen.

Identification tips

With the first warm temperatures in spring check every wound that weas may caused on the trees by mechanical injury, cold, poor pruning techniques, improper pruning time, borers, or other causes. Check for gummy sap near the wounds, it is the first symptom of cytospora infection.

Figure 5: Figure 4: Characteristic symptoms of Cytospora canker observed in the field. A, Necrosis of the underlying bark and cambium; B, apical desiccation of the branch during the initial infection phase; C, complete desiccation of the branches; D, conidia development along the trunk; E, cross section of the main trunk showing healthy and canker affected parts; and F, infected branch broken over time. Thompson, M. M., & Johnson, K. B. (2000). Summer heat and low soil organic matter influence severity of hazelnut cytospora canker. ResearchGate. https://www.researchgate.net/publication/258145952_Summer_Heat_and_Low_Soil_Organic_Matter_Influence_Severity_of_Hazelnut_Cytospora_Canker/figures?lo=1

2.4 Physiopathies

As Physiopathies, also known as abiotic stress, we define an external environmental factor that has a negative effect on the growth, yield or survival of plant capital. Some common abiotic stresses to crops are prolonged droughts, heat waves, hail, frost, floods, strong winds, deficiency and toxicity of nutrients etc.

Iron deficiency

A thin network of green veins appears on the tender leaves of the tops, while the rest of the lamina is yellow or whitish. Later the chlorosis extends to the entire lamina and in severe cases the leaves show necrosis. Leaf fall can still be observed starting from the tops. Twigs have little growth and show tip necrosis. Treatment of malnutrition with chelated iron supplementation is recommended.

Figure 6: Yara UK. (n.d.). Iron deficiency in plums. https://www.yara.co.uk/crop-nutrition/plum/nutrient-deficiencies-plums/iron-deficiency-plums/

Fruit cracking

All stone fruit, but particularly cherries and plums, are susceptible to splitting or cracking, which makes the fruit unsellable and is sometimes caused by rains before harvest. Another important factor in lowering fruit splitting or cracking is crop nutrition. The peel will become rather inelastic during a dry period. The fruit absorbs a lot of water when this is followed by irrigation or rain, which causes the rind to rupture at its weakest spot. In vulnerable cultivars, physiological stress and splitting can be decreased by eliminating pressures through proper watering and crop load reduction (pruning). Cultivar selection may also have an impact, especially in cases where late-season rainfall makes the issue worse. Additionally, crop nutrition is crucial in avoiding cracking and splitting incidents. Nitrogen, copper and calcium are the three main nutrients that help fruit skin thickness.

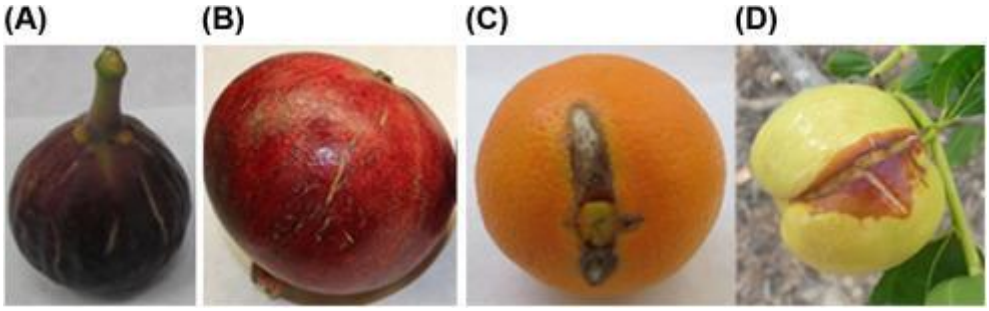

Figure 7: Fruit physiological disorders: Fig (F. carica) (A) and pomegranate (P. granatum) (B) fruit skin side cracking, and orange (C. sinensis) (C) and jujube (Z. jujuba) (D) fruit splitting. Photos courtesy Dr. Francisca Hernández.

3 Post harvest diseases

3.1 Brown rot (*Monilia laxa or fruticola)*

Caused by *Monilia laxa or fruticola* is the most important postharvest disease of stone fruits. Infection begins during flowering and fruit rot may occur before harvest but often occurs postharvest.

Symptoms and signs

Brown rot is a fungal disease that primarily affects fruits, especially stone fruits like peaches, plums, and cherries. The disease begins with the appearance of small, water-soaked spots on the fruit's surface, which eventually turn brown. As the fungus spreads, the affected fruit becomes soft and mushy, leading to significant decay. In advanced stages, a fuzzy or powdery layer of grayish-brown spores may develop on the surface of the fruit.

Infected fruits may also drop prematurely from the tree. Additionally, brown rot can cause sunken, dark cankers on tree branches, which may lead to further infection and dieback. Decaying fruit often emits a distinctive, unpleasant odor. Proper cultural practices, such as pruning, removing infected fruit, and ensuring good air circulation, are essential for managing brown rot.

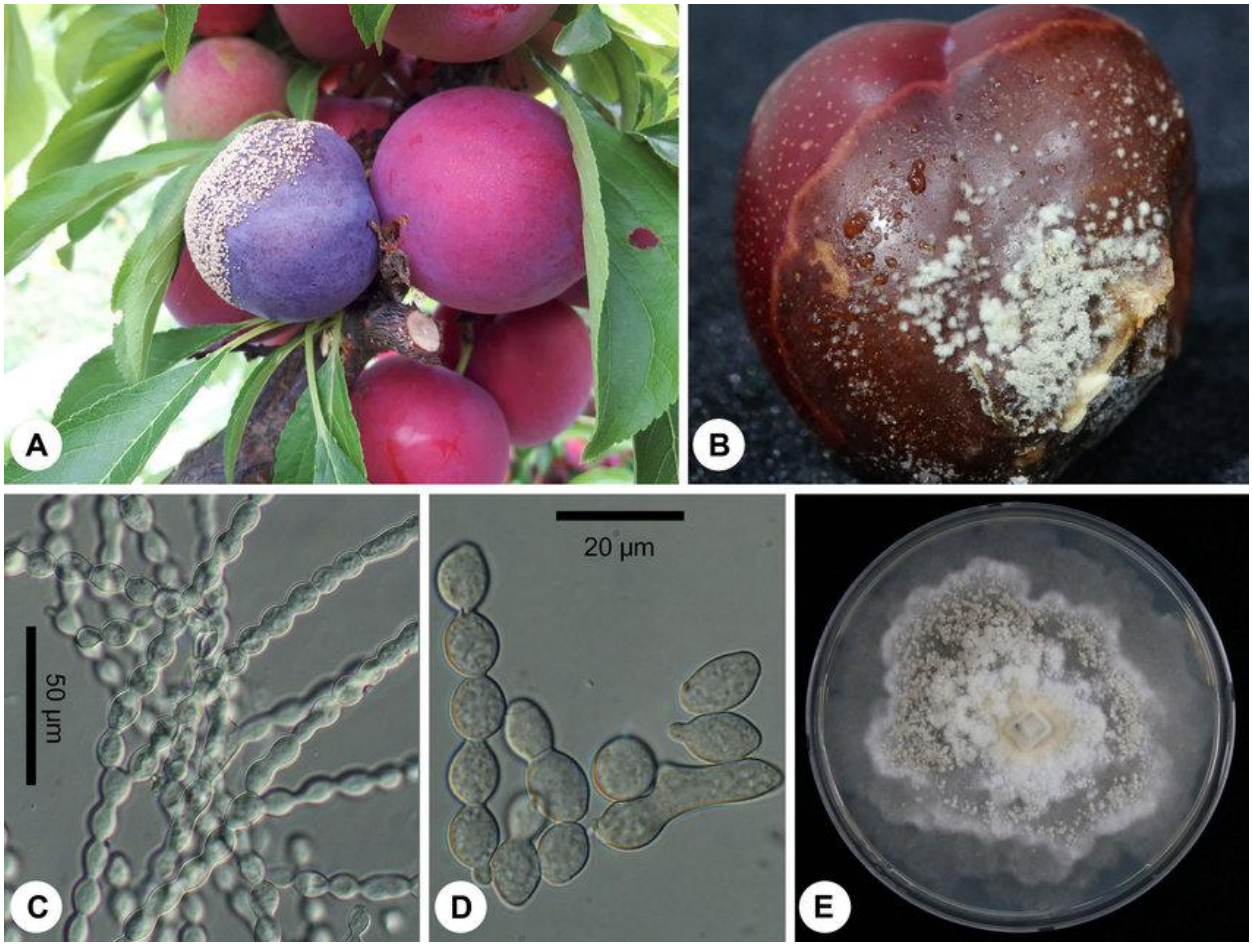

Figure 8: Monilia laxa a) on the tree b)post harvest c, d) Microscope view e) Fungi on petri dish. Photo from Oh, Hun-Tak & Choi, In-Young & Kim, Ju & Na, Young-Eun & Lee, Wang & Lee, Kui-Jae & Shin, Hyeon-Dong. (2017). Characteristics of Brown Rot Caused by Monilinia fructicola on Stone Fruit in Korea. Research in Plant Disease. 23. 322-333. 10.5423/RPD.2017.23.4.322.

Management

1.The destruction of the overwintering foci of the fungus is an important measure to deal with the disease, because in this way we reduce to a minimum the infections for the primary attacks in the spring and increase the effectiveness of the protective sprays. All affected shoots and branches of trees must be pruned and burned. This should be done before the leaves fall and ideally in the summer.

2. Three sprays are recommended a) at bud development b) at the white or pink tip c) at full bloom. Additional sprays may be needed in rainy weather. Formulations with cyprodinil, pyrimethanil, benomyl, imazalil, azoxystrobin myclobutanil etc. are used.

3. For fruit protection from pre or postharvest rot, it is recommended a spray before harvest or fruit immersion straight after harvest in benomyl solution. Also, it is imperative to avoid injury to the fruits during collection and packaging and to protect the fruits from wounds, e.g. insects. Keeping fruits in the refrigerator at an appropriate temperature as well. Recent experiments on biological control of post-harvest rots showed good results by dipping fruits in a suspension of *Bacillus subtilis.*

3.2 Gray Mold (Botrytis cinerea)

Caused by *Botrytis cinerea* which has a worldwide distribution and affects almost all cultivated plants. The fungus attacks almost all plant parts and organs and grows in both healthy and dead plant tissue. The fungus belongs to the Ascomycetes and forms conidiophores with a long peduncle and brown colour. The fungus survives on dead plant tissues saprophytically as well as on infected cultivated and native plants.

Symptoms and signs

Fruits are most often infected during their development on the tree. The pathogen enters from the top of the fruit or from the pedicel, settles there creating a small dry brown spot or causes no obvious symptom and remains dormant until harvest. The infection is mainly active in the warehouse and depending on the storage conditions and the degree of ripening of the fruits manifests itself in the form of a soft brown rot. Affected fruits have a fermentation smell. In an environment of high relative humidity, the characteristic gray mold appears on the affected surfaces. Infections can also occur from wounds during harvest. Inside the warehouse the disease is transmitted from the infected to the healthy neighboring fruits and can cause universal loss of production as the fungus grows in a huge range of temperatures from 1-30 degrees Celsius.

Figure 9: Hortgro Science. Gray mold on plum fruit. https://app.hortgro-science.co.za/decay-type/plum/grey-mould-rot/

Management

For the effective treatment of botrytis in plum fruits, the following measures are recommended:

1. Keeping orchards in good health with preventive spraying.

2. Harvesting the fruits in dry weather.

3. Avoid injury during harvesting, storage and handling.

4. Preserving the fruits at low temperatures immediately after harvesting.

5. For the treatment of serious infestations, treatments with fungicides, e.g. vinclozolin, cyprodinil

4. Agronomic practices for crop protection

Climate and soil

The plum tree easily adapts to different types of soil and climate. The Japanese plum is adapted to areas with mild winters as it blooms early while the European plum prefers cooler winters and moderate summer temperatures**.**

The cold needs of plum buds to break dormancy are 700-1700 hours below 7 degrees Celsius. High atmospheric humidity and heavy rainfall during the flowering period in spring are unfavorable factors for cultivation because they favor the growth of monilia, so areas with these characteristics should be avoided.

The plum tree thrives in a variety of soil types but performs best in deep light calcareous soils of medium texture with good drainage. It is considered sensitive to strong winds and exposed areas should be avoided for cultivation.

Varietal Choice

Selecting a variety involves assessing the particular soil and climate in which it thrives and favouring cultivars that combine market acceptability with resilience and/or tolerance to significant obstacles.

The species of interest are Prunus domestica (commonly known as the European plum), Prunus salicina (commonly known as the Japanese plum), and there are a variety of hybrids and other plums.

European plum varieties are suitable for dried plum production as well as for fresh consumption.

Varieties of Japanese plum are intended for fresh consumption. More specifically the variety of Japanese plum "Santa Rosa". The criteria we take into account for the selection of the species and the variety has to do with characteristics that we compare according to the area where the trees will be planted and the soil and climate conditions there.

Plant operations

The soil, which is to be used for the establishment of plum orchard, is plowed before planting to a depth of 30-40cm. The purpose of plowing is to destroy the perennial weeds and to loosen the soil,

which is necessary for the better development of the root system of the trees. Before planting, the planting locations of the trees are marked, the pits, measuring 45 x 45 cm, are dug and the trees are planted. When planting the seedlings are planted at the same depth as they were in the nursery, and topsoil is thrown at the base of the root system of the seedlings. To prevent harm to the root system, gently press the dirt into the pits until they are full. Bare-rooted saplings are planted. Following the planting process, the saplings are watered and a tiny amount of manure is applied around them to keep weeds from growing. Increasing the soil's humus content, retaining its fertility, storing water, and boosting output are the goals of cultivation. Mechanical methods are used, while chemical methods are used to combat weeds.

Planting systems

The plum tree is planted in squares, rectangular parallelograms or lines. The vigor of the subject and variety as well as the soil's fertility determine the planting distance. They typically fall between 3 and 4 meters for linear patterns and 6-7 meters for freeform forms.

From November, when the leaves have fallen, until the start of spring, when the buds have not yet formed.

Irrigation

The plum tree is particularly demanding on water during the summer months. The lack of water causes a decrease in production and fruit drop, while it is also associated with the splitting of the fruits

Irrigation in the summer months is recommended to be done with drip irrigation. In dried plum varieties, watering is significantly reduced in the last two months before harvest to increase the dry matter of the fruit.

Pruning

Regardless of whether the plum tree is European or Japanese, the two most common tree formations in plum horticulture are bilateral palmette and cup-shaped. As with other fruit trees, the goals of fruiting pruning for plums should be to preserve the trees' shape, remove any dry branches, expose the inner portion of the crown to plenty of light and airflow, replenish the fruiting wood, and guarantee a good yield.

The best approach is to remove some fruiting wood and prune heavily enough to promote new growth. In this manner, production will be decreased to a level that will help ensure that the tree remains healthy and that fruits of a suitable size are obtained.

Harvest

Fresh-to-eat plums are ripe when the fruit's flesh and skin take on the characteristic colour of the type. The flesh's consistency and the soluble solids (18%) can be combined to determine maturity. Colour, soluble solids, and flesh consistency—always in combination—are utilized as ripeness parameters for plums that are meant to be dried.

The onset of a reddish tint on the fruit's skin, which starts about 20 to 30 days prior to harvest and progresses to the distinctive reddish-deep red hue that is the last colour of a ripe fruit of this category,

is the first true sign that a fruit is starting to ripen. Shortly after the colon changes of the bark manifest, the green hue of the flesh starts to fade.

The consistency of the flesh.

This is the most crucial factor, after the flesh colour. Cohesion is simpler and more useful to measure. When the fruit is young and unripe, its flesh is extremely resistant to outside pressure forces. However, as the fruit ripens, its structure changes, becoming softer until it eventually loses its resistance to outside pressure.

Soluble solids. This is the third factor for harvest. As a lower value in soluble solids, that of 24% is taken.

Vibrators or manual labour are used to gather plums. While plums meant for drying are gathered with vibrators, those meant for fresh eating are harvested by hand. To preserve the fruit's pedicel and the fluff, the collection is typically done carefully and with two to four hands, ideally in the morning.

Fertilizer Specification for Plum

Plum trees require regular fertilization to ensure healthy growth and fruit production. Here are some fertilizer specifications for plum trees:

The Japanese plum responds to heavy nitrogen supplies by increasing its vegetation and fruit size, while the European varieties need less nitrogen and respond better to potassium fertilization. Empirical fertilization per hectare is 10-15 units for nitrogen as ammonium sulfate 50-75 kg of fertilizer, 5-10 units for phosphorus as superphosphate 25-50 kg of fertilizer and 15-20 units of potassium as potassium sulfate 30-40 kg, and every two years for phosphorus and potassium when soil reserves are insufficient. The nutritional needs of the plum tree are determined by foliar analysis. The nutritional necessity is also evaluated on the base of nutrients already available in the soil.

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CHAPTER 3

Peach [Prunus persica (L.) Batsch, 1783]

Author: Yordan Nikolov
Organization: Balkan Bridge

WHAT WILL WE LEARN IN THIS CHAPTER?

We're going to learn about the intricacies of peach trees, their fruit-related diseases both in the field and post-harvest, along with the physiological disorders they may develop. This comprehensive exploration encompasses disease management strategies and best practices aimed at optimizing peach cultivation.

Keywords: Brown Rot, fungus Monilinia fructicola, Peach Scab, fungus Venturia carpophila, Peach Leaf Curl, Gummosis, Powdery Mildew

Summary

1 Overview

The peach (*Prunus persica*) is a deciduous tree that bears edible juicy fruits with various characteristics, most called peaches and other varieties (the glossy-skinned, non-fuzzy varieties) called nectarines. Peaches and nectarines are the same species, though they are regarded commercially as different fruits. The skin of nectarines lacks the fuzz (fruit-skin trichomes) that peach skin has.

2 Field diseases and physiopathies

2.1 Brown Rot (*Monilinia fructicola*)

Brown rot is one of the most common and serious diseases affecting peach fruits. It is caused by the fungus *Monilinia fructicola*, and can also infect flower blossoms and shoots. The disease begins at the bloom stage. Infected flowers wilt and turn brown very quickly. Shoot infections (usually from flower infections) result in small (1 to 3 inches) gummy cankers, which provide the source of infection for fruit rot. Spores from infected flowers and cankers infect healthy green fruit during long wet periods. Once infected, fruit remains attached to the tree and provides an additional source of spores for more infections instead of dropping off in a normal fashion. Some infections only show when fruit begins to ripen.

Symptoms and signs

Fruit rot starts with a small, round brown spot, which expands to eventually rot the entire fruit. Infected fruit turns into a mummy on the tree. The fungus survives the winter on fruit mummies (on the tree and on the ground) and twig cankers.

Symptoms first appear in the spring as the blossoms open. Young fruits are normally resistant, but may become infected through wounds. As fruits mature, they become more susceptible to attack, even in the absence of wounds.

Identification tips

Diseased flowers wilt, turn brown, and may become covered with masses of brownish-grey spores. Fruit infections appear as soft brown spots which rapidly expand and produce a tan powdery mass of conidia. The entire fruit rots rapidly, then dries and shrinks into a wrinkled "mummy."

Management

Collect and remove diseased fruit from the tree as it appears. Collect and dispose of any diseased fruit on the ground. In the fall, remove all dried fruit mummies from the tree since this is where the fungus survives the winter. During pruning in winter, remove all cankerous parts of the tree.

Spray during full bloom and two subsequent sprays at 10 to 14-day intervals to prevent infections of flowers and young fruit. Fungicides are also required when the fruit ripens. It is important to begin spraying in 7-day intervals (typically, three times until harvest) when the fruit turns colour

from green to yellow and red. Starting a spray program when rotten fruit is already evident will result in poor disease control. Select a fungicide containing captan or propiconazole that is labelled for use on peaches. These fungicides are only effective if complete and thorough coverage of the tree(s) can be obtained. Resistant variety is Glohaven Peach. For biological treatment an efficient field strategy to control brown rot was previously designed based on the application of two biocontrol agents (BCAs), *Bacillus amyloliquefaciens* CPA-8 (CPA-8) or *Penicillium frequentans* 909 (Pf909), with calendar-based treatment but further studies need to be down to implement this strategy for fungi control.

Though pesticide products are available at gardening stores for homeowners, many gardeners are not inclined to use pesticide applications for home fruit production. Instead, hobbyist gardeners may use bags to protect the fruit from pests and diseases. Clemson University has tested and is promoting the use of specialty bags (*Figure 2*) that, if used properly, allow for the production of high-quality fruit with very little pesticide input. The bags are recommended for use in a three-step fashion: (i) properly take care of your trees to minimize tree stress; (ii) protect your fruit from pests and insects between bloom and the day of bagging; and (iii) enclose nail-sized, green fruit (typically 3 weeks after bloom) with a specialty bag to be removed at harvest.

Figure 10: Brown rot of peach. Clemson University – USDA Cooperative Extension Slide Series

Figure 11: Clemson Fruit Bag developed for the home orchard and hobbyist fruit gardener. Guido Schnabel, ©2015, Clemson University

2.2 Peach Scab (*Venturia carpophila*)

Peach scab, also known as "freckles", is caused by the fungus *Venturia carpophila*. Disease symptoms occur on the fruit as small (less than ¼ inch in diameter) velvety dark spots and cracks. In cases of severe infection, spots may join together to form large dark lesions. Leaf infection is usually not observed. Twig infections occur on the current year's growth and are light brown after 30 to 70 days, before later enlarging and becoming dark reddish-brown the next season. Spots on the fruit only occur on the outer skin so it is suggested peeling the fruit to remove all traces of the disease.

Management

Most varieties are susceptible to scab, although some are more severely affected than others are. Generally, scab is most severe the first year the trees bear fruit. Minimize infection by selecting planting sites that are not low-lying. Trees should be properly pruned to allow good air circulation. This helps to promote rapid drying of the leaves, fruit, and twigs.

Periods of rain with temperatures of 18 to 24 °C are optimal conditions for infection. Fungicides can provide adequate control of this disease if applications are properly timed. If disease control is desired, apply captan, myclobutanil, or wettable sulphur. Make five applications starting at full bloom at 10- to 14-day intervals.

Figure 12: Sullivan, C. (n.d.). Image credit: carolynsullivan139 via Q&Ahttps://www.gardeningknowhow.com/edible/fruits/peach/peach-scab-treatment.htm

Figure 13: Peach scab, Image credit: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org

Identification tips

Fruit: The most noticeable symptoms of peach scab are visible when fruit is maturing. Round, greenish spots grow on the stem side of the fruit and where fruit is exposed to the sun. As the spots grow, they turn black and irregular shaped, making the fruit unpalatable.

Spots on the fruit also can develop yellow disks around them as they grow, and the surfaces of the damaged areas are raised with a velvety texture.

Twigs and leaves: develop less noticeable lesions. On twigs, lesions are small and reddish-brown, becoming dark. Leaves develop round, yellow-green blisters on the underside, causing some leaves to die and fall off.

Timing

The spores of the fungus spread the disease on the tree when air temperatures are between 18º to 24ºC when there is rain, fog, or moisture from sprinklers or other irrigation. Spores from peach scab overwinter on twigs and branches.

2.3 Peach leaf curl (*Taphrina*)

They are the diseases caused by various species of the genus *Taphrina*. The result of the infestation is the intense leaf fall, the weakening of the trees and the reduced and degraded production. They are known as "rolling sheet".

Symptoms and signs

Early spring is when peach leaf symptoms are most noticeable. Because of parenchymal tissue hyperplasia, curling, and distortion, affected leaves exhibit aberrant lamina thickening, either local or complete. Initially curled or infrared, they eventually turn red-yellow or yellow-turf. The tree typically produces healthy leaves after severe defoliation.

Fruit drop and tree deterioration result from the growth of new vegetation. Aphid infestation also results in leaf deformation and curling. Aphid infestations, however, are different from fungus

infestations in that the lamina does not thicken, and the insects and their secretions are visible between the lamina folds.

The symptoms can be observed from May to June. The fungus requires cool and wet weather. Ideal temperatures for infection are 16-24°C at humidity levels above 95%.

Figure 14: Agravia. (n.d.). Peach leaf curl. www.agravia.gr

Figure 15: Notcutts. Peach leaf curl. https://www.notcutts.co.uk/garden-advice/problems-pests/peach-leaf-curl/

Identification tips

Inspect for leaves that begin to curl up, die and fall off the tree. After a while infected leaves will turn red.

Management

The goal of managing peach leaf curl is to eradicate the infestation during tree dormancy with a single spray. This spraying can be done with bordigal pulp, copper oxychloride, or other coppers in the fall after the leaves have fallen and until the buds have swelled. After the entrance of the pathogen to the plant tissue the disease extinction is impossible.

It is advised to remove and burn any impacted shoots during the growing season. It is advised to reinforce the trees by fertilizing them with nitrogen, decreasing the effects of dehydration with sporadic irrigations, and thinning the fruits in accordance with the plant foliage.

2.4 Shot hole disease

A disease that affects all stone fruits is fairly common and typically affects peaches, apricots, cherries, and plums. Because it affects the buds and dries out the twigs, the disease is frequently highly serious for peach trees and can also cause larger branches or trees to dry up. Referred to as shot-hole, and coryneum blight.

Symptoms and signs

The disease affects shoots, buds, flowers, leaves and fruits. The fungus settles in the surface tissues of the organs and causes necrotic spots, small wounds on the shoots and necrotic buds. The most frequent and characteristic symptoms appear on the lamina of tender leaves and the surface of young fruits.

The leaves initially have spherical, reddish-brown patches that are 2-3 mm in diameter. These spots eventually turn brown, dry in the middle, and have a red rim around them. Holes are created when dying tissue separates from the lamina's healthy portion and falls away. "Shrapnel holes" is the term for this condition.

Numerous spots frequently occur on the lamina, or they get larger and fuse together, causing huge portions of the lamina to necrotize. When the spots fall off, the leaf seems "torn." Leaves that are severely impacted fall early. Several additional parasitic or non-parasitic infections induce similar leaf marks and "shrapnel holes" in stone fruit.

The fruits develop spots that resemble those on the leaves. Frequently, the spots are sunken. Gum discharge frequently forms on the areas. The shoots first acquire little reddish-brown ellipsoidal patches, which then enlarge, sink, and transform into tiny wounds. On the wounds, a sticky secretion frequently develops.

Identification tips

Leaves: At the first small round, red spots of 2-3mm diameter appear on the leaves. Then they turn brown and they dry up in the centre. Inspect closely the leaves for small spots especially after wet weather.

Fruit: As on the leaves, the same spots are formed on the fruit. These spots are often submerged in the flesh of the fruit.

Gum on shoots: Small red-brown spots are formed on the shoots which develop into ulcers. Gum secretion is observed on the ulcers.

Management

For control, the following spraying schedule is advised:

1) using copper oxychloride or bordigallium pulp (Bordeaux mixture) in the fall and when the leaves start to fall.

2) Using the same medications during the hibernating time, right before eye swelling starts.

3) when the petals are falling with captan, folpet, chlorothalonil, azoxystrobin.

4) 20 days after the last spray with the same chemicals.

Furthermore, pruning and burning of the infected shoots is recommended.

Figure 16: The Farm at Green Village. (n.d.). Shot hole disease treatment and prevention. https://thefarmatgreenvillage.com/shot-hole-disease-treatment-and-prevention/

2.5 Physiopathies

The same as plum trees. They are in the same family. Nutrient deficiencies and fruit cracking or damages from frost and falling ice are the most severe Physiopathies of stone fruit.

As Physiopathies, also known as abiotic stress, we define an external environmental factor that has a negative effect on the growth, yield or survival of plant capital. Some common abiotic stresses to crops are prolonged droughts, heat waves, hail, frost, floods, strong winds, deficiency and toxicity of nutrients etc.

Iron deficiency.

A thin network of green veins appears on the tender leaves of the tops, while the rest of the lamina is yellow or whitish. Later the chlorosis extends to the entire lamina and in severe cases the leaves show necrosis. Leaf fall can still be observed starting from the tops. Twigs have little growth and show tip necrosis. Treatment of malnutrition with chelated iron supplementation is recommended.

Figure 18: Utah State University. (2017, August 4). Coryneum blight of stone fruit. Pesticide advisories. https://pestadvisories.usu.edu/2017/08/04/coryneum/

Figure 17: Utah State University. Iron chlorosis on a peach leaf. https://extension.usu.edu/planthealth/ipm/notes_ag/fruit-iron-chlorosis

Frost damage

Peach trees are one of the least winter hardy stone fruits. Most varieties will lose buds and new growth in -26 C° weather and can be killed in -31 C°. Peach tree winter care starts by choosing a variety of peach that is cold hardy for your climate. Peach trees in winter are exposed to a lot of stress. Choose a site on your land that is not overly exposed to wind, flooding. Prepare a peach tree for winter with good nutrition and adequate water. Peach trees are deciduous, going dormant and losing their leaves in fall. One of the most common times for winter injury to occur is in fall when an early cold snap damages a tree that isn't yet dormant. The other period when damage may be expected is spring when the tree is waking up and new sprouts are killed by a late frost. Preemptive peach tree cold protection, or what is called passive protection, will ensure the trees are defended early and well into spring.

Figure 19: Frost damage to young peach fruit. Growing small farms. (2018, January 4). Retrieved from: https://growingsmallfarms.ces.ncsu.edu/2016/04/freeze-damage-to-local-fruit-crops/

Figure 20: (Photo: John Strang, University of Kentucky)

3 Post Harvest Diseases

3.1 Brown Rot (Monilia fructicola)

Brown rote is caused by *Monilia fructicola* and it is the most important postharvest disease of stone fruits. Infection begins during flowering and fruit rot may occur before harvest but often occurs postharvest.

Symptoms and signs

Brown rot is a fungal disease that primarily affects fruits, especially stone fruits like peaches, plums, and cherries. The disease begins with the appearance of small, water-soaked spots on the fruit's surface, which eventually turn brown. As the fungus spreads, the affected fruit becomes soft and mushy, leading to significant decay. In advanced stages, a fuzzy or powdery layer of grayish-brown spores may develop on the surface of the fruit.

Infected fruits may also drop prematurely from the tree. Additionally, brown rot can cause sunken, dark cankers on tree branches, which may lead to further infection and dieback. Decaying fruit often emits a distinctive, unpleasant odor. Proper cultural practices, such as pruning, removing infected fruit, and ensuring good air circulation, are essential for managing brown rot.

Management

1.The destruction of the overwintering foci of the fungus is an important measure to deal with the disease, because in this way we reduce to a minimum the infections for the primary attacks in the spring and increase the effectiveness of the protective sprays. All affected shoots and branches of trees must be pruned and burned. This should be done before the leaves fall and ideally in the summer.

2. Three sprays are recommended a) at bud development b) at the white or pink tip c) at full bloom. Additional sprays may be needed in rainy weather. Formulations with cyprodinil, pyrimethanil, benomyl, imazalil, azozystrobin myclobutanil etc. are used.

3. For fruit protection from pre or postharvest rot, it is recommended a spray before harvest or fruit immersion straight after harvest in benomyl solution.

Figure 22 Bayer Crop Science. (n.d.). Brown rot. Bayer Crop Science.

https://www.cropscience.bayer.co.nz/pests/diseases/brown-rot

Figure 21: Molly Giesbrecht, Texas A&M AgriLife Extension Service, Bugwood.org , Brown rot..

Retrieved from https://www.ipmimages.org/browse/detail.cfm?imgnum=5491019

Also, it is imperative to avoid injury to the fruits during collection and packaging and to protect the fruits from wounds, e.g. insects. Keeping fruits in the refrigerator at an appropriate temperature as well. Recent experiments on biological control of post-harvest rots showed good results by dipping fruits in a suspension of *Bacillus subtilis.*

3.2 Blue mold rot (*Penixillium expansum*)

Another serious post-harvest disease of peaches is blue mold rot that is caused by *Penixillium expansum*. It can occur during storage if the fruit has been contaminated through harvest and handling wounds. Avoiding mechanical injuries and good temperature management are effective control measures.

Symptoms and signs

The fruits initially show circular, watery, brown spots. At first the spots are superficial but quickly begin to sink into the fruit and grow. Affected tissues acquire a soft watery texture and easily detach from healthy ones. On the surface of the spots in an advanced stage of infection and in combination with high humidity, conidiophores of the pathogen appear in places in the form small round dense rashes. The rashes are initially white or light blue in colour and later turn dark blue and blue. Affected fruits have a characteristic musty odor and taste. The fungus produces a toxin called patulin. The pathogen is primarily a wound parasite and is favoured by high humidity and temperature. It grows more easily on the ripest fruits. Infections are usually caused by the harvesting and packing of the fruits and they start from wounds on the fruit.

Management

It was found that pre- and post-harvest interventions with harpin increase the resistance of fruits to the pathogen. Encouraging results have also been given by various biological agents, such as Biosave110 TM and Aspire, which contain competitive microorganisms and which are applied preventively without having a therapeutic effect.

Figure 23: Luo, CX., Schnabel, G., Hu, M. et al. Global distribution and management of peach diseases. Phytopathol Res 4, 30 (2022). https://doi.org/10.1186/s42483-022-00134-0

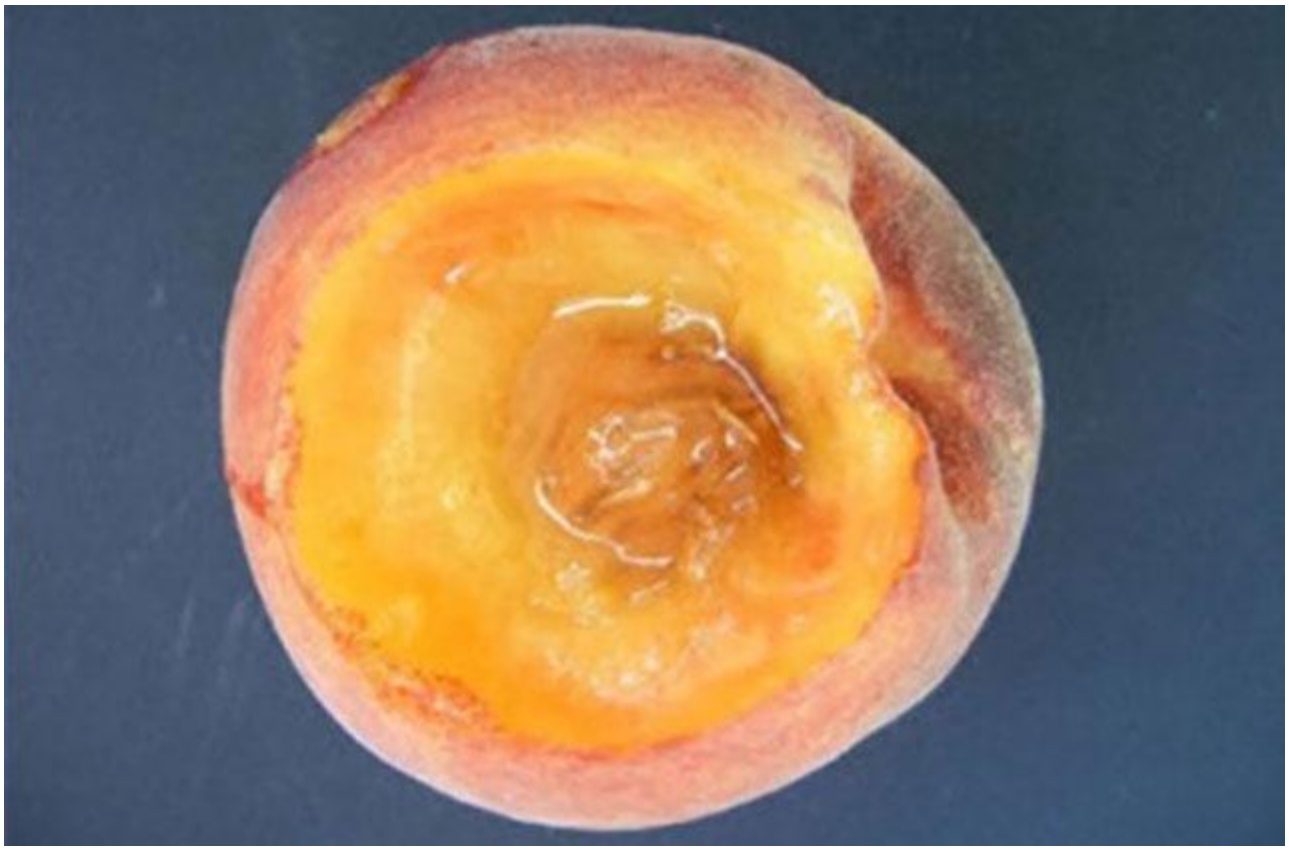

Figure 24: Penixillium expansum on a peach. CABI. Species information: Plantwise Plus. https://plantwiseplusknowledgebank.org/doi/full/10.1079/pwkb.species.39572

3.3 Rhizopus Rot (*Rhizopus stolonifer*)

It is caused by *Rhizopus stolonifer* and it is a major fungal pathogen of peaches, which is causing significant losses of peaches especially post-harvest. Rhizopus rot favours harvested or over-ripe stone fruit.

Symptoms and signs

Harvested or overripe stone fruit is preferred by rhizopus rot. Small brown lesions that are early symptoms can be mistaken for early signs of a brown rot infection. The fruit peel will easily separate from the rotting flesh underneath when Rhizopus rot is present; brown rot does not exhibit this feature. A fluffy white mass that eventually turns dark grey to black as the fungus sporulates is a sign of rapid fungal development, which is encouraged by warm temperatures. Fruit can surprise you overnight by growing "beards." It is highly probable that rot will spread from fruit to fruit at the site of contact because Rhizopus rots sporulate extensively.

The fungus thrives on the ground of the orchard, particularly on rotting fruit. As a result, as the season goes on, spore accumulation may happen, and the fruit on the tree may become contaminated by the airborne spores. Rhizopus rot does not affect unripe fruit. Fruit that is just beginning to ripen is susceptible to damage from insects, hail, or breaking. Temperature affects the course of rhizopus rot, with 27oC being the ideal temperature. The fungus will spread quickly through the fruit at optimal temperatures.

Management

Since this fungus mainly attacks fruit after harvest, the last fungicide spray prior to harvest should be one that includes Rhizopus rot on the label for stone fruit. When mature fruit is stored at 3°C, Rhizopus rot will be suppressed since the fungus will not grow or produce spores at temperatures below 4°C. In addition, handle fruit carefully to minimize wounds and bruising as these are entry points for the fungus, as well as keep storage bins and warehouses clean. Also, biological control of the fungus with antagonistic organisms such as *P. membranefaciens* had significant biocontrol efficacy against Rhizopus rot of peaches.

Figure 16: Image credit: H.J. Larsen, Bugwood.org

Figure 17: Image credit: HORTGRO, https://app.hortgro-science.co.za/decay-type/peach/rhizopus-rot/

4 Agronomic practises for crop protection

Climate and soil

The peach tree is one of the few fruit-bearing species that has expanded so rapidly and adapted to so many soil-climatic environments.

The peach tree thrives in areas with temperatures as low as -15 °C. Of course, it needs several hours of low temperatures to break the lethargy of her eyes. Spring frosts during the flowering period easily damage the tree's flowers. Flower buds drop or develop abnormally when we have a warm spring resulting in loss or reduced production. The quality of the fruits is better in areas with quite hot summers (up to 35 °C) and low relative humidity. Canning varieties are more sensitive to frost during flowering than table varieties.

The peach tree thrives in deep, well-drained soils without excess calcium carbonate. Excessive moisture and poor aeration of the soil can cause chlorosis in the leaves of the tree and their fall. The optimum soil pH value is between 6-7.5.

Varietal Choice

Selecting a variety involves assessing the particular soil and climate in which it thrives and favouring cultivars that combine market acceptability with resilience and/or tolerance to significant obstacles.

Plant operations

The soil, which is to be used for the establishment of peach orchard, is plowed before planting to a depth of 30-40cm. The purpose of plowing is to destroy the perennial weeds and to loosen the soil, which is necessary for the better development of the root system of the trees. Before planting, the planting locations of the trees are marked, the pits, measuring 45 x 45 cm, are dug and the trees are planted. When planting the seedlings are planted at the same depth as they were in the nursery, and topsoil is thrown at the base of the root system of the seedlings. To prevent harm to the root system, gently press the dirt into the pits until they are full. Bare-rooted saplings are planted. Following the planting process, the saplings are watered and a tiny amount of manure is applied around them to keep weeds from growing. Increasing the soil's humus content, retaining its fertility, storing water, and boosting output are the goals of cultivation. Mechanical methods are used, while chemical methods are used to combat weeds.

Planting systems

Peach trees are typically planted during their dormant season, from November, when the leaves have fallen, until the start of spring, when the buds have not yet formed. The planting distance depends on the vigor of the variety and the fertility of the soil, with typical distances ranging from 3 to 4 meters for linear planting patterns and 6 to 7 meters for freeform layouts.

Irrigation

The peach tree is particularly demanding on water during the summer months. A lack of water cause a decrease in production and fruit drop, while it is also associated with the splitting of the fruits

Irrigation in the summer months is recommended to be done with drip irrigation. For drying varieties, consistent watering may be significantly reduced in the last two months before harvest to increase the dry matter of the fruit.

Pruning

Peaches must be pruned each year. Some cultivars benefit from summer pruning done two to three weeks before harvest. Summer pruning consists of removing the dense growth in the center of the tree to allow more light into the tree and improves final fruit color. The two most common tree formations in peach orchards are bilateral palmette and cup-shaped. As with other fruit trees, the goals of fruiting pruning for peaches should be to preserve the trees' shape, remove any dry branches, expose the inner portion of the crown to plenty of light and airflow, replenish the fruiting wood, and guarantee a good yield.

Harvest

Peaches do not mature all at once, and normally it will be necessary to harvest a tree two to four times. Length between harvests is dictated by the weather as well as location of the fruit within the tree. Most peaches are harvested based on firmness and color. Harvest will vary depending on how you will be marketing your fruit. Fruit destined for the wholesale market is picked at a less mature stage so the fruit can better withstand the rigors of shipping. Fruit that you intend to sell locally can be left on the tree slightly longer to mature and soften. These "tree-ripe" peaches usually command a somewhat higher market price.

Extreme care must be taken not to bruise or damage peaches and nectarines during the harvesting process. Bruising and any damage will lead to early spoilage and a large reduction in the returns realized from the sale of the fruit.

Storage

Peaches are wounded easily, so workers must be extra careful when handling them, minimizing fruit transfers. To maintain fruit quality, they must be rapidly cooled immediately after harvest and stored at a temperature of 0.5-4.5 °C and a relative humidity of 90-95%. However, even in these conditions, peaches have a relatively short shelf life.

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CHAPTER 4

Watermelon [Citrullus lanatus]

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Organization: Rezos Brands SA

WHAT WILL WE LEARN IN THIS CHAPTER?

We are going to delve into the details of watermelon production, examining the diseases affecting the crop both in the field and after harvest, as well as the physiological disorders they might encounter. This thorough investigation will cover strategies for managing diseases and best practices designed to enhance watermelon cultivation.

Keywords: Watermelon, Diseases and Physiopathies, Crop Management, Sustainable Watermelon Farming Practices

Summary

1 Overview

Citrullus lanatus, commonly known as watermelon, is a member of the Cucurbitaceae family. Watermelon, as the largest cultivated member of the Cucurbitaceae family, is widely consumed worldwide and is significant from an economic perspective. According to Eurostat, the EU's leading producer of watermelon is Spain. With about 25% of the EU's watermelons, Italy comes in second place, followed by Greece and Romania.

Watermelons originate from tropical Africa and are well adapted to warm, seasonally dry habitats, requiring a long, warm growing season. Watermelons are usually grown for the consumption of their fresh, edible flesh. The part consumed is the placental region, or endocarp, while the consumption of the seeds is also important in some regions.

2 Field diseases and physiopathies

2.1 Downy mildew (*Pseudoperonospora cubensis*)

Downy mildew is a destructive plant disease caused by the air-borne oomycete pathogen *Pseudoperonospora cubensis*. *Pseudoperonospora cubensis* is responsible for devastating losses worldwide of cucumber, cantaloupe, pumpkin, watermelon and squash.

Symptoms and signs

Downy mildew is a foliar disease, easily recognizable by the development of chlorotic lesions on the adaxial leaf surface. As infection progresses, the chlorotic lesions expand and may become necrotic with necrosis occurring more quickly in hot, dry weather. More specifically, leaf spots may turn brown to black in colour. Through the infection of *Pseudoperonospora cubensis*, the leaves are mainly infected. However diseased leaves result in reduced yields, stunted plants and sunscalded fruit because of premature defoliation due to overexposure to direct sunlight.

Management

The management of downy mildew requires the use of tolerant cultivars in conjunction with fungicide applications. Host resistance is an important tool in disease control. An effective, appropriately scheduled fungicide treatment is the most crucial component of a successful downy mildew control strategy. Fungicides are most effective when applied prior to infection and reapplied at 5- to 7-day intervals.

Identification tip

- The oldest leaves are usually attacked first.
- Severely infected foliage appears scorched.
- The pathogen is favored by cool and moist conditions.

Figura 1 Downy mildew symptoms on watermelon (Jason Brock, University of Georgia, Bugwood.org); Downy mildew symptoms on watermelon tends to be distinct compared to other cucurbits. (Plantpath.ifas.ufl.edu

2.2 Alternaria Leaf Blight *(Alternaria cucumerina)*

Alternaria Leaf Blight is a leaf disease that affects many species of Cucurbitaceae, caused by the genus Alternaria and resulting in reduced fruit size, quality, and yield. *Alternaria cucumerina* is considered to be the causal agent of leaf blight in watermelons and other Cucurbitaceae crops.

Symptoms and signs

Alternaria cucumerina is primarily a pathogenic fungus on leaves; however, symptoms in fruits are also mentioned. Symptoms begin as yellow-brown flecks, usually 0.5 mm in diameter, on the upper surface of the crown leaves. They have a light green halo and gradually enlarge, becoming coalescent, with concentric ringing more commonly on the upper surface. Death of the leaves can be followed by lesions, several cm in diameter, forming on ripe fruit. Eventually, many leaves necrotize and die, leaving the fruits exposed to sunburn.

Management

Control of Alternaria Leaf Blight centers on good sanitary practices, and rotation out of cucurbits for 2-3 years further reduces inoculum levels. Tillage helps bury and facilitate the decomposition of residue. Farmers should avoid irrigation at the flowering and pod formation stages. At the end of the growing season, plowing under crop residue is also encouraged. Labeled fungicides should prevent outbreaks of this disease if applied properly. It is important for growers to apply preventative fungicides on a 7- to 10-day schedule and not skip applications.

Identification tips

- Disease symptoms first appear on older leaves as small necrotic spots that may be surrounded by a yellow halo.
- The disease is favored by continuous wet conditions.

Figura 2: Alternaria leaf blight on watermelon (Purdue University.edu); Trunk damaged by Phytophthora gummosis (Aggie-horticulture.tamu.edu)

2.3 Anthracnose (*Colletotrichum obiculare*)

Anthracnose is one of the important factors, limiting the commercial production of watermelon, caused by many species of the plant-pathogenic fungal genus Colletotrichum. Anthracnose can cause a 5-20% reduction in watermelon production or possibly result in no harvest at all. *Colletotrichum obiculare* is also a significant post-harvest pathogen. When watermelon is stored and transported, up to 100% of it may be lost.

Symptomps and signs

All the above-ground parts of watermelon are susceptible to anthracnose. Lesions gradually increase in size with abundant acervuli formation. Anthracnose produces blackish-brown lesions. Centers of older lesions on leaves fall out, giving them a'shot hole' appearance. Petioles and stems show sunken and dark-colored spindle-shaped lesions, which penetrate deeply and finally grid the stem. Infected young fruits show aborted growth or are abnormal. Lesions on young fruit are small, black, depressed spots. On mature fruits, lesions start as yellow, translucent, centered elevated pimples, which later turn into flat-topped, circular, water-soaked elevations (Figure 1B, C). Lesions on mature fruit further sink and show pink spore masses on a black or cream-colored background. The black lesions are the result of the black stroma left behind after the washing of spores, whereas the pink masses are like the spore masses found in culture media. Symptoms included water-soaked lesions on epicotyls, cotyledons and leaves. Infected plants collapsed and died.

Management

Anthracnose is managed by crop rotation, early season planting, resistant varieties and fungicide sprays. Due to the very low tolerance for fruit infection, growers must rely on repeated applications of protective fungicides for acceptable levels of disease control. Fungicides are available and commonly used for control. Benzimidazoles, quinone outside inhibitors (QoI), dicarboximides, and demethylation inhibitors are groups of single-site MOA fungicides that are labeled for anthracnose control.

Identification tip

- The disease occurs during warm and moist season.
- Infection is favoured by high humidity.

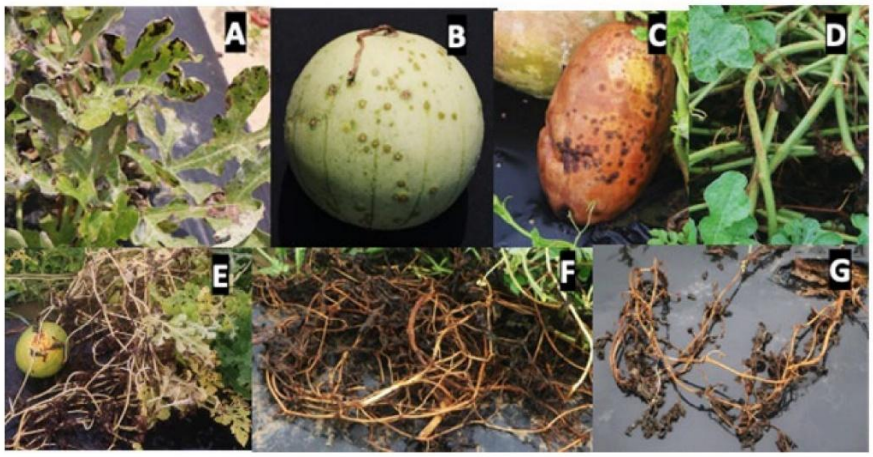

Figura 3: Anthracnose symptoms on watermelon. (A) Leaf; (B,C) fruit; (D) stem; (E–G) foliage (Patel et al., 2023)

2.4 Fusarium wilt (*Fusarium oxysporum* f. sp. niveum)

The hemibiotrophic fungus *Fusarium oxysporum* forma specialis niveum (Fon) is responsible for the development of fusarium wilt. The prevalence of the disease has grown dramatically over the past few decades due to the emergence of races that are able to overcome the market resistance. The devastating soil-borne disease affects the global production of watermelons and causes significant financial losses.

Symptoms and Signs

The infected watermelon initially displayed symptoms such as a reduction in leaf and vine pressure (turgor pressure), which can be recoverable at night; just a single or a few vines may be affected. The disease gradually progressed in the affected seedlings, turning them from dull green to yellow and ultimately necrotic. As the fungus spreads throughout the xylem vessel, the plant produces additional tyloses, which eventually restrict water flow and cause the vine to wilt.

Management

The formation of new physiological races and the 10- to 15-year persistence of chlamydospores make managing Fusarium wilt extremely challenging. Nonetheless, the following modern management techniques are available for preventing wilt disease:

- good sanitary practices: expulsion of an infected plan, removing diagnostical trays, observing disease symptoms of Fusarium wilt
- The introduction of a resistant variety
- Rotation of different crops (non-host crops) for at least 5–7 years
- Grafting watermelon with other cucurbit species
- Use of cover crops before the cultivation of watermelon
- Soil fumigation
- Fungicides: the use of fungicides alone is not effective in controlling *Fusarium* wilt but may help to reduce the level of disease damage.

Identification tip

- Although symptoms typically appear later, plants may be affected early in crop growth.

- Affected vines wilt, become dry, turn brown and die.
- The spatial distribution of infected plants in the field often appears as clusters or "hot spots".
- Brown-to-reddish discoloration of the vascular tissues in the plant crown and runners.
- Plant roots may appear white and healthy early in the infection.

Figura 4 Figure 4: Wilting disease symptoms of watermelon plants caused by Fusarium oxysporum f. sp. niveum (i) Showing brown necrotic lesions at the base of the stem (Muhammad Ziaur Rahman et al., 2021); (ii) Showing a severe form of wilting, laterally the whole plant wilted and died (Muhammad Ziaur Rahman et al., 2021); (iii) brown discoloration of inner crown area (xylem) in lower stem (John Damicone 2020)

2.5 Gummy stem blight (*Stagonosporopsis* spp.)

Gummy stem blight (GSB) is a major disease of watermelon, caused by three related species of Stagonosporopsis [*Stagonosporopsis cucurbitacearum* (syn. *Didymella bryoniae), Stagonosporopsis citrulli,* and *Stagonosporopsis caricae*]. In warm, humid weather, the disease can spread quickly, being one of the most destructive diseases of watermelon in greenhouses. Due to its soil and seedborne origin, this disease may occur at any point during the growing season, even in the initial stages of seedling growth.

Symptoms and Signs

Watermelon GSB symptoms include crown blight, stem cankers, and widespread defoliation, with symptoms appearing in the cotyledons, hypocotyls, leaves, and fruits. The disease mainly affects the foliage (leaves and petioles), while it can also frequently cause fruit rot and seedling blight. Brownish-black, wrinkled spots on leaves are developed and there will also be cankers, or lesions, on the vine stem, which will secrete a brown gummy substance.

Management

To manage GSB in watermelon, agricultural fungicides should be applied before the appearance of the disease. Crop rotation should be carried out in the event of a significant occurrence at the greenhouse or field. The most effective way to control GSB may be to develop cultivars that are resistant to the disease. Rotation with other crops on a two-year cycle and destruction of all the organic debris from previous crops are potential management strategies.

Identification tip

- Circular to irregular in shape, large (up to ¾ inch in diameter) and dark brown to black in color spots

- Spots often appear at the leas margin.
- Gummy stem blight thrives in wet, humid conditions.
- Spots may gradually expand and result in the death of the affected foliage.
- The fungus's fruiting bodies may appear as tiny black specks (on afflicted petioles).

Figura 5: Gummy stem blight lesions on watermelon leaves , Lesion of gummy stem blight on a watermelon leaf petiole (Purdue University's College of Agriculture

2.6 Physiopathies

These non-infectious conditions arise due to environmental stresses, nutritional imbalances, or genetic factors, which affect both growth and yield. Early detection enables precise management to enhance plant health and productivity. It also helps in differentiating non-infectious disorders from infectious diseases, facilitating the correct intervention.

Below are presented some examples of physiopathies in watermelon and tips for their identification.
Irrigation damage: When fruit is handled under high water pressure from heavy irrigation or rainfall, splitting occurs.

Cloudy weather damage: Water soaking occurs when excess water accumulates at the fruit's bottom, causing a water-soaked appearance, often in cloudy weather, when transpiration from vines is low, or deteriorating foliage.

Sunburn damage: Sunscald occurs when fruit is exposed to direct sunlight, especially on hot days, causing rind surfaces to reach temperatures exceeding 120°F. Fruits with little or no foliar cover are most at risk. Sunscald severity is related to fertility, foliage cover, diseases, and storm damage.

Ozone damage: When present in high concentrations, ozone will cause chlorosis and upper surface bronzing and scorching in older leaves, which leads to defoliation. Damage is more prevalent when fruits are maturing or when plants are under stress.

Pollination damage: Insufficient pollination is the main cause of hollow heart, a disorder that is expressed as a crack in the center of the fruit that expands to an open cavity.

Figura 6 Figura 6 The characteristic symptom of watermelon hollow heart (Plantpath.ifas.ufl.edu), ozone Injury in Watermelon (Gordon Johnson 2029); sunburnt watermelons sit in a field (University of Georgia College of Agricultural and Environmental Sciences

Management

The physiopathies can lead to crop losses if not managed effectively, impacting yield and overall plant health. In order to minimize these effects, farmers should maintain consistent watering and avoid excessive soil dryness and sudden changes in soil moisture. Adequate ventilation is also a critical management strategy. Farmers may use covers and harvest fruits timely during ripening to reduce the risk of sunburn.

Elements deficiency

Calcium deficiency: Blossom End Rot causes the fruit's blossom end to become sunken, darkened, and leathery due to calcium deficiency or irregular watering.
Consequences: Browning and shriveling occur at the blossom end of watermelon.

Nitrogen deficiency: The most frequent nutrient issue for watermelon production is a nitrogen (N) deficiency. N deficits can have an impact on crop yield and quality at any point in the growing season, but they can be particularly harmful to crops with fruit sizes between 4 and 6 inches in diameter.
Consequences: Low N availability inhibits plant growth since it is necessary for the synthesis of proteins, amino acids, nucleic acids, chlorophyll, and hormones. N- deficiency can results in yellowing of older leaves starting from the tips, and reduced fruit production.

Boron deficiency: B is an essential micronutrient of watermelon as it is involved in physiological processes that are critical for production, like the creation of the pollen tube, encouraging fertilization and fruit formation. In many high B-soil and high rainfall regions around the world, boron deficiency (BD) is a nutritional disorder. Plants development is impacted by BD as it hinders several essential metabolic activities.
Consequences: Plants with vegetative and reproductive defects; hence, adequate boron supply is necessary. Typical symptoms of a B-deficiency in watermelon include chlorosis and thick, curled leaves with dark, water-soaked spots.

Management

Watermelons' overall health and productivity suffer due to deficiencies in essential elements. This results in lower yields, inferior fruit quality, and heightened vulnerability to environmental stresses and diseases. Effective nutrient management, including timely fertilization and soil enhancements, as well as watering operations that avoid drought stress are crucial for preventing deficiencies. To identify and manage elements deficiencies before they have a significant negative influence on watermelon yields, regular soil testing and plant health monitoring are suggested.

Figura 7: Calcium deficiency in watermelons causing to blossom-end rot. (© Aggie Horticulture, Credit: Tom Isakeit); Calcium, and Boron may lead to the development of cracks (Agrifocuszambia.com)

3 Post harvest diseases

Post-harvest diseases can cause serious damage to fruit if not managed properly. They are usually caused by microbes such as fungi and bacteria.

3.1 Fruit rot (*Phytophthora capsici*)

Fruit rot is a serious disease in most watermelon producing regions. *Phytophthora capsici* infects watermelon at any stage of growth and can result in a range of symptoms. The emergence of water-soaked lesions is one of the initial symptoms. A white fungal growth, referred to as "powdered sugar," frequently covers the lesions, which have a diameter of several inches. Under moist conditions, the growth, containing a variety of sporangia, can fully cover it. Within a few days, infected fruit collapses completely due to fast decay.

3.2 Black rot (*Didymella bryoniae)*

Black rot is one of the major fungal diseases that damage the rind in its postharvest life. Affected fruit develops black, water-soaked spots. Spots emerge sunken and asymmetrical with time. These spots usually emerge on the fruit's blossom end. Under favorable environments, pycnidia and pseudothecia grow close to the dark centers of lesions.

Figura 8: Phytophthora fruit rot (Uga.edu), Phytophthora fruit rot (Cuccap.org), Black rot (Mathews L. Paret, University of Florida, IFAS)

Management

To mitigate post-harvest losses, follow these general guidelines:

- Avoid exposing harvested fruit to direct sunlight.
- Ensure the use of clean, smooth harvesting bins.
- Cleaning equipment regularly.
- Promptly remove old fruit from the packing shed and its surroundings.
- Plant in well-drained, tiled fields.
- Use raised beds and drip irrigation.
- Rotate crops.
- Powerwash equipment after it has been in infested fields.
- Apply fungicides in a preventative manner.
- Avoid over-irrigating.

Pre-harvest management is vital to reduce post-harvest losses.

4 Agronomic practices for crop protection

Successful production requires an integrated approach to manage pests and diseases, including preventative strategies that minimize the likelihood of occurrence and severity of infection. Implementing these measures effectively prevents pest and disease issues from reaching economic thresholds.
Key agronomic practices include:

Choice of cultivation environment

Watermelon is a warm-season crop that is highly susceptible to frost. Abundant sunshine and dry weather are crucial for watermelon production. For germination, a sowing temperature of 18 to 25°C and the ideal moisture content are needed. While a temperature range of around 35 to 40°C is desirable for watermelon of good quality throughout fruit development, an average temperature of 30 to 35°C is needed for growth. Warm days and cool nights might cause fruits to accumulate greater amounts of sugar. Watermelon cultivation is best suited for loamy, well-drained soils that are slightly acidic (pH 6.0 to 7.0), and rich in nutrients. Due to its high demand for water, watermelon requires 400–600 mm of rainfall distributed regularly throughout its growing season.

Varietal choice

Choosing the suitable watermelon variety is one of the most important decisions a grower has to make. Lower profitability or even the potential failure of the watermelon company result from planting a variety that is not appropriate for the market as well as the specific production circumstances. It is very important that the variety be tailored to the producing location, have a high degree of certain disease resistance traits, and have an adequate yield in addition to being marketable.

It is notable that dark green and striped watermelons are more likely to cause sunburn damage than light green and gray-green watermelons.

One important varietal attribute to take into account is the resistance *Fusarium wilt* and anthracnose diseases.

Rootstock selection

Rootstock selection for watermelon is frequently used to provide crops desirable characteristics like higher yields, resistance to disease, or enhanced environmental adaptation. Growers should take into account a number of criteria, including the climate, prevalent diseases, local soil conditions, and desirable features for maximum crop performance, when selecting a rootstock.

Land and Seed operations

December is the ideal month to sow watermelon so that the fruits will be ready for the summer. A couple of crosswise ploughings should be provided to land to prepare it for the fine tilth stage. The field has been leveled, and any weeds from previous crops should be removed.

It is preferred to use pre-sprouted seeds to improve crop stand in the field. The seeds should be soaked in water overnight and then kept in a gunny bag near a warm place. The seeds will start to germinate in about 3 to 4 days. Watermelon can be planted directly from seed or transplanted from a nursery.

Planting techniques and distance

Planting distances play a crucial role in cultivating crops with yield high-quality fruits while ensuring efficient management practices. The recommended seed rate for watermelon can vary based on factors like the variety, soil fertility, and planting method. Approximately 3 to 4 kg of seeds are required for a hectare.

Regarding planting distances, in general, the watermelon crop is spaced at 1.5 m between the rows and 1 m from one crop to the other. The vines require enough space for their spreading. Adequate spacing between watermelon plants promotes good airflow, reduces competition for nutrients and water, and minimizes the risk of diseases.

More specifically, in furrow method, furrow should be made 2-3 m apart, with 2-3 seeds at each place and the removal of the weak seedlings after germination and keep the plant-to-plant distance at 0.75–1 m along the furrows. If planting in hills, create hills that are about 1-1.5 m apart, with 2-3 seeds or one transplant per hi. If planting in hills, create hills that are about 1-1.5 m apart, with 2-3 seeds or one transplant per hill. In case of pit method, keep a pit-to-pit distance of about 2-3 m and sow 4 seeds per pit. Later, remove unhealthy plants and retain only 2 or 3 plants per pit.

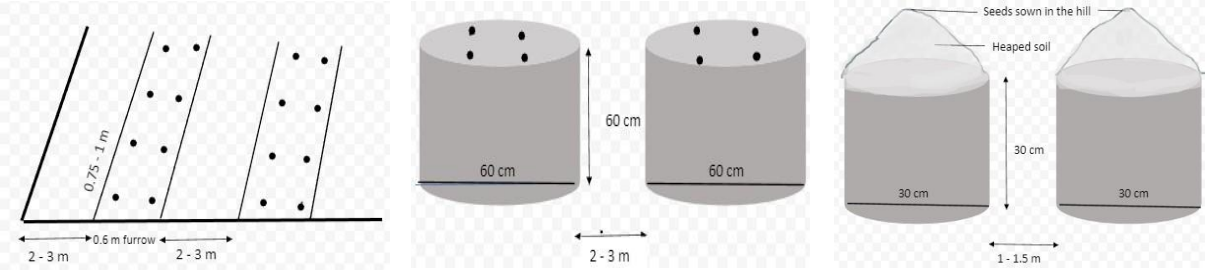

Figura 9 Methods of sowing; Furrow method; Pit method and Hill method (Deepika M, bighaat.com)

Regarding the depth, watermelon seeds should be planted at a depth of about 1 inch in well-prepared soil.

Pruning

Fruit quality and production are enhanced by pruning. Pruning excess fruit is necessary to ensure that the proper quantity of fruits develops and reaches commercial quality. In case the vines are about 1 m, apical shoots can be removed in order to promote growth of side shoots. The removal of any damaged or diseased fruits during the first stages of fruit setting and the retention of no more than 4–5 fruits per vine can increase fruit output and size.

Soil management

Watermelons grow best in well-draining soils with good water retention capabilities. The best soil types are usually loamy or sandy loam soils because they retain enough moisture to support plant growth while allowing for proper drainage. The ideal pH range for soil when growing watermelon is between 6.0 and 7.0.

Before planting, till the soil down to a depth of around 6 to 8 inches. To establish a clean environment for seedlings or transplants, remove any weeds and debris from the area.

Mulching can help maintain soil moisture, inhibit weed growth, and keep soil temperatures stable, all of which are advantageous for watermelon crops. Straw and grass clippings are the most common kinds of organic mulches.

Fertilization

Fertilization is integral to restore nutrients that are diminished following fruit harvest and pruning, thus facilitating vigorous vegetation growth. This process heavily relies on the application of essential macronutrients like nitrogen, phosphorus, and potassium, complemented by micronutrients. The primary objective of fertilization is to achieve sustainable, high-quality crop yields that are economically feasible, while also conserving soil fertility and minimizing environmental impact. To this end, developing a precise fertilization strategy is crucial, encompassing a farm management plan that stipulates the annual maximum nutrient inputs tailored specifically to the nutritional demands of the crop.

Proper fertilization is key to successful watermelon cultivation, influencing both the yield and the quality of the fruit.

The fertilization management for watermelons is adapted based on the variety of the crop and the local conditions of the cultivation area. Each region and variety may have different needs in terms of nutrient availability and uptake, while soil and climate conditions also affect the efficiency of fertilization.
Therefore, it is crucial to evaluate the potential of the key fertilization elements: Nitrogen (N), Phosphorus (P), and Potassium (K), before implementing any fertilization plan. These elements are essential for the growth and fruiting of watermelons.
The fertilization decisions should be based on soil test results and consider local agricultural guidelines. Adequate watering is crucial for nutrient uptake. Fertilizers should be applied when the soil is moist, and irrigation should be increased after fertilizing. The farmers should avoid overwatering, as it can lead to nutrient leaching and root rot.

Irrigation
Watermelon, a warm-season crop, requires adequate water for optimal growth and fruit development. Irrigation is crucial for maintaining consistent soil moisture, promoting healthy plant growth, and enhancing fruit quality. Watermelon plants require 1 to 2 inches of water per week, depending on soil type, weather conditions, and growth stage. Regarding the irrigation methods, drip, furrow, or sprinkler irrigation is applied. Drip irrigation is highly efficient for watermelon production. It delivers water directly to the root zone, while furrow irrigation is used in larger-scale operations, furrow irrigation involves creating shallow channels (furrows) between rows and flooding them with water. Sprinkler irrigation (spraying water over the crop) is less common than drip irrigation but is suitable for certain soil types and field layouts.
Watermelon typically needs more water during hot and dry periods.

Harvesting
Watermelon may usually be harvested 30 to 40 days after its flowering.
Farmers monitor the development of the watermelons closely, looking for signs of ripeness such as a dull sheen on the skin, a yellowish patch where the melon rested on the ground (known as the "ground spot"), and a dried tendril near the stem. When a watermelon is considered ripe, it is carefully removed from the vine using pruning shears or a sharp knife. It's important to leave just a small portion of the stem on the fruit as it contributes to its shelf life.

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CHAPTER 5

Orange [Citrus sinensis]

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WHAT WILL WE LEARN IN THIS CHAPTER?

We're going to learn about the characteristics of oranges trees, their fruit-related diseases both in the field and post-harvest, along with the physiological disorders they may develop. This comprehensive exploration encompasses disease management strategies and best practices aimed at optimizing orange cultivation.

Keywords: Orange tree, Diseases and Physiopathies, Post-Harvest Care, Farming Techniques

Summary

1 Overview

Oranges, scientifically classified as Citrus × sinensis, are dicotyledonous angiosperms and evergreen plants within the order Sapindales and the family Rutaceae. Originating from India and China, they hold a prominent status among citrus fruits due to their refreshing taste and significant vitamin C content. Offering a range of flavors from sweet to tangy, oranges are widely enjoyed as both a snack and a versatile ingredient in various culinary applications, including juices and desserts. Oranges play a vital role in global diets and are a major source of income for numerous farmers. Nevertheless, they are vulnerable to various diseases and physiological issues that can negatively impact their yield, quality, and financial returns.
According to Eurostat 2017, Spain, Italy, and Greece are the largest citrus fruit producing countries in the EU, with Spain accounting for 60%, Italy for 27%, and for Greece 9%. Orange groves account for 56%, small fruits for 31%, and lemons for 13%.

2 Field diseases and physiopathies

2.1 Huanglongbing (Citrus greening) (*Candidatus Liberibacter*)

Citrus greening, commonly known as Huanglongbing (HLB), is a plant disease caused by uncultured, phloem-restricted alpha-proteobacteria in the genus Candidatus Liberibacter. These pathogens are well-adapted, circulative, and systemic colonizers of the psyllids that transfer them into phloem cells. HLB is one of the most dangerous citrus diseases worldwide. Most trees that get infected die in just a few years. Although there is little risk to human or animal health, the disease has destroyed millions of acres of citrus crops.

Symptoms and signs

The disease presents with asymmetrical leaf mottling, often accompanied by yellowing of the leaf midribs. Sections of the canopy exhibit decline and dieback, eventually leading to the decline and dieback of the entire canopy. As the infection progresses, the tree produces characteristic yellow shoots. Affected fruit is typically lopsided, may have aborted seeds, and exhibits an altered flavor profile. Fruit yield diminishes, with smaller and prematurely dropping fruit becoming common. The tree's overall health deteriorates over 2–3 years, culminating in its eventual death.

Management

HLB control involves quarantine, clean stock, and certification programs (select certified disease-free seedlings) to prevent infected nursery stock movement. The psyllid vectors must be controlled. In areas without HLB, regular surveys, pesticide application, and clean plant material for replanting are effective approaches. Chemical sprays, such as insecticides, can also be used to control citrus psyllid populations.

Identification tip

Citrus greening symptoms on leaves include yellowing of one limb or one area of the canopy, yellowing of leaf veins, blotchy mottling, and/or green spots surrounded by completely yellow

leaf tissue; twigs and limbs begin to die back; fruits may drop prematurely and are often misshaped and lopsided; fruit has a bitter, salty taste.

Figure 1: Citrus greening on leaves (Orange Leader, 2020, www.orangeleader.com); Waxy psyllid droppings (www.citrusalert.com); Citrus greening symptoms (Adam Russell, 2019, Texas A&M AgriLife)

2.2 Phytophthora gummosis (*Phytophthora spp*)

Gummosis is caused by the fungus Phytophthora spp. Infection may occur from soil or nursery plants due to extended periods of moist and wet conditions. This disease is commonly seen in mandarins, sweet oranges, lemons, and other citrus fruits. Gummosis is one of the main diseases that contributes to citrus decline. Six Phytophthora spp. cause citrus fruit tree disease, with two causing the most significant reduction in fruit yield: Phytophthora *parasitica* and Phytophthora *citrophthora*.

Symptoms and signs

Gummosis causes gum formation on citrus trees. Diseased portions of the trees show symptoms of vertical cracking of the bark along with the formation and release of brown-colored gum-like substances from the lesions. In addition, it also shows symptoms of water-soaked, reddish brown along with a black, slimy appearance on the affected bark of citrus trees. The disease can lead to tree death due to girdling.

Management

To prevent and manage gummosis in citrus plants, a multifaceted approach is essential, beginning with careful site selection that ensures proper drainage and avoids water stagnation. Planting techniques such as setting the plants slightly above ground level help reduce water contact. It's also crucial to avoid excessive irrigation and adopt routine sanitary practices in the early growth stages, including the use of resistant rootstocks and grafting. Regular pruning and plant surgery are beneficial, alongside diligent soil preparation, irrigation management, fertilizing, and weed control. Finally, when necessary, chemical control using fungicides should be considered.

Identification tips

- Check for gumming, lesions, wilting leaves, and root rot symptoms; look for fruit decay.
- Assess environmental conditions like drainage and moisture levels. Susceptible rootstocks, excessive irrigation, freeze damage, high water tables, and salt accumulation contribute to its rapid growth and development.

Figure 2: Gummosis on the main branch of sweet orange tree (Mekonen M. ET AL., 2015, Journal of Horticulture 2(4):154); Brown rot caused by Phytophthora citrophthora on a citrus fruit; Symptoms of damage of brown rot caused by Phytophthora citrophthora on a citrus tree. (www.cropscience.bayer.eg/en)

2.3 Citrus canker (*Xanthomonas axonopodis*)

Citrus canker is a bacterial disease that affects citrus trees and is caused by the bacterium Xanthomonas axonopodis pv. citri. The disease is highly contagious and can cause severe economic losses in citrus production areas. Citrus canker is characterized by the appearance of lesions on the leaves, fruits, and twigs of infected trees.

Symptomps and signs

The primary symptoms include distinctive lesions on the leaves, fruits, and twigs of citrus trees. These lesions typically appear as raised, circular spots with a water-soaked margin and a yellow halo, distinguishing them from other diseases. Leaf spots can lead to premature leaf drop, while fruit lesions cause blemishes that render the fruits unsuitable for sale. Infected twigs exhibit sunken, raised areas, contributing further to the decline in tree health and fruit quality.

Management

Managing citrus canker requires prompt identification and implementation of control measures to prevent its spread and minimize economic losses in citrus production. Integrated management practices, incorporating various strategies such as resistant cultivars, windbreaks, and copper-based bactericides sprays, are designed to reduce citrus canker incidence. Starting with canker disease-free nursery plants is crucial to prevent the introduction of bacteria into new groves. Regular pruning of infected twigs and branches helps remove diseased tissue and reduce bacterial populations. Burning the pruned material can further prevent the spread of the disease.

Identification tip

Look for:

- Raised, circular lesions with a water-soaked margin and a yellow halo on citrus leaves, fruits, and twigs.
- Brown or yellowish lesions on leaves.
- Inspect twigs for sunken, raised areas or cankers that may ooze bacterial exudates.
- The presence of a distinct yellow halo around lesions is characteristic of this disease.

Figure 3: Xanthomonas spp. symptoms on leaves, fruits and stem and branch section (idtools.org/citrus_diseases)

2.4 Citrus Tristeza (*Citrus tristeza virus* - CTV)

The virus known as *Citrus tristeza virus* (CTV) (genus Closterovirus, family Closteroviridae) is the cause of terrible outbreaks that altered the development of the citrus sector. Tresza, stem pitting (SP), and seedling yellows (SY) are the three main syndromes induced by CTV. These syndromes arise from the diverse ways that CTV interacts with scions and rootstocks in different geographical areas. Infected budwood and a few aphid species are the main semipersistent transmitters of the virus's spread.

Symptoms and Signs

Stem pitting, rapid decrease, and yellowing of the seedlings are the most typical visible symptoms of CTV. The fruit on the tree starts to deteriorate and/or yield less fruit. Vein clearing, cupping, chlorotic leaf flecking, and corky veins can all be observed in the leaves. Symptoms including dwarfing, thinning of the foliage, and tree collapse could be due to root problems. CTV can also be recognized as bumpy or ropey spots on the tree's trunk. Phloem cells are killed by the virus. This prevents nutrients and water from the roots from reaching to the leaves as well as carbohydrates from the leaves from reaching to the roots.

Management

Management of the tristeza complex depends largely on preventive measures, such as using citrus rootstock species that induce tolerance to the tristeza disease and tristeza-free propagation material. By using a cross-protection management strategy, several citrus-producing countries are decreasing the damaging effects of CTV. Tristeza disease can be managed through vector control and exclusion and quarantine.

Identification tip

Fruit, leaves, and twigs may dry and die on infected trees. CTV can cause two significant diseases: stem pitting in grapefruit, pomelo, lime, and some sweet orange varieties and quick decline in citrus scions, particularly sweet oranges grafted on sour orange rootstock. This decline is caused by virus-induced phloem necrosis, disrupting carbohydrate movement to the root system, and degeneration of existing fibrous root systems. Infected plants may display thin foliage, leaf shedding, twig dieback, chlorotic leaves, and low-market-value fruits.

Figure 4: Symptoms (e.g. inverse pitting) induced by CTV below the bud union on sweet orange trees; Chlorotic and declining sweet orange infected by CTV, compared with a healthy-looking tree in the middle (EPPO Global Database); Brown citrus aphids, vectors of citrus tristeza virus (Citrus Industry Magazine)

2.5 Anthracnose (*Colletotrichum*)

Many Colletotrichum species, primarily C. *gloeosporioides*, are responsible for postharvest diseases. One of the most severe of these diseases is anthracnose. Plant pathogens, like the anthracnose-causing Colletotrichum, can attack fruit and vegetable crops in the field as well as during postharvest storage and commercialization. This reduces the crops' shelf life and necessitates the use of pesticides, as a disease mitigation strategy. Fruits and other plant parts, such as leaves, flowers, twigs, and branches, are infected by Colletotrichum spp.

Symptoms and Signs

According to Peralta-Ruiz (2023), the fungus may infect plants without causing any symptoms through developing an endophyte behaviour and remaining quiescent. Tissues wilt and dry due to anthracnose. Tissues wilt and dry out due to anthracnose. Plants that are infected exhibit browning, curling, cupping (in the case of immature leaves), and early drop in addition to black spots on their leaves. Flowers can also exhibit the symptoms mentioned before. Small, rounded spots may appear on the fruit's surface during the preharvest stage, but the fungus may remain latent as appressorium until the postharvest, when it can cause the fruit to decay, degrade, and develop black spots.

Management

The primary method of preventing damage is traditional chemical-based anthracnose management, both in the field and in commercial packinghouses following harvest. Synthetic fungicides do, in fact, work well to lessen the growth of fungus during fruit storage and the inoculum Colletotrichum in the field. Recent investigations have explored the use of biocontrol agents like biocoatings and biofilms, with extracts and essential oils, and antagonistic microorganisms for sustainable anthracnose postharvest management.

Identification tip

Anthracnose can be identified by its characteristic symptoms in various tree species. These include twisted green leaves with brown tips and tan to brown irregular spots or dark blotches on young leaves. Infected leaves may exhibit distortions, cupping, or curling. Severe cases can lead to leaf drop in spring. In cold rainy spring weather, anthracnose is most frequent.

Figure 5: Symptoms on citrus fruits caused by Colletotrichum spp.; Brown and dark lesions on orange (Daoud, H.B., et. (2019). Phytopathologia Mediterranea, 58, 175-185); Typical anthracnose on fallen orange fruits ; Anthracnose symptoms on leaf (Guarnaccia V. et al, 2017)

2.6 Physiopathies

These non-infectious conditions stem from environmental stress, nutritional imbalances, or genetics, impacting growth and yield. Early identification allows for targeted management, optimizing plant health and productivity. It also aids in distinguishing between non-infectious disorders and diseases caused by pathogens, ensuring appropriate treatment.
Here are some examples of physiopathies that you could find in orange trees, and tips to recognize them.

Water Stress: Both overwatering and underwatering can cause significant problems for orange trees. Overwatering can lead to root rot and nutrient leaching, while underwatering can cause wilting, leaf drop, and reduced fruit size and quality.

Sunburn: Excessive exposure to direct sunlight, especially during hot weather, can cause sunburn on the fruit and leaves. This results in scorched, discolored patches and may lead to a reduction in fruit quality and marketability.

Frost Damage: Exposure to freezing temperatures can damage the leaves, flowers, and fruit of orange trees. Symptoms include blackened foliage, fruit drop, and in severe cases, death of young trees. Frost damage is particularly harmful during the blooming period.

Wind Damage: Strong winds can cause physical damage, including broken branches, leaf loss, and fruit drop. Continuous wind exposure can also lead to desiccation and increased susceptibility to diseases.

Figure 6: Frost damage to young citrus leaves (ucanr.edu); Defence mechanism against high temperatures (UF/IFAS University of Florida); Sunburned citrus fruit (Grow Great Fruit)

Management

Consequences of frost, wind, and sun damage to orange trees include reduced yields, poor fruit quality, and potential economic losses. To effectively manage common physiopathies in orange trees, maintaining a balanced watering schedule to prevent both overwatering and underwatering, ensuring the soil is well-drained and retains adequate moisture, is crucial. Protect trees from extreme sun exposure by providing partial shade or using whitewash on trunks, and guard against wind damage with windbreaks and proper pruning. During frost events, the trees should be covered with protective materials. Consistent monitoring and timely interventions will help keep orange trees healthy and productive.

Elements deficiency

Orange trees are susceptible to several nutrient deficiencies that can significantly impact their health and productivity. Here are some of the most important nutrient deficiencies, along with their key identification features:

Nitrogen Deficiency: This deficiency is often due to poor soil fertility or insufficient fertilization. Pale green or yellow leaves, starting with older leaves, could be appear. Moreover, smaller fruit size may occur.

Iron Deficiency: Iron Deficiency is often caused by high soil pH. Yellowing between the veins of young leaves, while veins remain green.

Magnesium Deficiency: Magnesium Deficiency can be exacerbated by high levels of potassium in the soil, which competes with magnesium uptake. The yellowing of older leaves with green veins, may lead to a V-shaped pattern from the leaf edges inward.

Zinc Deficiency: In soils with a high pH or those that are sandy and low in organic matter, Zinc deficiency often occurs. Small leaves with a narrow, pointed shape (little leaf), interveinal chlorosis, and rosette-like clusters of leaves at the shoot tips exhibit.

Management

Element deficiencies can significantly impact the health and productivity of citrus trees like lemons, causing decreased yields, inferior fruit quality, and heightened vulnerability to environmental pressures and diseases. Effective management involves timely fertilization, soil amendments, and maintaining optimal pH levels. Understanding your soil's characteristics is crucial, as they directly influence nutrient availability. By implementing proper nutrient management practices, citrus growers can mitigate deficiencies and promote robust tree performance, ultimately enhancing crop outcomes and resilience.

Figure 7: Magnesium deficiency in citrus(Stephen H. Futch and David P. H. Tucker, edis.ifas.ufl.edu); Nitrogen deficiency - Dark green leaf is normal; the other two leaves are deficient - (Stephen H. Futch and David P. H. Tucker, edis.ifas.ufl.edu); Dieback of smaller twigs, multiple buds, and numerous small, weak shoots by Zinc deficiency (www.dpi.nsw.gov.au/agriculture)

3 Post harvest diseases

Various microbial infections and physiological disorders can affect fruits, vegetables, and other agricultural products after they have been harvested. These diseases can occur during handling, transportation, storage, and distribution processes, leading to spoilage, decay, and economic losses. Fungi, bacteria, and viruses are among the microorganisms responsible for post-harvest diseases, with factors such as temperature, humidity, and mechanical injury influencing their development.

3.1 Blue and green mould (*Penicillum italicum* and *P. digitatum)*

Blue mold (*Penicillium italicum*) and Green mold (*Penicillium digitatum*) are two major post-harvest diseases that affect oranges, leading to significant economic losses. Both molds initiate infection through wounds or damaged areas on the fruit peel. The initial symptoms for both diseases start as soft, water-soaked spots that quickly become covered with mold—blue-green in the case of Blue mold and olive-green for Green mold. As the infection progresses, these molds can spread rapidly over the fruit surface, penetrating deeply into the flesh, resulting in extensive decay and a musty odor. The affected areas may become sunken and wrinkled, causing the fruit to lose firmness. Optimal growth conditions for these molds include temperatures ranging from 10°C to 25°C (50°F to 77°F) and high relative humidity above 85%.

3.2 Sour rot (*Geotrichum candidum*)

Sour rot caused by the fungus *Geotrichum candidum*, begins at sites of injury, manifesting as small, soft, water-soaked lesions. These lesions quickly expand, resulting in extensive, watery decay. The infected areas often display a creamy to white fungal growth, and the fruit emits a distinct sour, pungent odor as the rot progresses. Optimal conditions for the development of sour rot include warm temperatures and high humidity, which facilitate the rapid spread and severity of the infection.

3.3 Black rot (*Alternaria alternata*)

Black rot, caused by the fungus *Alternaria alternata* affects oranges by forming small, dark lesions that expand and lead to internal decay, often starting around wounds. This fungus thrives in warm temperatures (20°C to 30°C) and high humidity (above 85%). It enters through mechanical damage or natural openings, with poor storage conditions exacerbating its spread. It affects most of the members of the citrus family and often causes severe losses. The disease primarily affects the aboveground parts of plants, leaves, and fruits. The first symptoms, however, usually appear on the leaves as black necrotic lesions. Later, black necrotic lesions are also formed on fruits, and with the age of plants, the fruits become soft and black rot.

3.4 Stem and Rot (*Diplodia natalensis)*

Stem-End Rot, caused by the fungus *Diplodia natalensis* (also known as *Lasiodiplodia theobromae*), typically manifests at the stem end of the fruit, causing a soft, brown rot that progresses inward. The initial symptoms include darkening and softening of the area around the stem, which eventually leads to a watery, mushy decay that can engulf the entire fruit. The development of this fungus is favoured by warm temperatures and high humidity. Proper sanitation, careful handling, low humidity and cooler temperatures during storage are crucial measures to prevent and manage Stem-End Rot.

Figure 8: Penicillium digitatum (Green mold) on orange (Citrus Fruit Processing, 2026), Symptoms of Alternaria Brown Spot (ABS) on citrus fruits, Sour rot caused by Geotrichum candidum in oranges (University of California - Agriculture and Natural Resources)

Management

Strategies for Managing Postharvest Diseases in Oranges:

- Keep harvested oranges out of direct sunlight to avoid heat damage.
- Do not harvest oranges when they are cold and wet, as it may lead to oleocellosis and the activation of fungal spores.
- Clean packing line equipment and remove old or leftover fruit from the packing area.

- Use appropriate disinfectants on storage surfaces and equipment to reduce the microbial load.
- Regularly inspect stored oranges for signs of decay and remove any affected fruit.
- Store oranges at the recommended temperature (4–7 °C) and proper humidity levels (85–90%) to slow down the growth of pathogens.
- Use packaging that allows for proper ventilation to reduce moisture accumulation and fungal growth.
- Train workers to properly handle the fruits and educate them on hygiene practices in order to minimize damage and contamination.

4 Agronomic practices for crop protection

Choice of cultivation environment

Selecting the right cultivation environment is crucial for protecting orange crops from various diseases and pests. Ideal orange groves should be located in regions with well-drained soil. The optimal temperature range for orange growth is between 12°C and 38°C, with the best fruit development occurring between 24°C and 32°C. Moreover, the selection of sites with good air circulation minimizes humidity levels around the trees, which can otherwise create favorable conditions for pathogens. The use of windbreaks can protect the orchard from strong winds that might cause physical damage to the trees and spread spores of harmful fungi. Finally, the optimal soil pH for oranges is between 6.0 and 7.5, as this slightly acidic to neutral range allows for the best nutrient availability and uptake by the trees.

Varietal choice

Different orange varieties have varying degrees of resistance to pests and diseases, climatic adaptability, and postharvest durability. It is crucial to select a variety that is well-suited to the local environmental conditions. For instance, some varieties are resistant to fungal infections and tolerate drought conditions, which can minimize the need for chemical interventions. In Spain, the 'Navelina' and 'Salustiana' varieties are popular choices due to their resistance to common diseases and pests. The 'Navelina' orange, in particular, thrives in the Mediterranean climate and produces thick-skinned fruits that are less susceptible to physical damage and postharvest decay.

Rootstock selection

The selection of rootstock plays a pivotal role in achieving success, as it significantly impacts tree vigor, disease resistance, and adaptability to soil conditions. Choosing a rootstock that is resistant to common soil-borne diseases such as Phytophthora root rot and nematodes can significantly enhance the health and longevity of orange trees. Additionally, rootstocks can be selected for their tolerance to abiotic stresses like drought and salinity.

Plant operations

Prior to the planting process, thorough site selection and soil preparation are essential. Soil testing should be conducted to assess nutrient levels and pH, ensuring optimal conditions for growth. During planting, attention to spacing is paramount. Proper spacing between trees, typically ranging from 4 to 6 meters apart, allows for adequate sunlight penetration and air circulation, while reducing the risk of disease. Moreover, the depth of planting holes should be carefully

managed, with depths ranging from 0.5 to 0.8 meters, depending on soil conditions and rootstock varieties. Mulching around the base of trees helps retain soil moisture and suppresses weed growth, further enhancing plant health and productivity. Regular monitoring and maintenance throughout the growing season, including pest and disease management, ensure the long-term success of the orange orchard.

Planting techniques and distance

It's critical to consider the distance between orange trees while planting in order to facilitate optimal air circulation, sunlight exposure, and nutrient distribution. Adequate spacing lessens the possibility of fungal spread while contributing to control disease. The typical distance between orange trees varies based on the variety, type of soil, and local climate conditions. A standard recommendation is to maintain 15 to 25 feet (4.5 to 7.5 meters) between trees in rows and 20 to 30 feet (6 to 9 meters) between rows. This spacing allows for sufficient room for tree growth, efficient irrigation, and ease of maintenance, contributing to healthier trees and higher yields over the long term. "Dwarf" citrus trees are smaller and require less area. These can be planted in rows closer together, and the rows themselves can be planted closer together.

Repotting (in the case of pot or container)

Repotting should ideally be done every 2-3 years for young orange trees, and less frequently, every 3-5 years, for mature trees. The best time to repot is during the early spring before the active growing season begins. This process involves carefully removing the tree from its current pot, pruning any circling or overly long roots, and transplanting it into a larger container with fresh, well-draining soil.

Pruning

Pruning is critical for protecting orange trees, promoting healthy growth, and enhancing fruit quality. It should ideally be performed annually before the new growth begins. The optimal time to prune the orange trees is between late February and April. In colder climates, consider trimming your tree as the weather warms up, which may be late February or early March. In the case of a hotter climate, the pruning should start sooner. Selective thinning is the preferred pruning technique for orange trees. It involves removing any inwardly or downwardly growing shoots as well as any diseased, dead, or damaged branches with great care. This technique improves air circulation and light penetration throughout the canopy, lowering the risk of disease and pest infestations. Regular properly performed pruning improves both the overall health and production of orange trees, resulting in a healthy and bountiful orchard.

Soil management

A vital part of agronomic strategies for protecting orange trees and guaranteeing optimal growth and fruit yield is soil management. Soil management requires maintaining the correct soil composition, nutrient levels, and structure. The soil should be well-drained, with a pH of 6.0 to 7.5, and high in essential nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, and trace elements like iron and zinc. Regular soil testing is required to identify nutrient deficits and adjust fertilization accordingly. Manuring is essential to improve soil fertility and structure; adding organic matter like compost or well-rotted manure improves soil texture, moisture

retention, and microbial activity. Furthermore, weed control is essential to reduce competition for nutrients and water. This can be accomplished by mulching, physical removal, or the use of cover crops that inhibit weed growth.

Fertilization

Effective fertilization processes are critical to enhance crop quality and quantity. Fertilizer requirements vary depending on soil quality, crop type, and stage of growth. Nitrogen, phosphorous, and potassium are the most common nutrients required. Fertilizers are usually applied at planting and then in split doses throughout the growing season to ensure a steady nutrient supply. Citrus is typically fertilized three times per year. The required amount varies depending on the age, size, and types of trees. It is well-mentioned that annual fertilizer requirements should be determined through soil testing and crop monitoring, adjusting for factors such as previous crop history and organic matter content.

Irrigation

Orange trees typically require regular watering, especially during dry and hot seasons. The amount of water needed depends on various factors, such as the age of the trees, soil type, and climatic conditions and can be met through a combination of rainfall and supplemental irrigation. The goal is to maintain a balance where the soil is moist but not waterlogged, as excessive water can lead to root rot and other diseases. It is well mentioned that young trees and newly planted saplings require more frequent watering to establish a strong root system. Drip irrigation systems are highly recommended as they deliver water directly to the root zone, minimizing water loss through evaporation and runoff.

Using soil moisture sensors and weather data can help optimize irrigation practices, ensuring that the trees receive the right amount of water at the right time.

Harvest

Identifying the optimal harvest time for orange trees is crucial to maximize yield and fruit quality. A thorough assessment of the orchard is the first phase in the harvesting process, and it helps determine the maturity of the oranges. Oranges should be harvested at full maturity but before they become overripe. The optimal harvest time varies depending on the variety of the orange and the specific growing conditions. For example, navel oranges typically reach maturity in the winter months, while Valencia oranges may not be ready until late spring or early summer. Indicators of maturity include the color change from green to orange, the ease with which the fruit detaches from the tree, and the development of the desired sweetness and acidity.

Techniques to harvest at the right time:

- Measurement of the sugar content (Brix) using tools such as refractometers,
- Assessment of the acidity levels,
- Visual inspections,
- Taste tests,
- Evaluating environmental factors such as temperature and rainfall.

By combining scientific measurements with practical experience, farmers can determine the precise moment when their oranges are at their peak, ensuring a bountiful and high-quality harvest.

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CHAPTER 6

Lemon [Citrus × limon (L.) Osbeck, 1765]

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WHAT WILL WE LEARN IN THIS CHAPTER?

We're going to learn about the intricacies of lemon trees, their diseases both in the field and post-harvest, along with the physiological disorders they may develop. This comprehensive exploration encompasses disease management strategies and best practices aimed at optimizing lemon cultivation.

Keywords: Lemon tree, Diseases and Physiopathies, Post-Harvest Care, Farming Techniques

Summary

1 Overview

Lemons (*Citrus limon*) are versatile and widely cultivated fruit crops known for their tangy flavor and various culinary and medicinal uses. They are an essential component of diets worldwide and serve as a significant source of income for many farmers. However, like any other crop, lemons are susceptible to a range of diseases and physiopathies that can adversely affect yield, quality, and profitability.

2 Field diseases and physiopathies

2.1 Botrytis rot (*Botrytis cinerea*)

Botrytis rot is caused by *Botrytis cinerea*, a ubiquitous fungus that damages twigs, leaves, blossoms, and fruit of citrus in areas with prolonged wet and cool conditions. The organism is a minor citrus pathogen, with a higher incidence of infection in lemons than other citrus crops.

Symptoms and signs

The Botrytis pathogen commonly infects tissue through injuries and forms grey, velvety mats of sporulating tissues. Infected twigs may die back several inches. Infected blossoms result in increased fruit drop and in injuries to the developing fruit. These fruit injuries are evident as ridges on mature fruit that result in a lower-graded crop during marketing. The name "grey mould" is used to describe the disease when it occurs as fruit decay during postharvest storage.

Management

General preventive measures, such as avoiding mechanical injury, protecting against frost and brown rot, and pruning regularly to improve air movement may help reduce the incidence of Botrytis diseases. Sprays of copper fungicides before rain or fog may help to reduce the blossom and fruit phases of the disease. Under prolonged cool, wet environmental conditions, frequent sprays are required and these may not be economical. Postharvest applications may be required in wet years to prevent fruit decay during storage and marketing.

Identification tip

Botrytis fungus can infect and kill young shoots. Botrytis develops after prolonged rainy conditions, especially in coastal lemons where infections can move from old blooms to developing new lemons in spring.

Figure 1: Botrytis symptoms on flowers and development of gray mould on post-harvest fruits (www.wikifarmer.com); Symptoms of Botrytis on fruit (www.mindenpictures.com); Fruit damaged by Botrytis rot (© 2016 Regents of the University of California, Credit: Jack Kelly Clark).

2.2 Gummosis (*Phytophtora*)

This pathogen represents one of the most dangerous fungal adversities for citrus trees. The elective host of *P. citrophtora* is lemon but also sweet orange is not exempt from its attentions.

Symptoms and signs

The attack of *P. citrophtora* occurs in the collar area, and then spreads to the basal portions of the trunk and adjoining parts of the large roots. The bark of the affected areas necrotizes. The outer bark (topsoil) rapidly desiccates, shrivels and eventually cracks in a longitudinal pattern. The buried portion (subsoil) goes into wet rot, due to the emergence of other microorganisms. The woody organs of affected individuals produce gum, even far from the infection points, which will eventually drip slowly downward, settling on the ground.

Fruits may also be affected; the symptom will be brown rot. The discoloration becomes apparent from 2 to 7 days after the onset of infection: it takes the form of a slight discoloration, often in a rounded area that rapidly takes on a dark-brown color. Affected tissues become soft and saggy, giving off a pungent, characteristic rancid odor.

Management

These pathogens live in the soil or on root residues. Infection is caused by mobile units, capable of swimming in water and coming into contact with the host. Rootlets are attacked in the elongation zone, while collar infections (gummosis) occur following small traumatic wounds on the bark and when the collar remains wet for more than 18 hours. Irrigation methods (lateral infiltration), transport of infected soil among fields or the use of infected propagation material, contribute to the rapid spread of pathogen propagules. For these reasons we should avoid heavy and poorly drained soils at planting, adopt resistant rootstocks (e.g., bitter orange), avoid water stagnation near the collar. In addition, removal of infected parts in the collar area should be avoided because, through the wounds produced, it exposes the plant to Mal secco attacks.

Identification tips

- Check for gumming, lesions, wilting leaves, and root rot symptoms, look for fruit decay
- Assess environmental conditions like drainage and moisture levels.

Figure 2: Gum oozing from cracks in trunk bark is the first external symptom of Phytophthora gummosis, Phytophthora sp. (© 2016 Regents of the University of California, Credit: Jack Kelly Clark); Symptom on the fruit (Salinas Cánovas, M.); Trunk damaged by Phytophthora gummosis (© 2016 Regents of the University of California, Credit: Jack Kelly Clark)

2.3 Mal secco disease (*Phoma tracheiphila*)

Mal secco is a disease of fungal nature, caused by *Phoma tracheiphila*. The fungus spreads through conidia that penetrate through wounds during October - February during rainy periods. It settles in woody vessels causing the characteristic syndrome of tracheomycosis.

Symptomps and signs

The first symptoms occur on the apical leaves, which show discoloration and yellowing especially at the veins. leaf drop and twig desiccation follow. Another symptom is the typical salmon coloration that infected wood takes on.

In the case of infection of the epigeal part, the course of the disease is slow and there is the emission of numerous suckers. The plant will die in 4-5 years. If the infection starts from the roots, the plant dies in a short time, 4-5 weeks.

Management

As always, prevention is the best defense. It is essential to adopt windbreaks and hail nets to avoid injury; avoid tillage (especially from mid-autumn to late spring) so as not to damage the roots; do not overdo nitrogen fertilization; carry out pruning operations preferably in late spring and at the same time remove suckers developing below the graft point; in the period between October and April and following adverse weather events (hail, frost, strong winds, etc.) treatments with copper compounds are useful.

In case the disease has already occurred, remove infected parts: cut and burn infected branches (cutting should be done at least 30 cm below the dry part, taking care to disinfect the tools used and protect the cutting surfaces with appropriate mastics); uproot infected stumps; do not practice grafting on infected plants.

Identification tip

- Look for yellowing and circular lesions on leaves, twig dieback, and fruit browning.
- Consider high humidity and recent weather conditions.
- Compare symptoms with other citrus diseases.
- If you think the disease is present, make cross cuts at the base of symptomatic branches and check for characteristic salmon-pink or reddish-orange discoloration of the wood and presence of gum in the xylem vessels.

Figure 3: Mal secco on leaves, stem and branch section (www.FreshPlaza.it); Plant affected by Mal secco disease (Forestry images: G. Perrotta, Università di Calabria, Bugwood.org)

2.4 Citrus Tristeza (*Citrus tristeza virus* - CTV)

Tristeza diseases, including quick decline, seedlings yellows, and stem pitting are different syndromes caused by different isolates of the tristeza virus. They differ in their virulence and their reaction to different scion cultivar and to the rootstock upon which the scion is growing.
Tristeza virus is spread through budding and grafting or by aphids feeding on citrus.

Symptoms and Signs

Susceptible rootstock and scion combinations infected with the virus show symptoms similar to those caused by other diseases that injure the roots or girdle the crown. Trees infected with tristeza show light green foliage, poor growth flushes, and some leaf drop. The trees may produce a heavy crop of smaller fruit because the girdling at the bud union prevents starch transport to the roots. Feeder roots die from the tip towards the main root. Diseased young trees bloom early and abundantly and begin producing fruit 1 to 2 years before healthy trees.

Management

Management of the tristeza complex depends largely on preventive measures, such as using tolerant rootstocks and tristeza-free propagation material. However, because of the insect vector, disease spread cannot be prevented completely. Symptoms of tristeza become more apparent during the hot summer months when increased water needs cannot be met by the declining root system. Observe quarantine restrictions to avoid spreading tristeza.

Identification tip

Fruit, leaves, and twigs may dry and die on infected trees. Citrus may die suddenly or after a slow decline. Other infected trees may recover from symptoms. Armillaria, Phytophthora, and red scale are among the more common causes of dieback.

Figure 4: CTV-infected plant in an advanced state (www.guidasicilia.it); The brown citrus aphid (Toxoptera citricida), vector of CTV-SP (Levy et al., 2022; Credits: Lyle Buss, UF insect ID lab); Some leafless branches and atypically dry fruit on a citrus tree declining from Citrus tristeza virus.
(© 2016 Regents of the University of California, Credit: Jack Kelly Clark)

2.5 Anthracnose (*Colletotrichum*)

The anthracnose fungus usually infects weakened twigs. The disease is most common during springs with prolonged wet periods and when significant rains occur later in the season than normal. During wet or foggy weather, anthracnose spores drip onto fruit, where they infect the rind and leave dull, reddish to green streaks on immature fruit and brown to black streaks on mature fruit (tear stains).
Anthracnose tear stains often occur with Septoria spot. The Septoria fungus itself, and possibly certain environmental conditions, may also cause tear staining. The stain cannot be washed off, but the disorder is generally not severe enough to require preventive actions. Certain conditions, however, such as applications of insecticidal soaps, which damage the protective wax on the fruit peel, can increase the severity of this disease.

Symptoms and Signs

Symptoms of anthracnose on citrus include twig dieback, premature leaf drop, dark staining on fruit and postharvest fruit decay. Dying leaves and twigs become covered with dark fungal spores by which the pathogen spreads.
Anthracnose may blemish the rind tissue of mature Valencia and navel oranges, grapefruit, and occasionally lemon. The disorder affects mainly fruit on stressed trees with old, dead wood.

Management

If a fungicide application is necessary, make applications in the fall that are directed at the whole tree. Good coverage is important.

Identification tip

Twig dieback, premature leaf drop, and dark staining on fruit can occur after infection by fungi including Colletotrichum. Dying leaves and twigs become covered with dark fungal spores by which the pathogen spreads. Anthracnose is more common after a prolonged wet spring.

Figure 5: Symptoms on fruit (http://www.agritech.tnau.ac.in/), symptoms on leaves (https://plantix.net/)

2.6 Physiopathies

These non-infectious conditions stem from environmental stress, nutritional imbalances, or genetics, impacting growth and yield. Early identification allows for targeted management, optimizing plant health and productivity. It also aids in distinguishing between non-infectious disorders and diseases caused by pathogens, ensuring appropriate treatment.

Here's some examples of physiopathies that you could find in lemon trees, and tips to recognize them.

Weather damage

Figure 6: Frost damage to young citrus leaves (© 2016 Regents of the University of California, Credit: Jack Kelly Clark); Foliage damaged by twig dieback (© 2016 Regents of the University of California, Credit: Jack Kelly Clark); Sunburned citrus fruit and leaves (© 2016 Regents of the University of California, Credit: David Rosen)

Frost damage: Dead leaves remain attached to trees damaged by cold weather. Injury is most prevalent on outer, exposed branches giving plants a scorched appearance.

Wind damage: Scattered dead twigs can develop on trees after hot dry winds. Wind damage is more prevalent on the more exposed trees, such as trees along borders, and if soil is dry or roots are unhealthy.

Sunburn damage: Leaves with chlorotic or necrotic spots and fruit with yellow to brownish, leathery areas occur mostly in the south and west canopy sides when sunburn is the cause.

Management
Consequences of frost, wind, and sun damages on lemon trees include reduced yields, poor fruit quality, and potential economic losses. Frost can lead to tissue damage and delayed fruit maturity; Wind can cause physical harm, weaken trees, and disrupt pollination; Excessive sunlight can result in sunburn damage, reducing photosynthesis and fruit quality.
Avoiding weather damage in lemon trees is vital as it prevents the entry of harmful fungi and bacteria, which can infect the plants. Mechanical methods to protect trees include windbreaks, shade structures, hail netting, mulching, pruning, and efficient irrigation.

Elements deficiency

Figure 7: Nitrogen deficiency in citrus causing a relatively uniform pale yellowing of leaves in new growth shoo. (© 2016 Regents of the University of California, Credit: David Rosen); Foliage damaged by magnesium deficiency (© 2016 Regents of the University of California, Credit: Jack Kelly Clark); Foliage damaged by zinc deficiency (© 2016 Regents of the University of California, Credit: Jack Kelly Clark)

Nitrogen deficiency: Foliage is pale overall when nitrogen is deficient. The causes include a true deficiency of nitrogen, adverse soil conditions, or unhealthy roots.

Consequences: Decreased vigour and yield, delayed flowering and fruiting, poor fruit quality.

Magnesium deficiency: Foliar yellowing begins at the leaf tip and margins and moves inward. A somewhat V-shaped dark green patch of foliage may remain near the leaf base.
Consequences: Reduced photosynthesis, poor fruit set, decreased yield and fruit quality.

Zinc deficiency: Extensive chlorosis develops between veins when zinc is severely deficient; leaves may be smaller in size on shoots that have shortened internodes.
Consequences: Impaired enzyme function, reduced nutrient uptake, decreased resistance to diseases and pests, poor fruit development and quality.

Management
Element deficiencies compromise the overall health and productivity of lemon trees, leading to reduced yields, poor fruit quality, and increased susceptibility to environmental stresses and diseases. Proper nutrient management, including timely fertilization and soil amendments, is essential to prevent deficiencies and ensure optimal tree performance. Keep in mind that element availability also depends on pH and soil structure, so a good knowledge of your soil is essential.

3 Post harvest diseases

When an organ such as a fruit is harvested from a plant, it continues to respire and transpire depleting both food reserves and water. Such changes ultimately lead to senescence. Treatments which slow respiration and water loss, such as cool storage, therefore help to delay senescence.

3.1 Blue and green mould (*Penicillum italicum* and *P. digitatum)*

Both infections emerge in compromised sections of the rind. Early signs manifest as tissue softening, succeeded by the formation of a water-soaked region. Subsequently, the infected site evolves into a white fungal growth, transitioning to blue or green hues with spore production. The white margin expands, measuring 10-20mm, particularly evident with green mold. Mold thrives optimally at 27°C. Growth ceases beyond 30°C, while it decelerates in temperatures below 10°C.

3.2 Grey mould (*Botrytis cinerea)*

The fungal pathogen, Botrytis cinerea can infect citrus trees through flowers, fruits or shoots and can cause die-back on shoots as well as post-harvest fruit decay. Manifestations often become more evident post-harvest, particularly during storage. Botrytis cinerea-induced ailments, commonly termed as "gray mold," are distinguished by the appearance of velvety grey spores on affected areas. These spores may not always be visible in the early stages of infection. Infected fruit surfaces may exhibit softness, accompanied by brown or gray protrusions and irregular scars.

3.3 Brown rot (*Phytophtora*)

Symptoms appear primarily on mature or nearly mature fruit. Initially, the firm, leathery lesions may have a water-soaked appearance. Lesions are tan to olive brown, have a pungent odor, and may turn

soft from secondary infections. Infected fruit eventually drops. Occasionally, twigs, leaves, and blossoms are infected, turning brown and dying.

3.4 Basal rot (*Phomopsis citri)*

Symptoms initially appeared as light- to dark-brown blemishes with small amounts of white mycelium on the lemons' blossom ends. Lesions gradually expanded to encircle the blossom ends. Finally, the whole fruit rotted; white mycelium covered the entire fruit, emitting a fermenting-like odor.

Figure 8: Green mould (www.ipmimages.org), Grey mould (www.wikifarmer.com), Brown rot (Invasive: Gerald Holmes, Strawberry Center, Cal Poly San Luis Obispo, Bugwood.org), Basal rot (Schena et al. 2011)

Management

Green and blue moulds, typically manifest on fruit that has incurred physical damage to the rind. Absent such injury sites, fungal spores remain dormant and cannot breach the fruit's surface.

To mitigate postharvest losses, adhere to these guidelines:

- Avoid exposing harvested fruit to direct sunlight.
- Refrain from picking cold, wet fruit as handling such fruit can rupture oil glands, leading to oleocellosis (burning of the fruit surface) and triggering fungal spore germination. Burn marks may take 2-3 days to appear.
- Wear cotton gloves during harvesting to minimize puncture marks from fingernails and jewellery.
- Utilize picking bags to reduce damage caused by friction against wooden or metal picking bins, allowing for gentle placement into bulk harvesting bins.
- Remove stems from fruit and avoid damaging buttons during handling.
- Ensure the use of clean, smooth harvesting bins.
- Regularly clean packing line equipment to prevent dirt and wax buildup, which can cause fruit abrasion.
- Cushion fruit on the packing line with foam, rubber, and smooth belts to minimize abrasion.
- Promptly remove old fruit from the packing shed and its surroundings.
- Treat harvested fruit with a registered fungicide within 24 hours of harvest.
- Dispose of rejected or rotten fruit promptly, avoiding accumulation in or around the packing shed or orchard.

4 Agronomic practices for crop protection

Choice of cultivation environment

Citrus can be grown on a wide variety of soils, from sand to loam and clay. Both acidic and alkaline soils are acceptable, but the optimal soil conditions for cultivating citrus entail a slightly acidic pH and good drainage. Both arid and humid climates are acceptable. As citrus trees are sensitive to low temperatures, the limiting parameter for growing citrus is the minimum temperature prevailing in winter time. Temperature is the most important limiting factor for citrus trees, as it affects their cultivation in certain areas. Citrus trees exhibit a range of activity from 12-13° C to 38° C; optimum development occurs at about 26-28° C. Damage from temperatures below 0° C severely limits plant development, with greater or lesser susceptibility varying by species, variety, status, vegetative, rootstock. Among citrus fruits, lemon appears to be the most vulnerable to low temperatures.

Varietal choice

Varietal choice is made by evaluating the specific soil and climatic conditions in which it operates and preferring cultivars that combine resistance and/or tolerance to major adversities with market acceptability. Cultivars particularly suited to the growing environment capable of offering good prospects for commercial success are chosen.

Rootstock selection

The selection of rootstock plays a pivotal role in achieving success, as it confers resistance to various pests, diseases, and environmental stresses like soil pH, salinity, and temperature extremes. Rootstock choice significantly impacts tree vigor, time to fruit production, and overall yield and fruit quality. To mitigate the risk of tristeza contamination, modern rootstock development involves hybridization or biotechnological approaches.

Plant operations

The planting process begins with deep plowing, typically at depths of 0.60 to 0.80 meters, using a subsoiler to avoid soil mixing. Soil refinement follows, removing previous crop roots. Fertilization is based on soil tests, ensuring rational application. The deep plowing is recommended in summer or early fall for optimal results. Citrus trees are ideally planted in late fall to early winter to minimize transplant stress. Late winter or spring planting may require additional watering.

Planting techniques and distance

Planting distances and training forms play a crucial role in cultivating orchards that yield high-quality fruits while ensuring efficient management practices. Maximizing light interception across the canopy, optimizing pesticide distribution, and facilitating cultivation operations are paramount considerations. It's essential to strike a balance between planting densities and environmental factors, such as orographic conditions and protective arrangements like wood protections or hail nets, particularly significant for lemon trees.

The ideal distance between citrus trees hinges on numerous factors, including species, cultivar, rootstock, environmental variables, and orchard management strategies. For optimal orchard development, planting densities exceeding 416 plants per hectare (6 x 4 m.) should be avoided, unless dictated by specific terrain characteristics. Modern planting practices typically adopt distances of 5x5 m or 6x6 m, with some variations like 6x5 m, prioritizing adequate spacing between rows to ensure proper aeration and discourage pathogen and insect proliferation.
Mechanical equipment usage necessitates sufficient row spacing to accommodate mature trees and allow equipment passage.
Long-term considerations, such as orchard longevity, susceptibility to freezing, disease prevalence, and potential non-agricultural development, guide spacing decisions. Employing planting techniques like elevating trunk bases to deter Phytophthora attacks and minimizing tillage to prevent root damage is advised.

Replanting
In some places, the replanting of the citrus grove on the same land is allowed after some years, so be sure to check the specifications of your own region.
Before replanting, the root residues of the previous crop should be removed, abundant fertilization with organic matter should be carried out; the new plants should be arranged in a different position from that occupied by the previous ones, and suitable rootstocks should be used.

Pruning
It's essential to achieve the desired tree shape as quickly as possible and then implement careful pruning practices to enhance production. Early pruning is essential in the initial years, followed by annual maintenance pruning to balance foliage, promote air circulation, and encourage new fruit-bearing shoots. Lemon trees typically produce numerous vigorous, upward-growing branches, which, if left unchecked, lead to disorderly and overcrowded growth, hindering uniform light distribution within the canopy.
The preferred planting method is the free form, resembling a 'globe' shape in citrus trees. This structure is achieved through gentle pruning on young plants to encourage the growth of three main branches positioned approximately 100-120 cm above the ground. Subsequently, attention should be given to removing suckers emerging from the trunk and branches, as well as eliminating excessively vigorous and upward-growing branches from the inner canopy.
While it's advisable to retain branches that naturally bend downward as they tend to bear fruit abundantly, it's important to thin out branches in lemon trees that come into contact with each other to prevent the spread of diseases through abrasions. These practices ensure the health and productivity of the citrus orchard over time.

Soil management
The management of soil aims to achieve several goals, including weed control, incorporation of fertilizers, optimization of rainfall and water retention, and simplification of harvesting procedures. Maintaining a consistent turf facilitates the movement of agricultural machinery, even during adverse weather conditions, improves water infiltration, prevents waterlogging, builds up organic matter reserves, and mitigates temperature fluctuations throughout the seasons.

Grassing can occur naturally or be implemented artificially.
Check the specifications of your own region for knowing if and when grassing is mandatory.

Fertilization

Fertilization serves to replenish essential nutrients depleted through fruit harvesting and pruning activities, promoting robust vegetative growth. Key elements such as nitrogen, phosphorus, and potassium are vital components in this process. Additionally, micronutrients are often administered foliarly based on analyses of both leaf and soil mineral content.
The overarching goal of fertilization is to ensure high-quality crop yields in economically viable quantities, all while upholding environmental sustainability, preserving soil fertility, and mitigating adverse effects. It necessitates a nuanced approach tailored to the specific characteristics of the soil and the crop's nutritional requirements.
A well-defined fertilization plan is imperative for farm management, outlining the maximum annual allocation of macronutrients suitable for the crop. This strategic planning ensures optimal nutrient management, contributing to the long-term success and viability of agricultural operations.

Irrigation

In regions where water scarcity is a pressing concern, irrigation plays a vital role.
The primary objective of irrigation is to fulfill the water requirements of crops while preventing water wastage, nutrient leaching, and adverse effects caused by waterlogging. This entails determining irrigation volumes through a water balance analysis, considering various factors such as phenological stages, soil composition, and prevailing climatic conditions.

Modern orchards employ three main irrigation methods: moderate rainfall sprinkling, micro drip irrigation, and spray irrigation. Each method can yield optimal crop production when appropriately managed, accounting for factors like timing, volume, and frequency of irrigation. The sensitivity of tree crops to soil salinity levels varies depending on factors such as species variety and rootstock. Elevated electrical conductivity (EC) levels between 1 and 2 may induce mild damage, while values exceeding 2 can lead to severe impairment.

Harvest

To identify the optimal harvest time, reference must be made to the right degree of ripeness, which is determined according to the utilization of the product through specific indices. The juice content of lemon fruit holds significant importance, particularly for its intended usage. For example, lemons are deemed of high quality if their juice content exceeds 25%. It's crucial to note that traditional methods of assessing fruit ripeness based on aesthetics are not applicable to lemons. The species' distinctive trait of re-flowering allows for fruit from various blooms, making it challenging to generalize characteristics such as fruit shape or skin color as indicators of ideal harvesting time.

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CHAPTER 7

Grape vine [Vitis vinifera L., 1753]

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WHAT WILL WE LEARN IN THIS CHAPTER?

We're going to learn about the characteristics of oranges trees, their fruit-related diseases both in the field and post-harvest, along with the physiological disorders they may develop. This comprehensive exploration encompasses disease management strategies and best practices aimed at optimizing orange cultivation.

Keywords: Downy Mildew, Powdery Mildew, Botrytis Bunch Rot, Esca, Flavescence dorée, Physiological disorders, Post-harvest diseases, Grey Mold, Blue Mold Rot, Rhizopus Rot

Summary

1 Overview

Vitis vinifera, also known as the European grapevine, is a species of grape widely cultivated for winemaking, table grapes, raisins, and grape juice. Its a climbing vine native to the Mediterranean region, Central Europe, and southwestern Asia. With thousands of cultivars, its grown globally in suitable climates. Its economic significance is immense, especially in the wine industry, but it faces challenges such as diseases and climate change.

2 Field diseases and physiopathies

2.1 Downy Mildew (*Plasmopara viticola*)

Grape downy mildew thrives in warm and humid regions during the vines vegetative growth phase. It spreads through splashing rain and wind. The infection process is rapid, often occurring in less than 90 minutes, typically in the morning, with symptoms appearing after about 4 days. Factors increasing soil, air, and plant moisture favor its growth, with rain and irrigation being primary contributors to epidemics. The disease develops optimally at temperatures between 20°C to 25°C, but can occur within a range of 10°C to 29°C.

Symptoms and signs

The fungus targets green parts of vines, especially leaves, causing various lesions ranging from yellowish and oily to reddish-brown, often confined by veins. Fungus sporulation appears as dense white growth within the lesions. Infected shoot tips curl, turn white with sporulation, then brown and die. Similar symptoms affect petioles, tendrils, and young inflorescences, which may dry up and drop. Young berries are highly vulnerable, appearing grayish with a downy fungus covering (gray rot), while mature berries are less susceptible but can still suffer from rachis infections without visible fungus (brown rot). Infected berries may remain firm and drop easily.

Management

Preventive measures include ensuring good soil drainage and minimizing overwintering inoculum sources. In vineyards using sprinkler irrigation, increase intervals between waterings if possible.

Fungicides against downy mildew are categorized as preventive or curative. Preventive fungicides should be applied before infection periods, and include a spreader/sticker agent to enhance rain resistance. For vineyards with downy mildew history, early season copper sprays are recommended, especially in wet springs.

Identification tip

Inspect the undersides of leaves for fuzzy, white to grayish growth, particularly in humid conditions. Look for patches or spots of this growth. Also, observe the upper surface of leaves for yellow or brown lesions, which could be signs of the disease.

Figure 1: Symptoms on leaves (www.teatronaturale.it); symptoms on berries (www.informatoreagrario.it)

2.2 Powdery Mildew (*Erisiphe Necator*)

During winter and spring, the fungus survives either inside dormant buds or as spore-producing bodies called chasmothecia. These chasmothecia release spores in late summer and fall, which are carried by rain onto vine parts like cordons and arms. When its warm and moist, usually between 21°C and 29°C, these spores germinate on the underside of leaves. After infecting new shoots in spring, the fungus produces more spores, especially in moderate temperatures. If the fungus stays dormant inside buds, new shoots can get infected after they start growing. Symptoms appear quickly in warm weather but are delayed in cooler temperatures, typically between 15°C and 20°C.

Symptoms and signs

On the upper side of the leaf, powdery mildew appears as a white or grayish powdery coating covering the surface, which consists of fungal spores. On the lower side, you may notice yellow or brown spots, though the powdery coating may be less evident. As the fungus spreads, the affected areas develop a powdery or dusty appearance. On fruit and rachises, powdery mildew appears as white masses, sometimes covering the entire berry surface. Dormant canes may display red blotchy areas as symptoms of powdery mildew infection.

Management

To effectively manage powdery mildew, begin treatment promptly and maintain consistency as needed. Treatments should align with fungicide type and vine growth stage. Apply treatments early to prevent spread post-budbreak, especially during dry spells. Prioritize sulfur or oil sprays before others and monitor with the UC Davis risk index. While some grapes may cease treatment near ripeness, continue until harvest or close to cane severance for others. Understand that fungicides work best as preventatives, with stronger measures required for severe infestations. Basal leaf removal improves fungicide coverage on clusters, providing around 50% disease control.

Identification tip

Inspect grapevines for a white, powdery fungal growth on leaves, shoots, and fruit clusters. Look for yellow or brown spots on leaves, which can turn necrotic over time. Powdery mildew often starts on younger leaves and shoots and spreads quickly in warm, dry conditions. Keep in mind that powdery mildew tends to have a powdery appearance on the upper surface of leaves, while downy mildew

presents as an oily stain in the upperside and downy growth on the underside of leaves.

Figure 2: symptomps on berries (www.terraevita.edagricole.it); symptoms on leaves (www.valentepali.com)

2.3 Botrytis bunch rot (*Botrytis cinerea*)

During winter, the fungus survives as sclerotia in leftover berries on the ground or vine, and in canes. When it rains or vines are watered, they produce spores carried by air or rain. Infections need water, depending on temperature. During flowering, the fungus can infect flowers, but typically waits until later in the season when berries have more sugar to spread. Infected berries can crack, spreading the fungus. As harvest nears, spores from infected fruit can directly infect ripe berries. Late-season infections are worst when humidity is high, theres moisture on the fruit, and temperatures range from 14°C to 28°C. Berries damaged by insects, birds, or machinery can become infected as the juice inside provides the needed water and nutrients for fungal growth.

Symptoms and signs

Before the fruit is ready to pick, warm and wet weather from frequent spring rains can lead to early-season shoot blight. This shows up as patches of soft brown tissue, which can kill parts of the plant. Shoots might wilt or break off, especially where leaves meet the stem. When the fruit starts to change color, infected berries in a cluster turn brown for white grapes or reddish for red and black grapes. If the weather stays mild, its damp, and theres not much wind, cracks can form on the outside of the berries. Fungus grows in these cracks, making the berries look gray and velvety.

Management

Managing Botrytis bunch rot involves a multifaceted approach including cultural practices, fungicide use, and selecting resistant grape varieties where possible. Cultural controls optimize vineyard conditions to minimize disease factors. This includes balanced canopies, moderate shoot growth, and leaf and cluster exposure. Techniques like shoot thinning and leaf removal help regulate canopy density. Fungicide application timing is crucial, especially before rainfall, during bloom or post-veraison. Late-harvest grapes need treatment before bunch closure and before harvest. Monitoring for symptoms and pest activity is vital. Fungicides should be used preventively, rotating different modes of action to prevent resistance.

During harvest, vineyards should be inspected for Botrytis symptoms to assess management effectiveness and plan for the next season.

Identification tip

Inspect grape clusters for fuzzy gray mold, particularly during humid conditions. Look for clusters with soft, browned berries and berries sticking together. These symptoms usually appear closer to harvest and may vary based on weather.

Figure 3: symptoms on berries (www.informatoreagrario.it); symptoms on vine shoot (www.agraria.org)

2.4 Esca (complex of fungi)

Symptoms typically appear in vineyards aged 5 to 7 years or older, but infections start in younger vines. Spores that cause the disease are found in diseased vine parts, and rain during fall to spring releases them. Pruning wounds provide entry points for infection, remaining vulnerable for weeks. Once infected, the pathogen establishes a permanent, localized wood infection unaffected by fungicides. Its severity is compounded by the lack of effective control measures since sodium arsenite, previously used, is now banned due to its harmful effects.

Symptoms and signs

Recent research has linked the symptoms of Decoy disease, formerly thought to be caused by physiological issues, to specific fungi present in the plants xylem vessels, notably *Phaeomoniella chlamydospora, Phaeoacremonium aleophilum*, and *Fomitiporia mediterranea*. These fungi induce a tracheomycosis and white rot, respectively, leading to a complex disease pattern.

Symptoms may vary yearly due to climate-induced toxin production variability. *P. chlamydospora* and *P. aleophilum* induce brown streaks and necrosis in stems, leading to a condition known as tigergrass. *F. mediterranea* causes white rot, disintegrating the stem wood. These fungi can remain dormant for years, with symptoms appearing inconsistently. They spread through spores released from fruiting bodies on stems, infecting plants via wounds and cuts. The disease can originate in nurseries as well.

Management

Despite numerous trials, an effective fungicide for the disease hasnt been found yet. Control strategies must be tailored, involving proactive measures in nurseries and vineyards to curb its spread.

Field interventions for prevention include: marking diseased plants in late summer, pruning marked plants separately, removing dead or severely affected plants and old wood, minimizing large pruning cuts, disinfecting and covering wounds. Pruning or back-cutting is crucial, but only if the entire infected part is removed. If necrosis reaches the collar area, the plant is irrecoverable and must be removed entirely. Dendrochirurgical procedures are used for esca disease, while Trichoderma

aspergillus is employed for control.

Identification tip

Look for interveinal striping on leaves and small, dark spots with brown-purple rings on berries. Watch for sudden shoot dieback, known as "apoplexy," and check for concentric rings of dark spots in stem cross-sections. Also, note the presence of brown streaks and pinkish-brown necrosis in stem cross-sections.

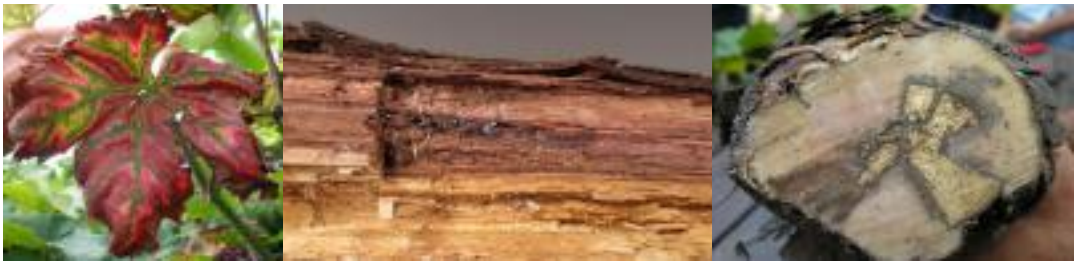

Figure 4: symptoms on leaf; Transverse section of a shoot with browning and exudate discharge due to colonization of the xylem by P. chlamydospora and P. aleophilum; Transverse section of a stem with white rot, caused by F. mediterranea. (www.wikipedia.org)

2.5 Flavescence dorée of grapevine (*Candidatus Phytoplasma vitis*)

Flavescence dorée, derived from the French words for "yellowing" and "golden," stands as a significant and detrimental phytoplasma disease affecting grapevines, posing a potential threat to vineyards. The causative agent, recently identified as *Candidatus Phytoplasma vitis*, is transmitted by the leafhopper, *Scaphoideus titanus*. Infection can lead to the death of young vines and a significant reduction in productivity for older vines. Flavescence dorée outbreaks occur sporadically, and the sensitivity of grapevine varieties to the disease varies. The incubation period, from infection to the onset of visible symptoms, typically spans a year or more, contingent upon the plants response to both the pathogen and environmental conditions.

Symptoms and signs

Flavescence dorée exhibits several symptoms, including yellow or red discoloration of leaves (which varies depending on the grapevine variety), downward rolling of leaves, and drying of stems and grapes. Notably, affected plants do not undergo cold hardening. While some plants may succumb to Flavescence dorée, others may show no symptoms, and certain varieties of grapevines can recover from the disease, although the process is not fully understood. Its important to note that the leafhopper *Scaphoideus titanus* cannot acquire Flavescence dorée from plants that have recovered or show no symptoms.

Management

Without control measures, Flavescence dorée can quickly spread throughout a vineyard, infecting all vines within a few years. Currently, there is no cure for the disease. Managing its spread involves uprooting infected plants, using selective insecticides to reduce leafhopper populations, and carefully monitoring propagation material. Sterilizing propagation material in water at 55°C for 45 minutes is an effective method.

Relying solely on insecticides is insufficient for complete suppression. During active leafhopper periods, avoiding mechanical or chemical control of host plants is crucial to prevent further spread. Molecular biology analysis allows for early and precise diagnosis, enabling swift intervention.

Identification tip

Look for yellow or red discoloration of leaves, which may vary depending on the grapevine variety; Downward rolling of leaves; Drying of stems and grapes; Absence of cold hardening. If the symptoms are present at the same time, the plant is diseased.

Figure 5: Figure X: symptoms on leaves (www.lanuovaprovincia.it); symptoms on leaves (www.grapesrl.it);Scaphoideus titanus (www.grapesrl.it)

2.6 Physiopathies

Most of vine physiopathies are caused by elements deficiency. Balanced nutrition, encompassing both macro and micronutrients, is pivotal for ensuring high-quality wine production and for preventing stresses that increase the plants susceptibility to diseases. Identifying nutrient deficiencies in plants can be achieved through careful observation of the leaves, although symptoms can sometimes resemble those of pathogen attacks. Here's the primary deficiencies that can affect grapevines:

Figure 6: Potassium deficiency, magnesium deficiency, iron deficiency (www.agronotizie.imagelinenetwork.com/)

Potassium Deficiency: characterized by yellowing and drying of leaf margins, along with "brunissure" during summer (browning covering the basal leaf edges). It leads to slower berry ripening, inadequate bud maturity, and reduced tolerance to environmental stresses. Its commonly found in clay or magnesium-rich soils or overly loose soils. Poorly effective rootstocks in potassium absorption may exacerbate the issue.

Magnesium Deficiency: Its severe expression is rachis desiccation, significantly impacting vineyard productivity. Symptoms include yellowing of distal veins on basal leaves for white berry vines or

rolling up of leaves for dark berry vines.

Iron Deficiency: Causes ferric chlorosis, resulting in leaf yellowing. Left unaddressed, it leads to flower dropping, millerandage, and stunted shoot growth. Calcareous soils are more prone to this deficiency, worsened by excessive nitrogen fertilization and frequent soil tillage. Opting for resistant rootstocks is the most effective approach to counter ferric chlorosis.

Management

Fertilization strategies are significantly influenced by the winemakers objectives such as the desired type of wine. For instance, potassium levels impact wine acidity, necessitating adjustments based on whether the winemaker aims to produce a classic method sparkling wine or a red wine for aging. Therefore, the winemakers oenological goals should drive their decisions. Another crucial factor to consider is the amount of plant material removed from the vineyard throughout the year, primarily through harvesting and pruning activities. The winemaker should develop a fertilization plan that aligns with farm objectives, considering plant material removals and anticipated productivity, alongside other factors like soil texture and existing vegetation cover.

3 Post harvest diseases

High consumer acceptance is achieved for fruit with a high sugar content or a favorable sugar to-acidity ratio. Berry firmness is also important for consumer satisfaction, along with the absence of defects such as decay, cracked berries, stem browning, shriveling, sunburn, dryness, and insect damage. Here's some of the post-harvest diseases that should be prevented:

3.1 Grey mold (*Botrytis cinerea*)

During the post-harvest stage, effectively addressing botrytis infections is paramount. Annual losses stemming from botrytis infections can vary between 5% and 20%, largely due to insufficient strategies during this period. Signs of infection include soft and watery texture in affected berries, with white cultivars turning brown and shriveled, and purple cultivars taking on a reddish hue. Healthy berries in contact with infected ones are prone to becoming infected themselves.

3.2 Blue mold rot *(Penicillium digitatum)*

The symptoms include sparse white growth, later turning bluish-green, berry decay, soft and watery texture. Infected berries emit a moudly flavour.

3.3 Rhizopus rot (*Rizophus nigricans*)

The symptoms are round irregular, light brown and water-soaked lesions, fermented mouldy smell, small and globose conidia

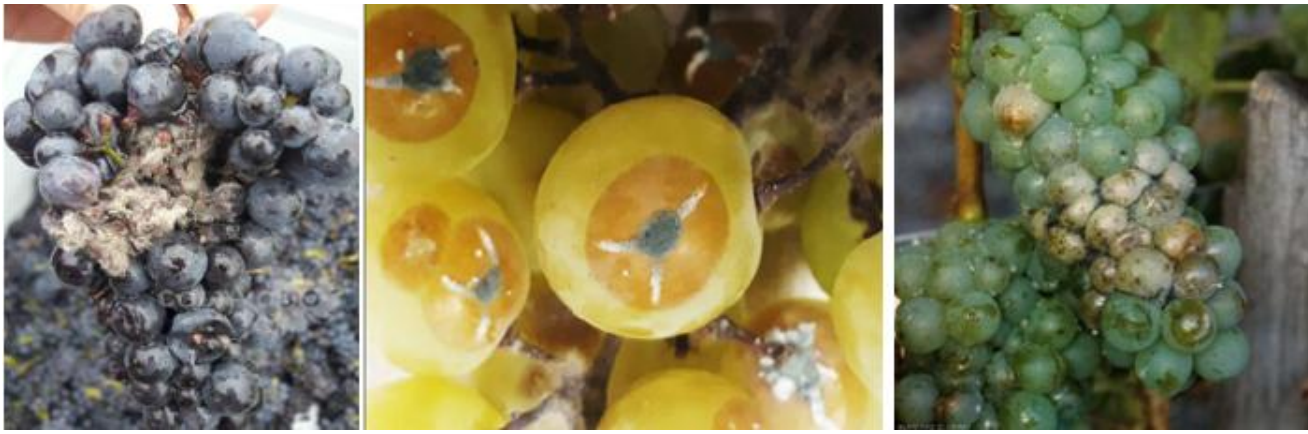

Figure 7: Botrytis symptoms (www.coltivobio.com); Blue mould symptoms (Guffar et al., 2021); Rizophus symptoms (www.ephytia.inra.fr)

Management

It is essential to employ materials that prevent infections in storage and maintain low temperatures, ideally around 0°C, which are unfavorable for the pathogens' growth. Upon arrival at the processing facility, grapes undergo rapid temperature reduction using specialized cooling cells. Subsequently, grapes are stored in conservation cells with consistent temperature and humidity levels (92-95% Relative Humidity). Preserving grape quality for extended periods involves various techniques, including natural and chemical antimicrobials. Natural options like controlled ozone, though experimental, show promise for disinfecting grapes and storage cells. Additionally, chemical antimicrobials, such as sulfur dioxide (SO2), are applied through special mats placed on grapes and storage floors. These mats release sulfur dioxide, inhibiting microbial growth and preserving grape quality.

4 Agronomic practices for crop protection

Choice of cultivation environment

Assessing the soil and climatic conditions of the vineyard site is crucial to meet the specific needs of grapevines. New plantings should be conducted only in areas that exhibit soil and climatic conditions conducive to vine cultivation.

The European grapevine is resilient and adaptable, allowing it to thrive in various regional soils. It can tolerate soils with total lime values exceeding 10 percent and sub-alkaline pH levels ranging from 7.3 to 8.1. However, its important to avoid excessively compacted soils prone to moisture stagnation and those that are overly humid or saline.

Temperature plays a significant role in determining the quality of the grapes. Environments with low ripening temperatures may result in deficient color and aroma intensity. Conversely, excessively high temperatures during ripening can hinder the synthesis of coloring compounds by accelerating the degradation of aromatic compounds and essential acids.

Varietal choice

Choosing the right grape variety is a decision that requires careful consideration. Factors such as the chosen cultivation method, suitability of grape varieties for the local climate, and market demand for

the selected variety at a favorable price all play vital roles.

There are two primary methods for establishing a vineyard: growing self-rooted plants or cultivating grafted cuttings. Regardless of the method chosen, each grape variety possesses distinct characteristics that are expressed based on specific climate and soil conditions, including pH or EC levels, water and nutrient requirements, as well as temperature and sunlight exposure. Therefore, the selection process should be meticulous and informed by factual data.

Rootstock selection

Since the 1850s, European vine-growers faced a significant threat with the emergence of the devastating Phylloxera aphid, previously unknown in Europe. Originating from America, where native grapevines had developed immunity, Phylloxera wreaked havoc on sensitive Vitis vinifera species, prompting growers to cease autogenous vine cultivation. Seeking a solution, European producers turned to America, where native vines were resistant. They began grafting traditional Vitis vinifera varieties onto American rootstocks, a technique combining the strengths of both plants. Despite this, in areas unaffected by Phylloxera, some smallholder farmers still opt for autogenous plants.

The choice of rootstocks is extensive, primarily determined by their tolerance to specific soil and temperature conditions. Among the commonly utilized rootstocks are those derived from various species such as Vitis riparia (for example, Riparia Gloire de Montpellier), Vitis rupestris (like Rupestris du Lot), as well as combinations like Riparia-Rupestris, Berlandieri x Riparia, Berlandieri x Rupestris, and others. Each rootstock differs significantly in morphological characteristics and cultivation techniques.

Regardless of the selected method, its crucial to purchase plants from reputable sellers to avoid any unforeseen issues.

Plant operations

In the process of establishing new vineyards, careful planning and preparation are essential to ensure optimal growing conditions and vine health. Initial steps involve soil analysis and pH testing, typically conducted during the winter season. Soil samples collected from various locations within the field provide valuable insights into nutrient levels and pH, guiding corrective actions under agronomist supervision.

Once soil analysis is complete, the next phase begins with site preparation. Initial operations include stripping and leveling, if necessary. When leveling, its crucial to limit earth movements to avoid compromising root exploration and slope stability. If significant soil volumes are affected, its advisable to set aside the surfa ce layer for later redistribution. In hilly areas prone to erosion, appropriate planting methods must be employed based on soil management practices.

Planting commences with ground breaking, typically with deep plowing (0.60-0.80 m). Traditional plowing can be replaced by subsoiling at 70-100 cm depth to preserve the active soil layer. Soil refinement follows at 35-45 cm depth using lighter equipment, ensuring careful removal of previous crop roots. Base fertilization is performed during ground breaking.

Summer or early fall is ideal for ground breaking, especially in compacted soils. After ground breaking, plots are prepared, with lengths often exceeding 100 m and widths determined by soil type

and surface water management. Drainage systems, whether ditches or depressions, are designed to maintain optimal soil moisture levels. Ditch depth typically exceeds cultivation depth (80-90 cm), with spacing adjusted based on soil permeability.

To prevent root asphyxiation in poorly permeable soils, raised bed arrangements are employed, typically 25-30 cm above ground level. Ideally, planting occurs in late fall or early winter to minimize transplant stress.

Planting techniques and distance

The timing of vineyard planting depends on factors like vine variety, weather, and grower preferences, with winter being the optimal period, particularly the latter half. Growers typically prefer 1-year-old rooted seedlings, sourced from reputable sellers. Planting involves marking precise locations on the soil and digging holes 30-50 cm deep. Seedlings are planted manually or using laser planters for accuracy. Its important to maintain the connection point of rooted benchgrafts above the soil to prevent scion rooting. Planting distances vary based on vineyard characteristics and grape varieties, typically ranging from 2-2.5 meters between rows and 1.15-

1.35 meters between plants. Closer distances are generally avoided due to potential root interference and overcrowding. Some farmers utilize anti-hail nets for crop protection.

Pruning

Achieving the desired vine shape swiftly and implementing meticulous production pruning are essential for maintaining a balance between vegetative growth and fruit production in vineyards. The main priorities of production pruning include ensuring optimal grape quantity and quality, balancing vegetative and productive activity, maximizing vineyard efficiency, and extending the plants lifespan.

Pruning is a foundational aspect of vineyard management, encompassing two key categories: Shaping prunings, which establish the vines desired structure, and Balanced prunings, further divided into Dormant and Summer pruning.

Dormant pruning, conducted during the vines dormant phase, involves the removal of excess wood to maintain a harmonious balance between fruiting and vegetative growth. The number of

buds left post-pruning varies depending on grape variety and environmental factors. Striking the right balance is crucial; excessive pruning can spur vigorous shoot growth, while insufficient pruning may lead to overly abundant fruit production, potentially compromising quality. Pruning timing is critical to mitigate risks of disease and frost.

Pruning demands precision and expertise, performed with specialized tools to ensure clean cuts. Proper wound care, including disinfection, minimizes the risk of infection. Summer pruning aims to rectify any pruning errors from the dormant phase and encompasses various techniques:

• Suckering: Prompt removal of young shoots post-sprouting to prevent later plant damage. • Deadheading: Trimming cane edges to redirect nutrients to flowering clusters, enhancing fruit quality.

• Defoliation: Manual leaf removal to enhance crop aeration and simplify pest and disease management.

• Cluster Thinning: Selective removal of immature fruiting clusters to bolster quality, a common practice in premium winemaking.

• Berry Thinning: Eliminating excess berries to alleviate overcrowding and stave off fungal infections in densely packed clusters.

Soil management

For plots with an average slope exceeding 30 percent, it is advisable to consider grassing the inter-rows and managing spontaneous vegetation through regular mowing. During planting, it is suggested to opt for point tillage or other methods focused on removing residues from previous tree planting. Grassing efforts can be alternated between rows during the first two years after crop establishment. For areas experiencing low rainfall during the growing season and characterized by specific soil types (e.g., clay, clay-sandy, loamy-loamy), the grassing requirement may be waived. Instead, consider alternate row tillage during the spring-summer period to aerate or decompact the soil up to a depth of 30 cm. Additionally, planting and burying green manure can be done in alternate rows during the initial establishment phase.

In plots with slopes ranging from 10% to 30%, it is suggested to consider grassing the inter-rows, along with managing spontaneous vegetation through mowing. However, in areas with low rainfall during the growing season and specific soil types, alternate row tillage can be considered as an alternative to grassing. Green manure planting and burying can also be conducted in alternate rows during the initial two years of crop establishment.

For plots with slopes less than 10%, it is always recommended to consider grassing the inter rows during the autumn-winter period to minimize nutrient loss. You can also sow and bury green manure.

Fertilization

Before applying any fertilization method in vineyards, soil and tissue testing are crucial to assess soil conditions. Various fertilization methods like top dressing, foliar fertilization, and fertigation are employed, with precision agriculture technologies aiding in optimizing strategies. Vines require specific nutrients at different growth stages, such as nitrogen for early growth and potassium for fruit development. The timing and type of fertilizer application vary based on factors like soil type, plant age, and grape variety.

Irrigation

The grapevine is considered a drought-resistant plant that only experiences severe stress in extreme cases of prolonged summer drought. Irrigation is considered a “rescue” intervention, since water stresses during the initial phase of berry growth can compromise both the quantity and quality of final production.

One of the most critical periods for water stresses in grapevines is during pre-growth, when water is essential for berry size and ripening. Moderate water stress can lead to a higher concentration of phenolic and terpene compounds in grape juice, but more severe stresses can reduce anthocyanin production and accumulation.

After veraison, water stresses have less influence on final berry size as phloem sap becomes the main nutrient source for the berries. However, moderate water stress can still affect plant growth and early ripening.

It is important to consider irrigation as a saving tool and not as a forced practice, avoiding watering too close to harvest to preserve the quality and health of the final product.

Harvest

Grape harvesting stands as a pivotal event for vineyard producers, often celebrated with festivities in many countries. The harvest typically begins 30-70 days after fruit set, signaled by color changes in the berries. Factors like environmental conditions, soil type, and grape variety influence the ideal harvest time. Producers monitor grape maturity closely, assessing factors such as sugar-acid ratios, phenolic content, and size for different types of grapes. To determine readiness for harvest, producers commonly use portable refractometers to measure sugar content, expressed in degrees Brix. Wine grape varieties are typically harvested between 12-24 degrees Brix, while table grape varieties range from 12-20 degrees Brix. Hand harvesting is the norm, with workers using knives or shears to cut whole bunches, especially for table grapes due to their sensitivity. Mechanical harvesting, used exclusively for wine grapes, involves machines shaking vines to dislodge grapes onto conveyor belts, though not suitable for grapes with thin skins.

After harvesting, grapes are swiftly transferred to wineries or packaging facilities, often requiring refrigerated transport for table grapes destined for distant markets. While mechanical harvesting offers efficiency, concerns remain about potential grape damage and oxidation, prompting careful consideration of methods for each vineyards unique conditions.

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- Questions with multiple answers + 1 for self-reflection

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CHAPTER 8

Apple [Malus x domestica Borkh]

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WHAT WILL WE LEARN IN THIS CHAPTER?

We will learn about growing apple trees, their tree- and fruit-related diseases, both in the field and post-harvest, and the physiological disorders they can develop. This comprehensive analysis includes disease management strategies and best practices to optimise apple tree cultivation.

Keywords: Apple tree Diseases and Physiopathies, Post-Harvest Care, Farming Techniques

Summary

1 Overview

Apple tree (Malus x domestica) is the most commonly grown fruit tree in our orchards and home gardens. Apple trees are the most important fruit of the temperate zone and second only to citrus plants worldwide. Most apple trees are small deciduous trees with a short trunk and a heavily branched crown. There are very many varieties of apple trees. Apple tree fruits are delicious and very healthy. They contain valuable nutrients such as vitamins, mineral salts, and water-soluble fiber. The apple tree is a light-loving species. Apple trees require a sunny location for good fruiting. They are pretty drought-resistant but must be protected from strong winds. Spring frosts can be a threat, damaging flower buds. When preparing a planting plan, it is essential to determine which tree species you will be planting. There should be at least two varieties of one species. This will ensure cross-pollination, as some varieties require pollen from another variety.

2 Field diseases and physiopathies

2.1 Fire blight (*Erwinia amylovora*)

Fire blight is the most dangerous bacterial disease of apple trees. It occurs on all organs of the aboveground part of the trees. The primary infection is caused by bacteria that overwinters on the periphery of blight and necrosis and in sleeping buds. In spring, from overwintering sites, the bacteria spread via wind, rain, insects, etc. Plant infections occur through natural openings (stomata, lenticel, honeypots, hydathodes) and injuries. During the growing season, the bacteria can survive and multiply on the surface of plants without infecting them, providing a source of infection throughout the season. Infected flowers wilt rapidly, shrink, and die, turning orange to brown. Initially, reddish-brown spots appear on the leaf margins, around the central nerve, or between the nerves. Over time, they enlarge, even taking over the entire leaf. Infected leaves shrink and usually curl inwards along the main nerve. Young green shoots wilt, turn brown, and die, and their tips usually curve into a pastoral shape. Infected fruits die and shrink, resulting in a mummy-like appearance. Gangrene develops on branches, and trunks. At the point of infestation, the bark is initially smooth, slightly swollen, and hydrated but later darkens, collapses, and shrivels. Towards the end of the summer, the bark may crack characteristically. The shape of the gangrene is usually close to an ellipse with jagged edges, sometimes resembling a wedge pointing upwards with its base. During the growing season, bacterial oozing may occur on all infected organs, initially grey-white, later yellow, and finally amber.

Prevention and eradication

In controlling the disease, it is vital to plant healthy nursery stock and varieties that are not very susceptible to the disease. It is essential to regularly inspect all apple trees and host plants growing in the vicinity. Infested plant parts, including those of host plants, should be cut out and burned. Disinfect the pruning shears each time by dipping the tip in denatured alcohol or spirit. After treatment, the wound should be protected by lubricating it with copper-containing emulsion paint. After the onset of the disease, it is advisable to reduce or altogether discontinue nitrogen fertilisation so as not to encourage intensive growth of the trees, which promotes the development of the disease. Summer pruning should also be avoided. It would help if you watched for secondary flowering on the trees, often after a period of stress such as drought. Late bloomers must be removed as soon as possible so

that bees or other pollinating insects do not transfer the bacteria from a diseased plant to a healthy one.

Figure 25: Fire blight typical symptoms on trees (https://www.sad24.pl/sady/czym-zwalczac-zaraze-ogniowa/; infected leaf (https://kb.pl/rosliny/choroby-roslin/zaraza-ogniowa-gruszy-i-jabloni-przyczyny-zwalczanie/); infected fruit set (https://poradnikogrodniczy.pl/zaraza-ogniowa.php)

2.2 Apple scab (*Venturia inaequalis*)

Apple scab is the most serious and annually occurring disease of apple trees. Susceptibility to the disease largely depends on the variety grown. There is a saprotrophic and parasitic phase in the life cycle of the fungus. The pathogen overwinters on fallen leaves, forming sheaths (pseudothecia) in autumn, which are the fruiting bodies of the perfect stage. In the pseudothecia, the fungus forms sacs filled with two-celled sac spores (ascospores), which are the source of primary infection in spring. The sowing of ascospores is favoured by rainfall. The disease develops most rapidly during high humidity, in a temperature range of 17-23°C. Primary infections can last from mid-April to mid-June and even into early July. During the growing season, the parasitic phase of *V. inaequalis* begins. As a result of the disease development, characteristic spots appear on infected plant organs (leaves, fruit, petioles, calyx sepals, fruit stalks). At first, they are irregular, velvety, olive-green. They turn dark brown to black with time, and their edges become marked. On the surface of the spots, conidial stalks with single-celled conidial spores form, providing secondary infection later in the growing season. The leaf tissue adjacent to the ageing spot becomes thinner, deformed, and perforated. On infected fruit, uneven tissue growth occurs at the spots. The apples become deformed and often break at the spot. Heavy and frequent rainfall favors the annual occurrence of apple scabs, particularly during primary infection.

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Figure 26: Apple scab, typical symptoms on fruit (https://agrecol.pl/dra_problem/parch-jabloni/); and leaves (https://drzewka-faworytka.pl/pl/blog/Parch-jabloni-objawy-i-zwalczanie/135)

Prevention and control

The disease is difficult to control, especially in seasons with high rainfall, so it requires regular and careful tree care. Agro-technical measures that promote rapid drying of leaves and shoots after rainfall, such as pruning and crown shaping, are essential. Loose, airy crowns with properly formed angles are easier to maintain in good health. Throughout the growing season, a critical treatment is to successively rake up fallen leaves, removing and burning them or shredding them and covering them with soil. In the fight against the disease, selecting resistant or low-susceptible varieties for cultivation is very important.

2.3 Apple powdery mildew (*Podosphaera leucotricha*)

A silvery bloom on apple shoots, observed in early spring, indicates their heavy infestation by *P. leucotricha*. In spring, a white mycelium with numerous stalks and conidial spores forms on the surface of tissues developing from infected buds. The unicellular spores spread downwind, providing a source of secondary infection. Severe infestation of leaves and shoots leads to stunted growth. Chlorosis develops on the upper side of symptomatic leaves, and the lower side of the leaf blade is covered with a powdery mycelial coating. The apical part of infected shoots usually shrivels, and buds overgrown by the pathogen become more susceptible to frost damage. Harsh winter weather conditions (heavy frost) can cause bud dieback. Symptoms of the disease are visible on the fruit buds in the form of a white, mealy coating. Infected apples become russet over time. The severity of the disease depends largely on the susceptibility of the variety. The disease contributes to the weakening of the tree. There is a marked inhibition of shoot growth, a deterioration in fruit quality, and significantly weaker fruiting. The symptom of the disease is a powdery coating that appears on leaves, shoots, fruit, and buds. Apples growing on infected shoots are covered with the reticulation of the russeting characteristic of the disease. In heavy infestation, the apple develops unevenly and is angular and underdeveloped. The disease's specificity is cyclic, meaning it does not occur at the same intensity yearly. After cold winters, powdery mildew is very limited because the buds in which the disease-causing fungus overwinters are frozen.

Prevention and control

As with scab, it is better to choose varieties that are less susceptible to the disease. It is vital to keep a close eye on the shoots and cut infected shoots, inflorescence rosettes, and leaves as early as possible when lesions are noticed. All removed parts should be removed and destroyed immediately. Leaving them around the tree is a source of further infection. In the early growing season, sulphur preparations are used as a preventive measure.

The green and pink bud stage is significant for controlling apple powdery mildew.
Subsequent treatments should be carried out at 7-10 day intervals to protect rapidly growing shoots and emerging new leaves and flowers.

2.4 Grey mould (*Botrytis cinerea*)

The fungus causing the disease is a polyphage infecting many orchard plants. It infects apple blossoms during flowering and petal fall. The first symptom of the disease is a reddish-purple discolouration of the skin around the flower remnants on the fruit set. It is followed by forming a small rot spot, the perimeter of which is darker and dry. The flesh at the site of the spot collapses and

Figure 27: Powdery mildew, typical symptoms on leaves (https://rajogrodnika.pl/pl/n/Maczniak-prawdziwy-jabloni/61); fruit and infected shoots (https://doradztwosadownicze.pl/jak-zwalczac-maczniaka-jabloni/)

dries out to form dry, clinging rot. No data indicates differences in the susceptibility of apple blossoms of different varieties to infection by *B. cinerea*. They are a very delicate organ, regardless of variety. The presence of an infection source and favourable weather conditions mainly determine their infection. Infection of apple blossoms can also result in the development of the disease only during storage. The fungus colonises the blossom remnants and develops in the high humidity conditions prevailing in the cold store, producing rot spots in the apple's clinging part.

Prevention and control

Remember to check your plants regularly for symptoms of grey mould. When you spot them, the affected parts of the plant should be removed, preferably burned. It would help if you also took extra care when picking the fruit. Avoid damaging the peel; the fungus can easily penetrate the fruit through such a wound. Any containers that hold fruit should first be thoroughly disinfected to remove any fungal spores left over from previous use. Careful adherence to prevention is the best way to prevent grey mould naturally. Growing plants should also be provided with plenty of light. Proper fertilisation of the plants is critical in preventing grey mould. Properly fertilised plants are more potent and less susceptible to disease. However, it must be remembered that a shortage of nutrients in the soil can be just as damaging as an excess. In particular, over-fertilisation with nitrogen should be avoided, as excess nitrogen encourages excessive growth of the green parts of the plant (leaves and shoots), making it easy for the grey mould fungus to spread to other plants.

Figure 28: Grey mould typical symptoms on apple trees (https://www.sad24.pl/ochrona/maczniak-szara-plesn-parch-jabloni-trzy-choroby-jedno-rozwiazanie-i-od-niego-zacznijmy/); fruit and skin (https://www.ogrodinfo.pl/ochrona-roslin/fontelis-200-sc-w-ochronie-jabloni-przed-chorobami-grzybowymi-cz-1-szara-plesn/)

2.5 Brown rot (*Monilinia fructigena*)

The disease occurs mainly on the fruit, causing rotting. Only occasionally can it cause blossom and shoot rot. Conidial spores infect the apples throughout their growth period. The site of infection is damage to the skin - mechanical, after hail, or due to pest feeding. The disease first infects the blossoms, which turn brown and die, leading to the death of entire short shoots and then entire branches, including the leaves. The dead leaves do not fall but hang on individual shoots/branches. Later, brown rot spots develop on the ripening fruit. Brown rot spots develop on infected apples and concentrically arranged grey-beige papillae (sporodochia) with conidial spores. The rotting fruit usually falls off prematurely or dries out and remains on the tree as black mummies until the following year. Infection of the fruit close to harvest time only results in the development of disease symptoms during storage.

Prevention and control

Remove infected fruit from the trees and underneath them, which are a source of secondary infection. If so-called mummies remain on or under the trees, they should be removed, as the pathogen overwinters in them. Diseased
shoots should be cut back. Protecting the trees from fruit-boring pests is very important, as the pests create 'gates' for the pathogen to enter by damaging the fruit. Fruit to be stored should be harvested carefully to avoid any damage. Fruit stored after harvesting should be inspected regularly, and diseased fruit should be discarded. Plant protection treatments are best carried out as a preventive measure during the fruit set period. If spraying is carried out before the fruit is harvested, choose products with a short withdrawal period. Plant protection treatments against scabs simultaneously prevent the development of brown rot.

Figure 29: Powdery mildew, typical symptoms on fruit, leaves (https://rajogrodnika.pl/pl/n/Maczniak-prawdziwy-jabloni/61); and infected shoots (https://doradztwosadownicze.pl/jak-zwalczac-maczniaka-jabloni/)

2.6 Apple bark rot, apple bitter rot (*Neofabraea alba*, *Pezicula alba* Gunth., *Pezicula malicorticis* /Jack./ Nannf.)

The pathogen develops saprotrophically on dead bark or in a parasitic form on shoots and fruit. The fungi overwinter on gangrene wounds and infected shoots. Primary infection is carried out by conidial spores, which form in light grey acervuli. The bag stage is of little importance in the development cycle of the pathogen. The conidial spores spread with water droplets infecting the shoots through various types of bark damage. Symptoms of the disease on shoots are dried and sunken necrotic patches shaped like an ellipse. Young, infected shoots die above the necrosis. Under favourable environmental conditions, fruiting bodies of the conidial stage can develop on the dead tissue. The disease is hazardous in nurseries and young orchards. In summer, from June until harvest, fruit infection can occur. Conidial spores are transferred with raindrops from infected shoots to the fruit. They germinate on the apples' surface, and the reticular spores penetrate the lenticel. Symptoms of the disease only develop in the cold store. Small rot spots form around the lenticel (so-called eyeleting), which enlarge over time and, joining together, form several centimetres long rot. The central part of the spots is dark brown, while their periphery is slightly lighter. The pathogen grows inside the fruit, causing the flesh adjacent to the affected part of the apple to rot. The skin at the site of the spots collapses but remains taut and smooth. Under its surface, acervuluses form, from which conidial spores emerge as a greyish-beige suspension. Susceptibility to the disease depends mainly on the cultivar grown.

Prevention and control

With an infestation of apples by Pezicula spp. last season > 5 %, it is advisable to control the disease, especially if there is rainy weather in the pre-harvest period and gangrene wounds on the apple stems. Depending on the variety's susceptibility, one control treatment (2 weeks before harvest) or two control treatments (one month and two weeks before apple harvest) should be carried out. Control of apple bark blight reduces the source of fruit infection. In young orchards (1-3 years old), protective treatments are necessary, especially after pruning and hailstorms.

Figure 30: Apple bark rot, apple bitter rot, typical symptoms on trunk (https://rolmarket.pl/Najczestsze-choroby-jabloni-oraz-ich-zwalczanie-blog-pol-1643279477.html); and fruit (https://sadowniczeabc.pl/gorzka-zgnilizna-jablek/

2.7 Fruit tree canker (*Neonectria galligena*)

The incidence of the disease is favoured by the cultivation of susceptible varieties and the location of the orchard in frost ponds. Symptoms of the disease include browning and collapse of the bark and necrosis on shoots, branches, and trunks. They are overwintering mycelium and the carmine-coloured fruiting bodies of the perfect stage in the canker sites. Throughout the growing season, conidial spores are also formed en masse, which, spread with water droplets, are the most important source of infection. Infection is favoured by all kinds of mechanical damage to the bark. Crown formation at too acute an angle can contribute to bark and wood cracking at the base of branches or even breakage. The pathogen colonises such damaged sites. Infection can also occur through leaf scars or after fruit breakage, especially if autumn is long and warm. In necrosis, concentrically arranged layers of dead bark are a characteristic symptom. The pathogen can cause a closed and an open form of canker. The disease contributes to the death of shoots, branches, and even entire trees.

Prevention and control

Since we do not yet have plant protection products for canker of fruit tree preparations that effectively combat the mycelium inside the vessels, the control of this disease is pure prevention (planting healthy plants and rapidly eliminating infected and spore-forming specimens). If you notice canker on shoots and branches, cut and burn them, and treat the cut wound with horticultural ointment. All damage, cracks, and cuts should be quickly smeared with horticultural ointment to prevent the pathogen from entering. The most important thing in dealing with tree cankers is prevention, which consists of preventive sprays. These should mainly be carried out after spring pruning and crown shaping and after any tree damage, e.g., from hailstorms. Less infested trees are returned to a healthy state by removing infected branches and boughs. After such sanitary pruning, we lubricate the wounds with horticultural ointment. Removing diseased shoots is vital, as spores can develop on them over many years and infect other trees in the orchard and garden. It is also worth spraying with copper preparations to reduce infection during autumn leaf and fruit drops.

Figure 31: Fruit tree canker typical symptoms on tree trunks (https://www.sadyogrody.pl/agrotechnika/103/rak_drzew_owocowych_zwalczanie_zima_i_na_przedwiosniu,16995.html); and stems (https://agrecol.pl/dra_problem/rak-drzew-zgorzel-kory-na-jabloni/)

2.8 Stem base rot of fruit trees (*Phytophthora cactorum*)

The primary sources of infection are buoyant spores (zoospores), which spread in the aquatic environment, and mycelium overwintering on plant debris. The fungus also produces spores (oospores) that enable it to survive in the soil for many years. The first symptoms of the disease are visible in spring in the form of delayed bud bursts and leaf discolouration. The buoyant spores infect the stomata, causing cracks or mechanical damage to the bark. A characteristic symptom of the disease is the occurrence of initially brownish-red, watery spots on the root neck of the rootstock and the ground side of the trunk, where the bark gradually dies, peels, and falls off, creating extensive wounds that expose the wood. In a later stage of the disease, the phloem takes on a reddish-brown to dark-brown colour. The disease can lead to ringing of the trunk, contributing to tree death. Trees growing on wet and heavy soils are most often affected. Diseased trees are characterised by stunted growth. Fruits do not grow to the correct size for the variety and chlorotic leaves in spring take on a reddish colour from mid-summer onwards.

Prevention and control

Damage thresholds - none. It usually takes 1-3 years from infection to tree killing. The disease is found late, usually only after secondary symptoms are visible in the crown of the tree, caused by significant development of the rot. If symptoms of the disease are noticed early, an attempt should be made to save the tree by exposing the root neck, cutting out the infected tissue, and watering it with a suitable preparation. Trees close to infected trees should also be watered. The treatment should preferably be carried out after flowering and repeated after a month.

Figure 32: Stem base ring rot of fruit trees, typical symptoms on stems and trunk (https://www.sadowniczy.pl/Najczestsze-choroby-jabloni-blog-pol-1581424928.html); and stem base (https://www.forumogrodnicze.info/viewtopic.php?t=89914

3 Post-harvest diseases

Apples should be harvested in good weather, early enough, at the time of their ripeness for harvesting, not for consumption. Care must be taken during harvesting, packing into crates, and transporting the apples to ensure they are not damaged. Proper storage. SmartFresh technology, i.e. harvesting the fruit in the harvest maturity window and rapid cooling in the storage chambers, blocks ethylene receptors, slows down the ripening of the fruit, and prevents the development of storage diseases. They are checking the condition of the apples. Regular inspection allows early elimination of infected apples and avoids significant losses. The most effective method of combating storage diseases is to apply fungicide sprays during the growing season when apples are most vulnerable to infection. Sources of infection are often post-harvest residues, infected leaves, or branches, so these need to be removed from the orchard as soon as possible. Fungal diseases can also develop on damaged bark or shoots, so post-harvest disinfection treatments are necessary.

3.1 Apple bitter rot (*Pezicula alba Gunth*)

Apple bitter rot has become the most severe storage disease. Sometimes, losses caused by this disease reach 20-50% of stored apples. The disease is perfidious because it remains latent inside the fruit for a long time, and it is impossible to tell whether the stored apples are infected. The sources of infection are gangrene at bark wound sites and dead short shoots, on which conidia of fungi from the genus *Pezicula* develop. The spores drop onto the apples with raindrops and, through the lenticel distributed on their skin, penetrate the fruit's interior, where they develop. Varieties with many prominent lenticels (e.g. Gala, Golden Delicious, Champagne, Ligol, Ruby) are most susceptible to infection with apple bitter rot. The disease manifests itself when the fruit reaches consumption maturity. Low temperatures and a controlled atmosphere in the storage room slow down the development of the disease. It manifests itself by light brown eyes on the skin, which darken over time and may be several to a dozen in number. The skin at this point is shiny, smooth, taut, and slightly concave, and the flesh underneath is soft but not watery.

3.2 Apple grey mould (*Botrytis cinerea*)

The grey mould of apples is Poland's second most common storage disease. The culprit is the fungus *Botrytis cinerea*, which infests the blossoms and fruit compounds, taking over the bract area. Even before harvest, the fungus manifests itself in the form of dry cup rot or soft cup rot, and during storage,

it causes nest rot in the apples. Rot spots appear at the calyx of the apple and gradually spread throughout the fruit. The fruit wrinkles, and the skin begins to be covered with a grey coating containing mycelial hyphae and conidial spores. These can infect neighbouring fruit in the storage room, leading to the nested spread of the disease. Varieties susceptible to apple grey mould include Alwa, Cortland, Gala, Gloster, and Ligol. The development of the disease is favoured by low temperatures, rains, and high humidity during apple blossom, rains preceding the harvest period, the placement of damp fruit in storage, and poor ventilation of storage chambers. The disease develops in different types of storage facilities, both controlled atmosphere (KA) and reduced oxygen (ULO) storage.

3.3 Apple scab (*Venturia inaequalis* (Cooke) Winter)

Apple scab caused by the fungus *Venturia inaequalis* is one of apple orchards' most dangerous and common fungal diseases. Late storage scab, which originates from scab-covered leaves, only reveals itself during storage in the form of small, dark spots on the fruit. Apple scab infection is favoured by rainy weather, as falling raindrops carry the spores of the fungus from the leaves to the fruit. Apple scab is the only storage disease that does not lead to the rotting of the fruit but only deteriorates its appearance and reduces its consumption value. The high harmfulness of apple scab is due to the increasing resistance of this fungus to subsequent fungicides.

3.4 Wet rot of apples (*Penicillium expansum*)

Wet rot of apples is caused by the fungus *Penicillium expansum* or several other fungi of the genus Penicillium. The fungus spores are found in the soil and on wooden crates and float in the air. Infection occurs when apples are picked or transported carelessly. The spores enter the fruit through lenticels at the bruised area, damage to the skin, and broken stalks. The fungus causes rapid rotting of infected apples, which become soft disintegrating when lightly touched. Greenish or white patches with clusters of dusty spores are visible on the surface of infected fungi. The brown, watery flesh with an unpleasant odour is visible inside the apples. The fungus *Penicillium expansum* produces a dangerous mycotoxin (patulin) in rotting fruit. Because of this and the rapid infection rate, infected fungi must be removed from storage immediately.

3.5 Brown rot of apples (*Monilinia fructigena*)

Apple brown rot is caused by the fungus *Monilinia fructigena*, which occurs on stone and pome fruit trees. In the storage variety of the disease, the first sign is a small rot spot surrounding the area of damage to the fruit's skin. The rotting area gradually spreads over the entire fruit, shrinks, dries out, and turns black. With high humidity, the surface of the rotten fruit is covered with pseudosclerotia containing spores of the fungus. The source of apple brown rot infection is the dried mummies of last year's fruit left under the trees, on which the fungus spores develop in the summer. Apple varieties with delicate skins are the most susceptible to brown rot. The disease is more common in storage than cold storage and manifests in the first weeks without causing significant losses (2-3%).

Management

Rational disease prevention involves making full use of all available methods to reduce the disease risk, on the one hand, and making the best use of chemical protection agents, on the other. It is crucial to create good conditions for plant growth through proper fertilisation, tree screening, and selecting a site that meets the requirements of the variety. An essential role in disease prevention is played by reducing the source of infection, including vetting and removing infected organs and whole trees, as well as a urea treatment to limit the number and development of fungal fruiting bodies. Signalling critical periods, observing the development of pathogens, having weather stations, and even using simple thermometers and rain gauges are considerable aids in properly conducting chemical protection. Introducing varieties that are less susceptible to infestation plays an essential role in reducing losses caused by disease. Non-chemical methods are an important part of the integrated plant production system, as they allow the use of plant protection products to be reduced, thus significantly reducing environmental pollution and limiting risks to consumers. The most critical non-chemical methods include Selecting a suitable site and not planting orchards in low-lying areas favourable to tree frost, which often leads to increased susceptibility to disease development. The site also determines the specific microclimate, favouring or limiting the development of certain diseases. For example, more frequent protection against diseases is necessary in areas with longer-lasting humidity.

- Selecting varieties with a high degree of disease resistance, especially if conditions in the area are more favourable for their development.
- By pruning the trees correctly, the crowns become more light and airy, reducing the wetting period for leaves and fruit and thus preventing possible infections. Thanks to the well-formed crowns of the trees, it is also possible to spray them accurately, which is particularly important when combating so-called complex diseases. The effectiveness of the treatment can only be achieved with good coverage of the entire tree, including the top part, and proper penetration of the preparation into the crown.
- Removal from the vicinity of orchards of old and wild apple trees and other host plants of apple pathogens that are potential sources of infection in the orchard.
- Adequate fertilisation, especially of nitrogen, as over-fertilisation with this element leads to increased susceptibility of plants to disease, prolongs the vegetative growth period, making young tissues very susceptible to infection by pathogens such as *V. inaequalis, E. amylovora, or P. leucotricha*. Inadequate fertilisation can stimulate apple trees to grow stronger, leading to crown thickening and creating more favourable conditions for infection.
- Raking and destroying fallen leaves to reduce leaf overwintering pathogens (*V. inaequalis*) and collecting and destroying fruit mummies (*M. fructigena*).
- Remove infested shoots in early spring, e.g., to reduce the source of apple powdery mildew.

For some apple diseases, preventing losses is only possible through proper chemical protection. Proper protection is only possible with a good knowledge of pathogen biology and plant protection products' properties. A thorough analysis of the current situation in a particular orchard is essential before deciding on a protective treatment and the choice of fungicide. Above all, the susceptibility of the cultivar, the developmental stage of the plant and pathogen, the abundance of the source of infection, atmospheric conditions, the properties of the preparation, the rotation of compounds with different mechanisms of action, and the occurrence of fungicide-resistant forms of the fungus must be taken into account.

Protection of apple trees before and after harvest

The pre-harvest period is the last time to protect against storage diseases. Rainy weather makes it easier for pathogens to penetrate the lenticel on the fruit surface, following the weather forecasts when carrying out preventive spraying before the fruit is harvested. Washing out the preparation with rain renders the protective treatment ineffective and may contribute to the pathogen's resistance to the active substance. The withdrawal period is an essential factor in the choice of preparation, so treatments are carried out approximately one month before the planned harvest. Post-harvest protection can be ensured by fogging the apples in a cold room with a fungicide designed for fumigation. After harvest, it is also necessary to protect the apple trees in the orchard and to protect wounds on the trees and other damage caused during agro-technical operations, harvesting, and pruning. Post-harvest fungicide spraying in the orchard must be carried out in three stages (every ten days or so): immediately after harvesting the fruit, after 30-50% of the leaves have fallen, and at the final stage of leaf fall. Using a mixture of fungicide preparations containing active substances belonging to different groups for spraying increases the effectiveness of the treatment.

Control strategy

In recent years, fruit growers have had an increasingly limited choice of active substances registered to control fungal diseases in apple crops. Choosing the right strategy to combat pathogens effectively is all the more critical. The first half of the season is crucial in the fight against apple scabs, powdery mildew, or grey mould. It is advisable to choose plant protection products that have a preventive or intervention effect on all these diseases. It will reduce the number of spraying operations, which will also translate into lower costs while maintaining maximum effectiveness. These requirements are met by certain SDHI products, which are often referred to as fungicides for particular tasks. They are particularly recommended during critical periods in terms of risk and weather conditions, which can make it impossible to carry out an effective treatment to interrupt the infection.

4 Agronomic practices for crop protection

Choice of cultivation environment

Fruit trees grow, and fruit are best on sites not previously used for orcharding. It is suitable for the area intended for the orchard to be slightly raised about its surroundings. It makes it less likely for the trees to freeze during harsh winters and for the flowers and buds to freeze during spring frosts. Gentle slopes are not difficult to cultivate, and, at the same time, the reasonably intensive air movement that occurs there causes colder masses to flow to lower-lying areas during frosts and freezes. In addition, on slightly elevated sites, the wind quickly dries the leaves and fruit after rain, and thus, the risk of fungal solid disease symptoms decreases. An organic orchard should not, for the same reason, be tightly covered on all sides with a dense row of trees, shrubs, or other covers. In extreme winds, shelter can be provided on one or at least two sides from which the wind blows most often. It is a good idea to keep natural trees (if they exist) so that birds and beneficial insects, the fruit grower's allies in the fight against pests, can find shelter in them. Stones and boulders collected around the plantation serve a similar purpose, providing a habitat for beneficial organisms. On the periphery of the orchard or outside the fence, you should find plants such as verticillium, yarrow, columbine, arborvitae, and elderberry. In or around the orchard, it is advisable to create favourable conditions for

the development and existence of predatory mammals and birds, which are the orchardist's allies in the fight against orchard pests. To this end, piles of stones are left near the orchard, where weasels, for example, live, and high poles with crosspieces are placed in the orchard for birds of prey. Nesting boxes for birds should be placed on the trees.

Varietal choice

Choosing the suitable varieties to plant is very important when establishing an orchard. Orchardists should choose varieties that have more excellent resistance to the most critical diseases (scab, powdery mildew, fire blight) and are more resistant to frost. Both old and new commodity varieties with higher disease resistance can be planted. The choice of variety will depend on several factors: climate and soil conditions, proximity to the market, consumer attractiveness, farm profile, or form of sale (direct, markets, industry). We should not only choose varieties that sell well but also those that are just entering the market and will be attractive. This requires knowledge of the market at home and abroad, including price relations between varieties. Several varieties should be planted because there is not even a European market for varieties. We choose varieties with different ripening times to have fresh fruit for a long time and find time to harvest and process it. The fruit should be of good quality not only after picking but also after storage. In addition, their appearance, flavour, and firmness are considered. Some apple varieties are characterised by alternate fruiting, i.e. they bear fruit every other year. Therefore, the regularity of tree fruiting should also be taken into account. Annual fruiting can be achieved for many varieties by thinning the buds or blossoms.

Rootstock selection

Apple rootstocks affect varietal characteristics such as growth strength, frost resistance, or disease susceptibility. Therefore, choosing a suitable rootstock is just as important as selecting an apple variety that bears fruit with the desired characteristics. The different rootstocks for grafting apple trees affect the same apple variety differently. They influence the abundance of yield and regulate the strength of growth, frost resistance, and disease susceptibility of the resulting tree. The most important properties of apple tree rootstocks are to give the tree the right height and to adapt it to the prevailing climatic conditions. Therefore, the characteristics that should guide our choice of rootstock are frost resistance and growth strength.

Plant operations

Preparation of the site for the plants is critical. First, the soil needs to be weeded, enriched with organic fertilisers, and given a suitable pH and structure. Doing this as early as possible, at least six months before planting, is a good idea. However, if this is not possible, it does not disqualify you from gardening, even though you will have much work to do later. When preparing the planting plan, it is crucial to determine which species of trees we will be planting. This should be at least two varieties of one species. This will ensure cross-pollination, as some varieties require pollination with pollen from another variety.

Planting techniques and distance

Determining straight rows and appropriate distances between trees and shrubs will make subsequent maintenance and harvesting easier. Planting can be done in autumn or early spring in April. After digging a hole large enough for the roots to fit in, form a small mound at the bottom and place the

tree on it so the grafting point is about 10 cm above the ground. Dig holes for trees and shrubs at the points marked with stakes. The dimensions of the holes should allow the roots to spread freely (diameter 40-50 cm, depth 30-40 cm). If you add, for example, compost to the hole, deepen it accordingly. Just before planting, the roots of the seedlings should be inspected again. Roots that are mechanically damaged or too long are removed. If you are planting trees and shrubs by hand, it is best done in teams of two. One person digs the hole at the marked location so that the top humus layer of soil, the ploughing layer, is deposited on one side. On the other side, another less fertile layer of soil is deposited. At the bottom of the hole, a mound is made of the arable layer. On top of this, a second person places the plant's roots, holds the tree or shrub, and tramples it down as the soil is added. While holding the tree, shake it lightly with short, vigorous vertical movements. The soil then thoroughly fills the spaces between the roots. Cover the roots with lightly tamped soil and water generously (5 - 10 litres of water). After the water has soaked in, add a suitable amount of soil, and then tamp down thoroughly, making sure not to pull the plant upwards, which can cause the roots to break off or damage the bark. The trees should be planted a few cm deeper than they grew in the nursery (up to 10 cm deeper on light soil), and the rooting point should be above the soil surface. If the soil covers the site of the plant's ennoblement, it can lead to roots growing on the noble part of the tree, in which case the yield will be significantly reduced. Stakes are driven in before planting the tree on the west side about 10 cm from the plant.

Replanting

If a new orchard is established on the site of an old orchard, soil fatigue may occur due to harmful nematodes, microorganisms, and root excretions in the soil. This manifests itself in stunted tree growth. Green manure (mustard, lupin, phacelia) should be applied if such symptoms are observed. This will result in a plump and nutrient-rich soil, which will be available to the newly planted orchard plants.

Pruning

Pruning apple trees is a critical tree care procedure to ensure they fruit abundantly each year. Proper pruning of apple trees will ensure that we strike a balance between vegetative growth and fruiting. Pruning apple trees aims to give the tree the proper habit and form. Pruning apple trees is one of the most essential elements of care and cultivation. Its purpose is to produce the most abundant apple crop possible and make it easier for us to harvest. Trees with a branched crown (consisting of a main shoot (leader) and several side shoots) should have their leader cut and shoots below 140 cm removed. By pruning the branch guide, you encourage the tree to produce vigorous new growth, from which the crown will form. Remove branches growing at a too-acute angle, which may break off under the weight of the fruit, and shade the rest of the crown. Remove shoots that compete with the canopy. Do not cut back the branch until it has outgrown its support. Always cut on dry days (low humidity). Use disinfected pruning tools - e.g. soaking them in denatured alcohol. This will prevent the spread of fire blight bacteria or other diseases on the tools. Wounds caused by removing thick branches should be protected against drying out and pathogen attack.

Soil management

Apple trees can thrive in average soil with a pH close to 7, provided it is well-drained and free of standing water. However, maximum yields are recorded on fertile sandy soils and clays with a pH

between 6 and 7. Start by carefully ploughing the field to a depth of at least 50 cm and removing all weeds. We can add about 20 tonnes of manure per hectare and then plough superficially again. Many commercial apple growers also add lime to the soil before planting apple trees to improve the soil pH. Cover crops reduce soil erosion during heavy rains or wind storms. They also improve soil aeration and orchard stability, and some fix nitrogen. They also act as a filter for apple irrigation and regulate the temperature in the orchard. Lucerne, vetch, legumes, and swollen clover (*Trifolium fragiferum*) have proved beneficial when planted as cover crops in orchards.

Fertilisation

Fertilisation is critical in the first years of cultivation because the apple tree will not grow at the correct rate without it. However, before we apply fertiliser, we should perform a chemical analysis of the soil. Only on this basis can we determine which components are missing and choose the right fertiliser. This is a significant step because the amount of essential elements in the soil determines the development of the tree. Nitrogen, for example, determines the green mass, phosphorus determines the root mass and bud formation, potassium affects the fruit, and magnesium affects photosynthesis. The first fertilisation should already be applied in the first year of cultivation around the middle of ma. The next dose of fertiliser is applied after a further 4 to 5 weeks. Mulching the soil around the trees with manure or compost also has a good effect. Cover the manure with a thin layer of soil so it decomposes more slowly and evenly and supplies the plants with nutrients. Fertilisation continues every year. However, once the crown has been formed, nitrogen fertilisation is reduced to slow down the growth of the shoots and encourage the apple tree to bear fruit. Foliar fertilisation is also a good option. It has a quicker effect than a soil fertiliser, although it should be used as a supplementary fertiliser. Foliar fertilisation should be carried out at 12-26^{o} C in sunny weather.

Irrigation

Apple trees have high water needs due to their large leaf area and fruit containing much water. Soil drought, caused by periodic rainfall deficits, adversely affects shoot growth, fruit set, and growth. Even short-lasting water shortages harm shoot growth and fruit weight gain. Rainfall deficiency for young apple trees in nurseries and orchards results in stunted growth. Therefore, every orchardist should carry out the irrigation of apple trees in orchards. In young trees, the adverse effects of a lack of water in the soil are most potent. The critical period is the first spring after planting the apple trees in the orchard. At that time, the ratio between the aboveground part and the tree's root system is disturbed in case of water shortage. If a water shortage occurs in the soil, the apple trees cannot take up the right amount of water needed to sustain physiological processes and maintain proper shoot and fruit growth. A reduction in transpiration and CO2 uptake, caused by the closure of stomata, results in a reduction in photosynthesis and, therefore, tree productivity. Irrigation of apple trees in orchards is a necessary measure. Fruit trees develop and yield best when the soil moisture is close to the field water capacity (soil moisture that occurs 1-2 days after heavy rainfall).

Harvest

The apples are moderately sensitive to bruising and stand transport quite well. Before harvesting the apples, we need to 'thin' the trees. The thinning of apple trees is crucial to obtain a good yield and normalizing production during the year (to minimise the 'Biennial' or 'Alternate Bearing' phenomenon). The idea is to remove underdeveloped, damaged fruit and those attacked by diseases

and pests to leave enough valuable nutrients for the smaller amount of healthy and standard-sized fruit you want to harvest a few months later. Sometimes, the choice can be more difficult, as we may have to remove healthy and good-looking fruit if there is no damaged or unhealthy fruit. Alternatively, commercial fruit growers can regularly check the sugar levels in the apples to determine the optimum harvest time. Unfortunately, when it comes to harvesting apples, we usually only have an 8-12 day window. Apples are harvested mainly by hand and are very sensitive to bruising. Sorting must take place immediately after picking, as damaged apples release ethylene more quickly, which can harm the remaining fruit. An excellent yield for a properly tended apple tree grown in a home garden is around 80-180 fruits per season. By contrast, when apple trees are grown in production in apple orchards, using sophisticated pollination, fertilisation, irrigation, and plant protection methods, 400 to over 800 (and in some cases, over 1,200) fruits per season can be obtained.

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CHAPTER 9

Raspberry [Rubus idaeus L.].

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WHAT WILL WE LEARN IN THIS CHAPTER?

We're going to learn about the intricacies of raspberry trees, their fruit-related diseases both in the field and post-harvest, along with the physiological disorders they may develop. This comprehensive exploration encompasses disease management strategies and best practices aimed at optimizing raspberry cultivation.

Keywords: Raspberry, Diseases and Physiopathies, Agronomic practices, Farming Techniques

Summary

1 Overview

Raspberries (*Malus x domestuca Borkh*) are shrubs with tasty and healthy fruits eaten raw or as preserves. Their health-promoting properties are due, among other things, to the presence of anthocyanins - the components that give the fruit its red or purple colour. Anthocyanins have antioxidant and anti-inflammatory properties. Raspberries are most commonly used to make juices and jams or eat fresh fruit, e.g., in desserts. Recent studies have shown that they also have anti-cancer effects, and the fibre they contain reduces sugar and cholesterol levels. Raspberries are also a source of vitamin C, which is necessary for forming collagen, which forms connective tissue, improves wound healing fracture regeneration, protects against bleeding and bruising, stimulates the immune system, and facilitates the fight against pathogenic microorganisms.

Raspberries are shrubs that like a sunny position, but they also do well in partial shade. When choosing a variety, it is worth paying attention to when the bush bears fruit. The range of fruiting times between different raspberry varieties can vary - from spring to autumn. There are also differences in fruit colours. Red is the most popular, but yellow and black can also be found. The biggest problem in raspberry cultivation is stem blight, usually caused by a complex of pathogens.

2 Field diseases and physiopathies

2.1 Raspberry shoot dieback (*Didymella applanata, Botrytis cinerea, Leptosphaeria coniothyrium, Elsinoe veneta, Verticillium spp. and Fusarium spp.)*

Raspberry shoot dieback is the most dangerous disease of fungal origin. The full name of the disease is raspberry shoot dieback. Didymella applanata causes the fungal disease. The disease can also be caused by *Leptosphaeria coniothyrium, Botrytis cinerea, Elsinoë veneta, Verticillium spp., and Fusarium spp*. The first symptoms of the disease can be observed in June. The pathogen infects shoots where buds and leaves emerge. Brown spots develop around the infection sites, gradually increasing in size. Over time, the spots become so extensive that they may even cover the entire circumference of the shoot. The tissue within the spots turns silvery grey after a while, and by mid-summer, characteristic black dots form on the affected areas. These are the fruiting bodies of the fungus, in which conidial spores develop to spread the disease further. Infected shoots grow weaker. The shoots die at the end of the growing season or in the spring of the following season.

Prevention and eradication

You can choose those less susceptible to stem dying among the many raspberry varieties. A raspberry plantation should be planted at a suitable distance from each other to ensure optimum ventilation and drainage. This will prevent infection, which is favoured by high temperatures and humidity. Do not allow the plantations to become too dense. To do this, cut back excess shoots and weed the plantation regularly. Use a balanced fertilisation adapted to the needs of raspberries, avoiding over-fertilisation with nitrogen. Avoid watering the plants after the leaves. If you plan to use automatic irrigation, choosing drip irrigation and avoiding sprinkling is best. After the fruit has been harvested from the plantation, shoots that have already borne fruit, biennial shoots, and all diseased shoots should be cut close to the ground. Preventive plant protection treatments should be carried out before flowering. If necessary and if symptoms of the disease are observed, subsequent treatments are carried out at the beginning, complete and end of flowering. The last treatment is carried out after the fruit has been harvested and the shoots have been cut.

2.2 Anthracnose (*Elsinoë veneta*)

Symptoms of the disease appear as small, purple spots forming in the cortical soft tissue of the shoots. The spots gradually enlarge and become greyish-white, surrounded by a purple-red border. Longitudinal bark cracks appear in place of the spots, intense on two-year-old shoots. Sometimes, severely infected shoots freeze over the winter and die or develop distorted lateral fruit-bearing shoots with deformed fruit. The fungus also infects flowers, flower stalks, calyx sepals, fruit and petioles, and leaves in high humidity conditions. Symptoms observed on most organs are similar to those on

Figure 33 Raspberry shoot dieback, typical symptoms on raspberry plant shoots (https://www.agro.bayer.com.pl/doradztwo/agrofagi/zamieranie-pedow-malin); (https://agrecol.pl/dra_problem/zamieranie-pedow-malin/); and plant bushes (https://poradnikogrodniczy.pl/choroby-malin-i-ich-zwalczanie.php)

shoots, but the spots are usually finer. Fruits developing from infected flowers are green, diminutive, and often shrivel. Sometimes, due to infection, individual drupes wrinkle, turn brown and shrivel. Under high humidity conditions, a severe infection of various raspberry organs can occur, resulting in premature defoliation of the plants, diminutive and deformed fruit, and sometimes mass shoot dieback. The occurrence of the disease results in significant losses associated with a drastic reduction in yield.

Prevention and eradication

To reduce the incidence of the pathogens that cause raspberry shoot dieback, it is necessary to: plant healthy plants, cultivate resistant varieties of raspberries, run raspberries by wires, which allows rapid drying of shoots and facilitates precise coverage of plants with the application liquid, properly fertilise plants, mainly with nitrogen - too high doses of this component contribute to increased susceptibility to disease, weed the plantation and remove the excess of young shoots, thickening the rows, on irrigated plantations or plantations established on fertile soil cut all the shoots by the end of May and on plantations of summer varieties remove 2-year old shoots immediately after harvesting the fruit. In the case of raspberry anthracnose, avoid sprinkler irrigation, cut and destroy infected shoots, and remove wild raspberries and blackberries from the vicinity of the plantation, which may be the source of the disease. Carry out the first plant protection measures before the raspberry blossoms, when the young shoots grow to a height of 10-20 cm. Subsequent treatments can be carried out every ten days during the flowering phase and at the end of flowering. The last treatments are carried out after the

fruit has been harvested and the old fruit-bearing shoots have been cut (which destroys the spores of the fungus). Treatments are adjusted according to the timing and severity of the disease.

Figure 34: Anthracnose typical symptoms on whole plants (https://poradnikogrodniczy.pl/choroby-malin-i-ich-zwalczanie.php); on stems (https://dlaroslin.pl/content/511-co-na-antraknoze-maliny); and on the leaf (https://agrecol.pl/dra_problem/antraknoza-malin/)

2.3 Grey mould (*Botrytis cinerea*)

In plantations that are too dense and in years with much rainfall, grey mould is the cause of shoot dieback and fruit rot. Flower buds and flowers become infected, turning brown and dying. A characteristic grey, fluffy coating of the fungus appears on diseased fruit. Light brown, widespread spots are visible on diseased shoots in various places. Infected shoots grow poorly and are susceptible to frost. The symptoms of shoot infestation, especially in the early stages, are similar to those caused by the fungus *D. applanata*. The difference is that the necroses caused by *B. cinerea* are more extensive, lighter in colour, and have no clear boundary between healthy and diseased tissue. In autumn and winter, the infected tissue turns grey and often peels. On the necrotic tissue, characteristic black, flat discs of 3-10 mm in size, which are spores of the fungus (sclerotia), form, usually already in autumn. They are the identifying feature of the disease on second-year shoots.

Prevention and eradication

You can choose those less susceptible to grey mould among the many raspberry varieties. A raspberry plantation should be established by planting at the correct spacing, which ensures optimum ventilation and drying of the plants. This will prevent infection, which is favoured by high temperatures and humidity. Do not allow the plantations to become too dense. To do this, cut back excess shoots and weed the plantation regularly. Use a balanced fertilisation adapted to the needs of the raspberry, avoiding over-fertilisation with nitrogen. Remove infested fruit and plant shoots where possible. Avoid watering the plants after the leaves. If automatic irrigation is planned, it is best to choose drip irrigation and avoid sprinkling. After harvesting, the fruit should be put into the refrigerator immediately. After the fruit has been harvested from the plantation, shoots that have already borne fruit should be cut back close to the ground. Preventive plant protection treatments should be carried out from the beginning of flowering. Subsequent treatments should be carried out every ten days if necessary, and symptoms of the disease have been noticed. Treat when conditions are favourable for

disease development (high humidity). Carry out chemical sprays in accordance with the instructions on the label, taking into account the withdrawal period.

Figure 35: Raspberry grey mould, symptoms on fruit (https://agrecol.pl/dra_problem/szara-plesn-malin/); (https://pzdpodlaski.pl/co-zrobic-aby-maliny-nie-plesnialy)

2.4 Raspberry white leaf spot (*Mycosphaerella rubi*)

Young raspberry leaves first show dark green, small, almost circular spots that are well visible on the upper side of the leaf. As the leaf develops, the spots enlarge (6 mm in diameter) and become whitish grey, clearly cut off from healthy tissue—the infected, necrotic tissue sprouts. Severely affected leaves turn yellow and fall prematurely. Early defoliation worsens the condition of the shrubs, which grow more slowly, yield poorly, and become very susceptible to frost damage. Disease symptoms in the form of small spots, sometimes more elongated, can also occur on shoots, petioles, calyx sepals, and fruit stalks. On the spots, mainly in the central part, the fungus forms characteristic small, black conidial stage formations (pycnidia). The spores released from these are the primary source of pathogen spread in the plantation.

Prevention and eradication

Conduct systematic vetting from pre-flowering to fruit harvest. Avoid sprinkler irrigation. Agro-technical measures to limit the severity of the disease: do not allow the plantations to become too dense (rows no wider than 40-60 cm) to ensure good aeration and rapid drying of the plants, systematically weed the plantations, run by wires, remove excess shoots. Fertilise correctly with

Figure 4: White raspberry leaf spot, typical symptoms on raspberry leaves (https://commons.wikimedia.org/wiki/File:Sphaerulina_rubi_02.JPG); (https://www.wikiwand.com/pl/Bia%C5%82a_plamisto%C5%9B%C4%87_li%C5%9Bci_maliny)

nitrogen. An excess of this element prolongs the growth period and increases the susceptibility of the tissues to infection. On irrigated plantations or those established on fertile soil, cut all one-year shoots by the end of May. This avoids early infection and reduces disease pressure. In plantations, use chemical treatments to control other fungal diseases, using fungicides containing thiophanate-methyl, triazoles (e.g. tetraconazole), and strobilurins (e.g., trifloxystrobin).

2.5 Raspberry *Verticilliosis* (*Verticillium dahlia*)

It is a disease that is quite difficult to diagnose. Typical symptoms are usually observed in summer, during hot and dry weather. The leaves of infected plants show extensive yellow streaks between the nerves, which later turn brown, and the leaf edges curl upwards. Infected leaves wilt and die. As a result of infection, blue or brownish-blue streaks appear on the shoots. Wilting of the leaves is then observed, and shoot death occurs later. The longitudinal cross-section of infected shoots shows a distinct brown colouring of the wood. Infected plants usually die within 1-3 years. Symptoms of verticilliosis can occur on all shoots growing from the rootstock or only on individual shoots if the plant's entire root system has not been infected.

Prevention and eradication

Prevention and prevention are The most effective ways to protect your crop from verticilliosis. Avoid growing susceptible plant species in the same area for several seasons. Choose healthy seedlings from a reliable source, and go for varieties of plants resistant to Verticilliosis. Maintain proper drainage and avoid overwatering. Quickly remove infected plants together with their roots. Regularly control weeds and pests that can carry pathogens. Avoid overly dense planting and provide plants with a permeable substrate. Disinfect the soil and maintain high hygiene and disinfection of gardening tools. Look out for preparations containing strains of bacteria and fungi that antagonise pathogens, such as *Trichoderma spp.,* which can limit the development of fungal diseases in the soil. Preparations containing *Bacillus subtilis* or *Pseudomonas fluorescens* can also be used as a preventative measure, enhancing plant resistance and inhibiting pathogen development and plant wilting. Other recommended methods include mycorrhiza, which, through symbiosis with plants, can increase their resistance to environmental stresses, including fungal infections.

Figure 36: Raspberry verticilliosis typical symptoms on plant bushes (https://rolniczeabc.pl/258512,Wertycylioza-u-malin-mylnie-diagnozowana-wyniszcza-plantacje-w-3-lata.html/); dead shoots (https://pl.wikipedia.org/wiki/Zamieranie_malin#/media/Plik:Didymella_applanata_(1).jpg/)

2.6 Raspberry rust (*Phragmidium rubi-idaei*)

The first symptoms of rust are visible in spring on the upper side of young leaves in the form of yellow-orange cups, which are clusters of aecia filled with aeciospores. Eciospores may also occur on petioles, inflorescence stalks, and calyx sepals. On the underside of the leaves and sometimes on the peduncle, calyx sepals, and drupes, orange-coloured clusters (uredinia) of medullary spores (urediniospores) form. Among the urediniospores, black clusters (telia) of spores (teliospores) appear, representing the next developmental stage of rust. Heavily infected leaves drop off prematurely, weakening the plants and consequent decrease in their frost resistance and poorer yield. Symptoms of raspberry rust are also observed on shoots, on which deep necrosis develop at the site of infection in winter. Such damaged shoots easily break off or dry out in the following season, especially during hot weather.

Prevention and eradication

You can choose those less susceptible to rust among the many raspberry varieties. A raspberry plantation should be established by planting at the correct spacing, ensuring optimum ventilation and drying of the plants. This will prevent infection, which is favoured by high temperatures and humidity. Do not allow the plantations to become too dense. To do this, cut back excess shoots and weed the plantation regularly. Avoid watering the plants after the leaves. If you plan to use automatic irrigation, choosing drip irrigation and avoiding sprinkling is best. After harvesting the fruit from the plantation, shoots that have already borne fruit, biennial shoots, and all diseased shoots should be cut to the ground. If symptoms of the disease are noticed, the first plant protection treatment can be applied at the beginning of flowering.

Figure 37: raspberry rust typical symptoms on leaves (http://agrecol.pl/dra_problem/rdza-malin/); (https://www.modr.mazowsze.pl/doradztwo-pdr/technologia-produkcji/produkcja-ogrodnicza/1251-rdza-maliny-powazny-problem)

2.7 Raspberry dwarfism (*Rubus stunt phytoplasma, RSP*)

Raspberry dwarfing is a hazardous disease caused by mycoplasmas. Symptoms of this raspberry disease are only visible the second year after infection. Raspberry dwarfism is mainly transmitted by raspberry pests such as jumpers. Numerous thin shoots grow at the base of the shoot, on which no flowers appear. The bush takes on a broom-like habit. Short lateral branches develop on the two-year-old shoots. Distorted flowers develop on them, bearing fruit poorly. The condition of the bushes deteriorates from year to year, with the result that raspberries affected by the disease cease to bear fruit and die.

Prevention and eradication

When bushes with dwarfing symptoms are noticed, raspberries with even the slightest symptoms of infestation should be removed from the plantation along with their roots. Use healthy seedlings from reliable sources to establish raspberry plantations. When growing raspberries, it is essential to control pests such as jumpers and aphids, which are disease vectors.

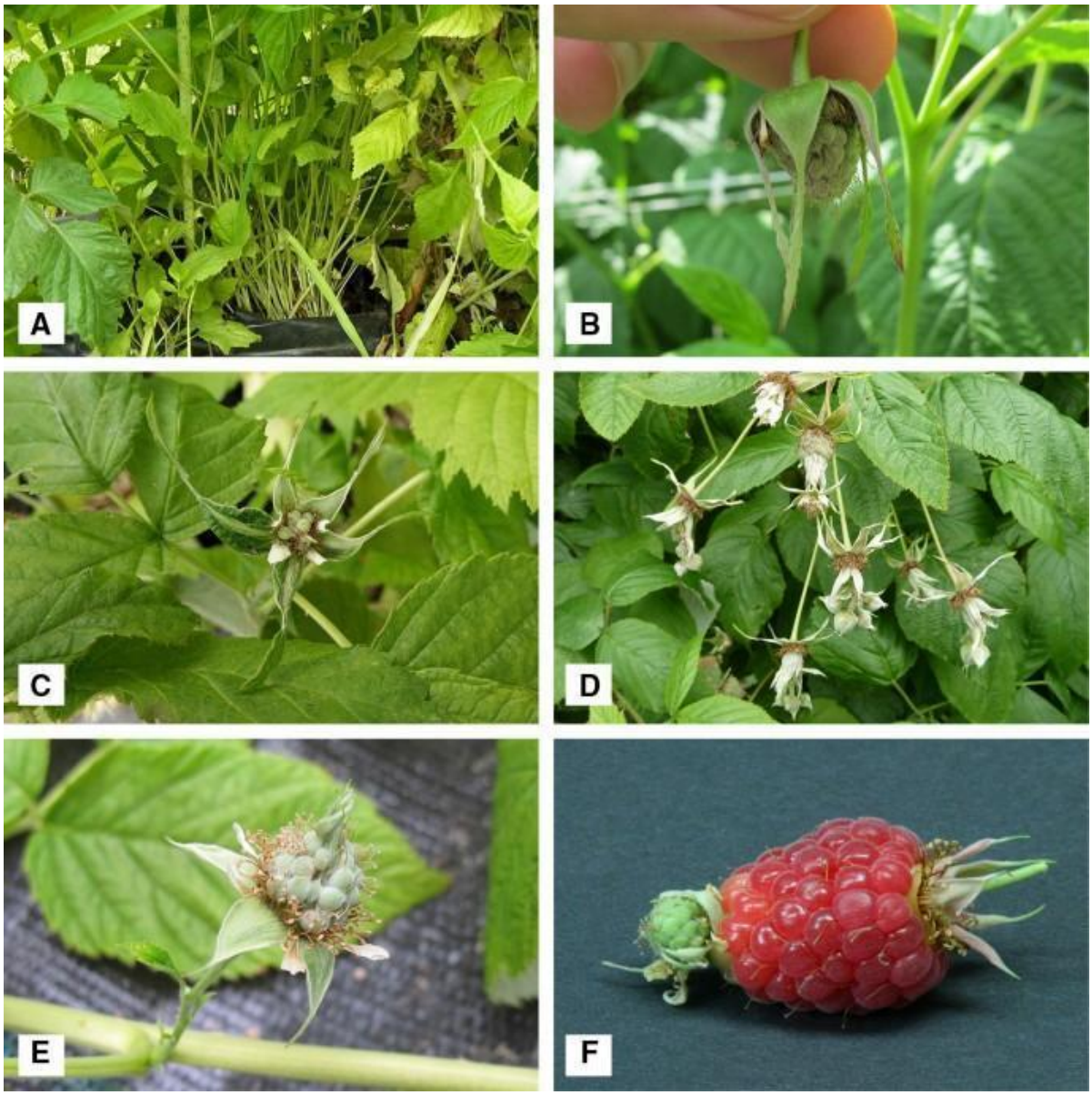

Figure 38: Rubus stunt disease symptoms on naturally infected red raspberry (Rubus idaeus). a Witches' broom, b enlarged sepals, c phyllody, d flower proliferation, e initial fruit malformation, f advanced fruit malformation (https://link.springer.com/article/10.1007/s41348-019-00247-3)

2.8 Raspberry powdery mildew (*Sphaerotheca macularis Wallr. ex Fries*)

Disease symptoms occur mainly on the leaves, less frequently on the drives and fruit. Bright green spots appear on the upper side of infected leaves. Within these discolourations, but on the lower side of the leaf, a white, powdery coating of mycelium and conidial spores develop. Infected leaves are finer and narrower than healthy leaves. A white coating of mycelium may also cover the tops of infected shoots. cluster of fire spores. Sometimes, small fruiting bodies (chasmothecia) form on older spots in the felt-like fungal mycelium, initially yellow and later dark brown. If the infestation is severe, the shoots become long and narrow, and the leaves are dwarfed and often bend upwards.

Sometimes, flower buds, flowers, and fruit are also infected. As a result of infection, fruit quality deteriorates, and, in severe infestation, fruit covered with a mycelium infestation is unsuitable for trade. The disease causes localised losses only in plantations of susceptible raspberry varieties. Heavily infected plants are stunted in growth, which reduces the size and quality of the crop.

Prevention and eradication

Plant healthy plants with optimum spacing. Systematically weed the plantation and cut and remove excess young shoots, which will ensure better airiness of the plantation. Fertilise correctly with nitrogen (excess nitrogen encourages disease development). Reduce sources of infection by cutting infected shoots. Some fungicides that protect raspberries against grey mould also reduce the incidence of raspberry powdery mildew.

Figure 39: Raspberry powdery mildew symptoms, mycelium on the lower side of the leaf (https://pl.wikipedia.org/wiki/M%C4%85czniak_prawdziwy_maliny#/media/Plik:Podosphaera_macularis_a1_(1).jpg)

2.9 Raspberry root rot (*Phytophthora rubi W.F. Wilcox & J.M. Duncan*)

Severely infected shoots wilt and die rapidly, often bending into a pastoral shape. The disease in the plantation occurs in patches, usually appearing first in lower-lying areas. Few suckers grow on infected shrubs. The apical buds do not develop on infected two-year-old shoots, and only lateral buds develop. The fruit is small and often shrivels before harvest. Leaves turn yellow, wilt, and curl upwards. Older leaves during hot, dry summers wither and look burnt, but they do not fall off and remain on infected shoots. A distinct dark brown or purple rot appears at the base of diseased shoots. When the bark is removed, a distinct discolouration of the wood is observed, including part of the roots. The root system of affected plants is severely damaged. In the affected part of the root, large, yellow-coloured oospores, spore forms of the pathogen, are often visible in the axial cylinder. The harmfulness of *P. rubi* is very high, as under favourable conditions for development, especially on moist, poorly drained, and heavy soils, the pathogen can destroy raspberry plantations.

Prevention and eradication

Plant only healthy, certified seedlings on fertile, airy soil and in a place where raspberries have not been grown for years. On heavy and waterlogged soil, drainage should be carried out. Shrubs should be grown in a raised bed system so that the top of the root system is raised above the ground. A suitable method is to grow resistant varieties.

Figure 40: Raspberry root rot (https://pl.wikipedia.org/wiki/Zgnilizna_korzeni_maliny)

2.10 Viral and phytoplasmic diseases

Raspberry vein chlorosis virus - characteristic symptoms occur on the leaves of young shoots in the form of nerve chlorosis. It can involve all or only lateral nerves, with no change in the primary nerves. With heavy infestation, the chloroses merge, and the leaf blade becomes deformed. Stunted growth and weakened plants may result. The virus is transmitted with infected plant material and the raspberry *aphid Aphis idaei.*

Raspberry mosaic, *Raspberry leaf mottle* virus (*Raspberry leaf mottle virus),* and Raspberry yellow *net virusi* (*Rubus yellow net virusi*) - chlorotic and yellow mottling is observed on the leaves, lightening of the nerves, streaking along the nerves and leaf blade deformation in the form of blisters and leaf edge curling. Under conditions of high disease severity, plant growth and yield are impaired. The blackberry aphid Amphorophora rubi transmits the viruses causing the disease.

Raspberry leaf blotch virus - typical symptoms of the first disease are dwarfing of bushes, weak and thin shoots growing out of sleeping eyes, uneven ripening, and decaying fruit. The virus is transmitted with pollen and seeds, the symptom of the disease being chlorotic spots that cluster together, covering more and more of the leaf blade over time. On the underside of the leaves, there is no cuticle at the location of the spots. Hence, this part of the leaf blade is light green instead of the characteristic grey. Growth of infected shrubs is stunted, and shoots may die, leading to a reduction in yield. Fruit often ripens unevenly and falls apart quickly. The vector of the virus is the raspberry bollworm (*Phyllocoptes gracilis*).

Prevention and eradication

Viral diseases are a significant problem in raspberry cultivation, as they cannot be controlled in plantations. They can only be reduced by controlling the pests that transmit them. Plants infected with the virus remain diseased for the rest of their lives and threaten healthy plants. In order to protect raspberries from the diseases mentioned above, it is advisable to establish a plantation containing healthy, certified seedlings. Deformed bushes with deformed leaves or chlorotic discolouration should be removed from the crop. In addition, it is advisable to control aphids, which are often vectors of plant viruses, thus preventing the spread of these diseases.

2.11 Bacterial diseases

Root gall of raspberry (Agrobacterium tumefaciens) - the bacteria enter the plant through any injuries to the root system and lower parts of the shoots. By stimulating excessive cell division and growth, they cause the formation of nodule-like growths of varying sizes on the central and lateral roots, the root neck, and the leaf shoot's lower part. On heavily infested plants, stunted shoot growth, chlorosis of the leaves, and sometimes wilting and dying of the shoots are observed. Weakened plants result in a decrease in yield and fruit quality. Tumours impede water and assimilate transport. The occurrence of the disease is favoured by the presence of bacteria in the soil, high soil moisture, and a neutral or alkaline soil reaction. Also, the presence of nematodes in the soil that damage the root system increases the severity of the disease symptoms.

Prevention and eradication

The most critical steps in prevention are those to be taken before planting. Above all, attention should be paid to the quality of the planting material. Any symptoms on the roots, nodules, or even small swellings should disqualify raspberries. Raspberries should be grown in fields free of *Agrobacterium tumefaciens*. If the bacteria are found in the soil, the crop should not be grown for five to six years. Crops should not be grown on high pH, waterlogged fields, and if the bacteria are found, it is advisable to acidify the soil by applying physiologically acidic fertilisers. Damage to plant roots should be avoided during cultivation operations. When nodules are found on excavated nursery stock, plants with nodules on the main root should be destroyed, roots with nodules on the lateral roots should be cut out, and the rest of the root system should be submerged in clay with copper fungicide.

3 Agronomic practices for crop protection

Choice of cultivation environment

Plain or gently sloping land is most suitable for raspberry plantations, where machinery and equipment needed for maintenance operations can operate without hindrance. Raspberries should not be grown in low-lying areas where frost heaves can form because of the risk of frost or plant damage. Raspberries root shallowly; therefore, soils that are poor in water or excessively wet and heavy soils are unsuitable. Raspberries are susceptible to both deficiency and excess water in the soil, so irrigation is essential on light, sandy soils. The best soil for growing raspberries is fertile, nutrient-rich bonitation class III and IV soils. Loess soils are excellent. The water table should not exceed 50-70 cm from the soil surface. The soil reaction should be slightly acidic (pH 6.0 to 6.5). Raspberries should not be planted in succession or where strawberries, tomatoes, or potatoes have previously been grown because of the possibility of root infection by verticilliosis. Raspberries should not be planted after perennial faba bean plants because of the risk of disease and pest development, such as swollen beetle larvae after alfalfa clover.

Varietal choice

Red-fruited raspberries are most commonly grown on commodity plantations, whether fruiting on two-year-old shoots in summer or repeating fruiting in autumn, i.e., fruiting on one-year-old shoots. Raspberry varieties are divided into summer and autumn. Summer raspberries ripen on last year's shoots and are, therefore, quite sensitive to hard frosts. Traditional raspberries bearing fruit only on biennial shoots in summer are exposed to frost, diseases, and pests, but they yield exceedingly

abundantly with proper care. Both raspberries bearing fruit on two-year-old shoots and those bearing fruit on one-year-old shoots (repeat fruiting) are grown for dessert, as well as for processing and freezing. Qualified nursery stock should be used to establish plantations of raspberries and other plant species, as this guarantees the varietal purity and healthiness of the seedlings.

Cultivation of raspberries

Before planting raspberry bushes, prepare a suitable site for them. Raspberries are slightly acidic and well-drained soil (pH - 6.5). The bushes grow best in fertile and humus soil. On the other hand, they do not tolerate heavy and very waterlogged soils or light and sandy soils. Raspberries should be placed in a sunny position but sheltered from direct sunlight. The site to be cultivated should be weed-free.

Plantation surroundings and agro-technical measures

In order to screen the raspberry plantation from other crops or to fence off busy traffic routes, plant a row of trees or a high hedge on the west and north-west sides. Shade is quickly established by planting one or two rows of fast-growing trees along the border of the plantation. Some of the best shields are formed by alder, hazel, or birch trees. Strong-growing trees such as poplars, acacias, or ash trees should be avoided, as they will soon become competitive with the crops on the plantation. New plantations are generally established after removing old plantations, where old trees and shrubs, for example, are growing along borders, fences, roads, and around wasteland. Wild scrub next to plantations should not be destroyed. The scrub and bushes between plantations are a refuge for beneficial insects and birds, which find shelter there. This beneficial fauna significantly reduces the occurrence of many species of harmful insects and mites. The scrub around the plantation also creates a favourable environment for pollinating insects, mainly bumblebees. The diverse natural environment is conducive to maintaining a biological balance. When fencing in plantations, shelter should also be provided for small predatory animals such as martens, weasels, polecats, and ermine, which help to reduce the population of field mice or voles. Shelter for predatory animals is provided by scrub and stone debris, which the plantation fence should leave. In order to reduce the number of *roaches* in the soil, mechanical soil cultivation with a plough, disc harrow, or soil tiller is recommended. The pests are destroyed mechanically, and those discarded on the soil surface are picked out and eaten by birds.

Plant operations, planting techniques, and distance

The right time to plant raspberries is autumn. Moist soil then promotes rooting before winter. During spring planting, the heavily swollen flower buds may be damaged. The spacing between raspberries depends, among other things, on how the plantation is managed and what equipment is used for maintenance. Raspberries grown in rows by wires are planted at 2.5-3.0 m spacing between rows, with strongly bushy varieties in the row at 50 cm intervals while weakly bushy varieties at 30 cm intervals. Plants are planted 1-2 cm deeper than they grew in the nursery. In large plantations, the plants are planted with a planter attached to a tractor. When planting, the roots must be gently, carefully spread and placed at the bottom of the prepared hole. The planting is buried to a height of 3 buds from the ground. Remember to cut the plant 20-30 cm above the ground when planting in autumn.

Replanting

There are two dates for replanting raspberries: spring and autumn. The two dates differ regarding the care that has to be carried out on the plantation afterward. When repotting raspberries, carefully dig up the whole bush, not damaging the roots. The distance between the bushes should be 1.5 or 2 m. Then, transplant the raspberries into the previously prepared hole to accommodate the bush's root. Dig a 15-20 cm deep hole under each raspberry bush. Place the cuttings in the holes and cover them with soil. You can cover them with a small mound of soil or compost, no more than 2-3 cm. Finally, water all the plants generously. If you plan to plant raspberries in autumn, you must protect the plants from frost. Therefore, the mounds should be covered after planting and cutting to 30 cm of shoots. Spring planting has to be watered after planting.

Pruning of raspberries

Raspberries require systematic pruning and proper management. After the plants are planted, in early spring, the shoots are shortened just off the ground, which encourages more young, vigorous shoots to grow from the base or crown of the plant. Raspberries fruiting only on two-year-old shoots are usually managed as a single row by a structure made of posts and wire. During the season, the number of young shoots per row is limited. After the fruit is harvested, all fruiting shoots are cut, and the number of annual shoots left to bear fruit the following year depends on the formation system of the espalier. Young shoots are long and need to be tied to the structure. Raspberries grown for the autumn fruit harvest are usually managed without scaffolding, and after the fruit has been harvested, all one-year-old shoots are mown just off the ground. The following year, the shoots growing out of the carpel should be thinned, which benefits fruit quality and plant health. Covering the crowns with white fleece in early spring accelerates the growth of young shoots while covering the rows of plants at a later date accelerates their flowering and ripening of the fruit. In fruit-bearing plantations, the aim is to obtain a sufficient number of solid and balanced shoots, so it is recommended to remove weak, thin shoots that thicken the habit of the bush. Pruning is carried out in early spring, as soon as the growing season starts. Spring pruning of raspberries is aimed at renewing the shrubs. All frosted or dried shoots that have not started to develop should be removed during this period. Cutting back-side shoots about 10-15cm above the ground is also advisable. This allows the plants to spread better. Autumn pruning is much more radical. The older shoots should be pruned hard and cut off all side shoots. This prevents the spread of many raspberry diseases and pests.

Regulation of acidity in raspberry plantations

Combining chemical and non-chemical protection methods is the most effective way to control weeds. Non-chemical protection methods include mechanical treatments - tilling the soil, mowing redundant vegetation, maintaining cover crops, mulching - and physical methods such as burning weeds with propane. Uncontrolled weed growth reduces plant growth and yield. The greatest threat is posed by weed growth in spring and summer. The optimum way to maintain inter-rows on a plantation is with grasses of perennial meadow grasses - red fescue, meadow meadow grass, and perennial ryegrass. Mulches of natural origin also serve to reduce weed infestation. These can be textile waste, cereal and rape straw, sawdust, plant chips, wood bark, manure, aggregated brown coal, compost, and fruit pomace. A unique approach is required to mulch raspberries bearing fruit on biennial shoots. Such plantations can be established on embankments, the sides of which are covered

with black polyethylene film or polypropylene fleece, and the central part (about 20 cm) is covered with bark or straw.

Fertilization

Fertilisation should always be based on soil analysis. Fertilisation needs about N can be estimated from the organic matter content of the soil. The need for liming depends on the reaction and agronomic category of the soil and the period of use of lime. Liming is best carried out one year before the plantation is established. Phosphorus fertilisers can be applied pre-crop and before *planting*, while potassium fertilisers are best used immediately before planting. In raspberry cultivation, these mistakes can be easily corrected due to the plants' shallow rooting.

To begin with, we apply manure at a rate of 30 to 40 tonnes per hectare per our acreage. We repeat the manure application every four years, not exceeding 30 - 40 tonnes per ha. In years when we do not use manure, we can supplement the fertilisation with mineral fertilisers at a rate of 60 kg of nitrogen in divided doses (40 kg in spring at the start of the vegetation and 20 kg in summer) and 70 kg of phosphorus and 120 kg of potassium per ha (depending on the size of the plantation). It should be remembered that nitrogen fertilisers are applied in spring and summer, while phosphorus and potassium are applied in autumn. A well-cared-for and fertilised plantation can give a good yield for 12 to 15 years.

Irrigation

Under our climatic conditions, irrigation significantly impacts the plants' growth, yield, and condition. Therefore, water is a non-renewable good and should be used very sparingly. Water should be drawn from an acceptable source in permitted quantities. Particular attention should be paid to the efficient use of water in the selection of the installation and in the irrigation process itself. Drip systems are recommended for the irrigation of orchard plants due to their highest water use efficiency. The irrigation frequency depends on the plants' size and weather pattern, and the individual water doses are determined by the depth of the root system and the water capacity of the soil.

Harvest and holding

The raspberry harvest starts in early July and continues until late autumn, depending on the variety. The raspberries are harvested without stalks when fully ripe: the fruit has reached the proper colour, is soft and dry, and separates easily from the receptacle. In summer, the fruit is picked twice or thrice a week; in autumn, it is picked more slowly - once or twice a week. The harvested fruit is stored in a cool, darkened place.

Fresh raspberries are best eaten as soon as possible but can be stored in the fridge/cooler for up to a few days. Store raspberries in a single layer on a paper towel in a container to prevent them from crushing and absorbing moisture. Avoid washing the raspberries before storing them, as extra moisture can speed up spoilage. Raspberries can be frozen, allowing you to enjoy them all year round. Before freezing, spread the raspberries on a baking tray in a single layer and freeze individually. Once frozen, transfer the fruit to sealed containers or freezer bags. Raspberries can be dried in a fruit dryer or the oven at a low temperature. After drying, store the raspberries in a sealed container in a cool and dry place. Freeze-drying raspberries is drying using a unique method colloquially called 'freeze-drying,' whereby the fruit retains most of its nutritional value, shape, colour, and the flavour and aroma is more pronounced.

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CHAPTER 10

Prunus avium and Prunus cerasus – Sweet and Sour Cherries

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WHAT WILL WE LEARN IN THIS CHAPTER?

We're going to learn about the intricacies of cherry trees, their fruit-related diseases both in the field and post-harvest, along with the physiological disorders they may develop. This comprehensive exploration encompasses disease management strategies and best practices aimed at optimizing cherry cultivation.

Keywords: Cherry tree, Diseases and Physiopathies, Post-Harvest Care, Farming Techniques

Summary

1 Overview

Cherries are popular and delicious fruit-bearing trees belonging to the genus Prunus within the Rosaceae family. Cherries are renowned for their sweet and tart flavors, vibrant colors, and versatility in culinary applications. Cherries belong to the genus Prunus, which also includes other fruit-bearing trees such as plums, peaches, and apricots and there are two main types of cherries: sweet cherries (Prunus avium) and sour or tart cherries (Prunus cerasus). They are commonly grown in orchards and can be trained to various pruning systems, such as open-center or central leader.

2 Field diseases and physiopathies

2.1 Brown Rot (*Monilinia fructicola*)

Brown rot is one of the most common and destructive diseases affecting cherry trees. It typically appears as brown, rotten spots on the fruit, which eventually become covered in grayish-brown spores. Brown rot can also infect blossoms and shoots, causing blossom blight and dieback.

Symptoms and signs

Brown rot, caused by fungi belonging to the genus Monilinia, is a common and destructive disease affecting various fruit trees, including cherries. The most noticeable symptom of brown rot is the decay of fruit. A characteristic feature of brown rot-infected fruit is the presence of tufts of grayish-brown spores (conidia) on the surface, especially in humid conditions. In addition to infecting fruit and blossoms, brown rot can also cause blight on twigs and shoots. This can result in the loss of branches and overall decline in tree health.

Management

Managing brown rot in cherry orchards involves a combination of cultural, biological, and chemical control methods. Key actions that must be taken include e.g.:

- Removing and destroying infected fruit, blossoms, and plant debris promptly to reduce the source of inoculum
- Applying mulch around trees to reduce soil splashing onto fruit and lower the risk of infection
- Applying fungicides preventatively or curatively
- Monitoring weather conditions, particularly humidity and rainfall (as brown rot development is favored by warm, wet weather)
- Considering planting cherry varieties that are less susceptible to brown rot if available and suitable for your growing region

Identification tip

One useful identification tip for brown rot is to look for the characteristic brown, mummified fruit that remains on the tree or falls to the ground. Additionally, inspect the surface of the infected fruit for grayish-brown spore masses (conidia) that may appear as tufts or clusters. These spore masses are typically present in humid conditions and are a definitive sign of brown rot infection.

Figure 1: Brown Rot https://cdn.mos.cms.futurecdn.net/JYWiYkYSCjJE2FppUZh5Ua.jpg

2.2 Powdery Mildew (*Podosphaera clandestina*)

Powdery mildew is a fungal disease that appears as a white powdery coating on leaves, shoots, and fruit. It can cause leaf distortion, premature leaf drop, and reduced fruit quality and yield. It mainly affects sweet cherries.

Symptoms and signs

One of the most characteristic signs of powdery mildew is the presence of a white, powdery coating on the surfaces of leaves, shoots, blossoms, and sometimes fruit. Infected leaves may become distorted, curled, or twisted as the disease progresses. In severe cases, the distortion can be quite pronounced and affect the overall appearance of the foliage. Powdery mildew can also infect cherry blossoms and young fruit, causing them to become distorted or deformed. Infected blossoms may fail to develop properly or drop prematurely, while infected fruit may exhibit surface blemishes or reduced quality. In addition to direct damage to fruit, powdery mildew can reduce overall fruit yield and quality by affecting the health and vigor of the tree. Regular monitoring of cherry trees for symptoms of powdery mildew, especially during periods of warm, dry weather, can help growers detect and manage the disease effectively.

Management

Integrated pest management (IPM) approaches that combine multiple control tactics are often most effective for managing powdery mildew and reducing reliance on chemical interventions. Regular monitoring of orchards for disease symptoms and timely implementation of control measures are essential components of an effective powdery mildew management strategy. To properly manage powdery mildew, we need to avoid excessive nitrogen fertilization, as high nitrogen levels can promote succulent growth that is more susceptible to powdery mildew infection, Utilize biological control agents, such as fungal antagonists or beneficial insects, incorporate fungicide applications into a comprehensive spray program based on disease forecasting models or regular monitoring of orchards for disease symptoms and implement proper post-harvest handling practices, including rapid cooling and storage at appropriate temperatures, to minimize post-harvest powdery mildew development.

Identification tips

- Look for a characteristic white or grayish powdery growth on the surfaces of leaves, shoots, blossoms, and sometimes fruit.
- Infected leaves may become distorted, curled, or twisted as the disease progresses. Look for leaves that exhibit abnormal shapes or growth patterns, such as cupping or wrinkling.
- Familiarize yourself with reference images of powdery mildew on cherry trees to help with identification. Many agricultural extension websites and plant pathology resources provide images and descriptions of common plant diseases, including powdery mildew.

Figura 10: Powdery Mildew https://www.goodfruit.com/wp-content/uploads/powderyMilderCherries.jpg

2.3 Cherry Leaf Spot (*Blumeriella jaapii*)

Cherry leaf spot is a fungal disease that causes circular, purple lesions on leaves, which eventually turn brown and cause premature leaf drop. Severe infections can weaken the tree and reduce fruit production

Symptomps and signs

Cherry leaf spot is favored by warm, humid weather and can spread rapidly within cherry orchards, particularly during periods of prolonged leaf wetness. he most characteristic symptom of cherry leaf spot is the presence of circular lesions on the leaves. These lesions initially appear as small, purple spots that gradually enlarge in size, becoming brown or black as the disease progresses. What's more, severe cherry leaf spot infections can cause infected leaves to drop prematurely from the tree. This premature defoliation weakens the tree and reduces its ability to photosynthesize and produce energy. Under favorable conditions, the fungus may produce fungal fruiting bodies (acervuli) within the lesions on infected leaves. These fruiting bodies may appear as tiny, dark structures embedded in the leaf tissue.

Management

Main strategy for combating cherry leaf spot is to prune cherry trees to improve air circulation and sunlight penetration within the canopy, which can help reduce humidity and inhibit cherry leaf spot development and to avoid overhead irrigation to minimize leaf wetness and reduce the spread of the disease. Other things that can be done include rotating between different classes of fungicides with different modes of action to reduce the risk of fungicide resistance development and removing then destroying infected leaves, shoots, and plant debris promptly to reduce the source of inoculum and prevent the spread of the disease within the orchard.

Identification tip

- Look for small, circular lesions on the leaves of cherry trees..
- Look for leaves that exhibit abnormal shapes or growth patterns.
- Lesions may girdle the stem, leading to dieback and reduced growth.

Figura 11: Cherry leaf spot https://extension.unh.edu/sites/default/files/styles/max_width_480px/public/media/2023-10/cherryfig.2-1.jpg?itok=ADPyZx-B

2.4 Shot Hole Disease (*Wilsonomyces carpophilus*)

Shot hole disease, caused by the fungus *Wilsonomyces carpophilus*, is a common issue affecting cherries and other stone fruits. It manifests through small lesions on leaves, fruits, and twigs.

Symptoms and Signs

On leaves, the disease causes reddish or purple spots that gradually enlarge and turn brown. The affected tissue then dries out and falls, leaving distinctive round "shot-hole" patterns. On fruits, it appears as small, corky, dark lesions or scabs, which may cause fruit deformation. Young twigs may develop dark, sunken lesions, potentially leading to dieback.

Management

Managing shot hole disease involves several key practices. Fungicide applications are recommended during wet periods in the spring, particularly after blooming. Good orchard sanitation is crucial, including the removal and destruction of infected plant debris and fallen leaves, as these can harbour fungal spores. Pruning to improve air circulation within the tree canopy can help reduce moisture accumulation, making conditions less favourable for the fungus.

Identification tip

To identify shot hole disease, look for the characteristic holes in the leaves, where small lesions have fallen out cleanly, giving a "shot-hole" appearance. This is a distinctive sign of the disease and helps differentiate it from other leaf spot conditions.

Figura 12: Shot Hole Disease

https://myplantin.com/_next/image?url=https%3A%2F%2Fstrapi.myplantin.com%2Flarge_Cherry_Shot_Hole_Disease_f6cdb15ba7.webp&w=1920&q=75

2.5 Physiological disorders

Cherry trees can also suffer from physiological disorders such as sunscald, which occurs when fruits or branches are exposed to intense sunlight, causing damage and tissue death.

There are few physiological disorders that we can mention:

- Sunburn - it occurs when cherry tree foliage or fruit is exposed to intense sunlight, leading to tissue damage and discoloration. Sunburn is more common during hot, dry weather and can affect leaves, fruit, and branches.
- Heat Stress - high temperatures can cause stress to cherry trees, leading to symptoms such as wilting, leaf scorch, and reduced growth. Heat stress can be particularly problematic during heatwaves or prolonged periods of hot weather.
- Water Stress - both drought stress (insufficient water) and waterlogging (excessive water) can negatively impact cherry trees. Drought stress can cause wilting, leaf drop, and reduced fruit production, while waterlogging can lead to root suffocation and root rot.
- Gummosis – it's the exudation of gum or resin from wounds or lesions on cherry tree branches or trunks. It can be caused by physical injury, insect damage, disease infection, or environmental stressors. Gummosis can weaken affected branches and provide entry points for pathogens.

Management

There are some certain things we can do to avoid those disorders:

- Temperature and Sunlight Regulation
- Weather Protection
- Pest and Disease Management
- Monitoring and Record-Keeping

3 Post harvest diseases

Post-harvest diseases of cherries can significantly reduce their quality and shelf life if not managed properly. Preventing post-harvest diseases in cherries involves various strategies, including proper handling during harvest, careful sorting to remove damaged fruits, maintaining proper storage conditions (such as low temperatures and adequate ventilation), and using fungicides or bactericides when necessary.

3.1 Gray Mold (*Botrytis cinerea*)

It usually occurs in damaged or wounded fruits and spreads rapidly under cool and humid conditions. Infected cherries develop a fuzzy gray mold, which can lead to fruit rot and loss. Botrytis cinerea-induced ailments, commonly termed as "gray mold," are distinguished by the appearance of velvety gray spores on affected areas. These spores may not always be visible in the early stages of infection. Infected fruit surfaces may exhibit softness, accompanied by brown or gray protrusions and irregular scars.

3.2 Bacterial Canker (*Pseudomonas syringae*)

Bacterial canker can infect cherries through wounds or openings in the fruit skin. It causes sunken lesions with darkened edges on the fruit surface. Bacterial canker can spread rapidly, especially in moist conditions, leading to fruit rot and loss.

3.3 Rhizopus Rot (*Rhizopus spp.*)

Rhizopus rot is caused by fungi of the genus Rhizopus. It typically occurs in overripe or damaged cherries and is characterized by soft, watery rot with white mycelium and black sporangia. Rhizopus rot can spread quickly, especially in warm and humid environments.

Management

Key aspects of management include:

- Sanitation - keeping the harvest and storage areas clean and free of plant debris, which can harbor pathogens and regular cleaning and sanitizing harvesting equipment, containers, and storage facilities to prevent the spread of diseases
- Temperature and humidity control - maintaining proper storage conditions, including low temperatures and controlled humidity levels, because rapid cooling of cherries after harvest helps to slow down the growth and spread of pathogens
- Chemical control - timing of chemical applications is crucial, and it's essential to follow recommended pre-harvest intervals (PHIs) to ensure that residues are within safe levels
- Integrated Pest Management (IPM)
- Packaging - using clean and sanitized packaging materials to prevent contamination of cherries during storage and transportation

- Sorting and grading - sorting cherries carefully to remove any damaged or diseased fruits before storage or transportation and grading them based on quality parameters to ensure that only high-quality fruits are packed and marketed

4 Agronomic practices for crop protection

Choice of cultivation environment

The choice of cultivation environment greatly influences the growth, health, and productivity of cherry trees. Cherries thrive in temperate climates with distinct seasons, where they can experience a period of winter chilling followed by spring warmth for optimal flowering and fruit set and regions with moderate temperatures during the growing season and minimal temperature fluctuations during critical growth stages to avoid frost damage or erratic fruit development. Those plants need sites with ample sunlight exposure, as cherries require full sun for optimal growth and fruit production. Also, access to adequate water resources for irrigation, especially during periods of drought or fruit development is a must.

Varietal choice

Choice of cherry varieties depends on various factors, including climate, soil conditions, market demand, and intended use. The most popular varieties of cherries divide due to their flavor, so we can put them in two groups: sweet and sour. The most well known type of sweet cherries is Bing (cherries that are large, dark red, and have a rich, sweet flavor), and the most widely grown sour cherries are Montmorency cherries (they have bright red skin and tart flavor).

Rootstock selection

Rootstock selection is crucial for cherry cultivation, as it can influence tree vigor, productivity, adaptability to soil conditions, and disease resistance. Selected rootstocks should provide adequate vigor control to match the soil and climate conditions of your orchard and have well-suited to the soil conditions in your orchard, including soil texture, pH, and drainage. It is best to consider rootstocks that offer resistance or tolerance to soil-borne diseases common in cherry orchards, such as Phytophthora root rot and bacterial canker. Also, local adaptation can increase the likelihood of success and reduce the risk of tree loss or poor performance due to environmental stressors.

Plant operations

In cherry production, plant operations encompass various tasks and activities involved in the establishment, management, and maintenance of cherry orchards. They consist of site preparation, planting, training, pruning, fertilization, soil management, pest and disease management, pollination, harvesting and post harvesting handling. By effectively managing these plant operations, cherry growers can optimize orchard productivity, fruit quality, and profitability while promoting the long-term sustainability of their operations.

Planting techniques and distance

Planting cherries requires attention to detail regarding spacing, depth, and soil preparation. Spacing between cherry trees depends on factors such as the rootstock used, soil fertility, and intended orchard management system. Planting cherry trees in late winter to early spring while they are dormant is

cruical (planting during periods of extreme cold or wet weather should be avoided). This allows the trees to establish roots before the onset of the growing season. What's more, you should consider the pollination requirements of cherry varieties when planning orchard spacing. Soil test should be conducted to assess pH, nutrient levels, and soil structure. Cherries prefer slightly acidic to neutral soil with good drainage and incorporating organic matter, such as compost or well-rotted manure, into the soil may improve fertility and soil structure. In order to plant cherry trees correctly, dig planting holes that are wide and deep enough to accommodate the root system of the cherry tree and spread the roots out evenly in the planting hole and ensure the graft union (if present) is above the soil line. By following these planting techniques and spacing guidelines, you can establish a healthy and productive cherry orchard that will provide abundant fruit for years to come.

Replanting

Replanting involves removing old or diseased trees and replacing them with new ones to maintain a healthy and productive orchard. To properly replant cherry trees, there are few steps that must be taken: assessment of existing orchard, soil testing and preparation, removal of old trees and selection of new trees.

Pruning

Pruning is essential for maintaining tree health, promoting optimal fruit production, and managing tree size and structure. Good time for pruning cherries is the dormant season, meaning late winter to early spring before bud break but you should avoid pruning during wet or freezing conditions to minimize the risk of disease transmission and frost damage. We can mention few goals of pruning:

- Removal of dead, diseased, or damaged branches to improve tree health and prevent the spread of pathogens
- Thinning out crowded or crossing branches to improve light penetration and airflow within the canopy
- Shaping the tree to a desired form (e.g., open-center or central leader) to promote even growth and fruit production
- Managing tree size and vigor to optimize fruit quality and ease of harvest

Soil management

Soil management contains of soil testing, soil amendments, nutrient management, mulching, soil drainage, conservation and health monitoring. By implementing effective soil management practices, cherry growers can create optimal growing conditions for their trees, leading to healthier trees, higher yields, and better quality fruit. It is essential for cherry production as it directly impacts tree growth, fruit quality, and overall orchard health.

Fertilization

Fertilization is an important aspect of cherry tree management and it ensures its well-being. But before applying fertilizers, conduct a soil test to determine the nutrient levels and pH of the soil. Soil tests provide valuable information on the specific nutrient needs of cherry trees and help prevent over or under-fertilization. Also, cherry trees have specific nutrient requirements at different stages of growth. Nitrogen (N) is essential for vegetative growth and fruit development, while phosphorus (P) and potassium (K) are important for root development, flowering, and fruit set. Micronutrients such

as calcium, magnesium, zinc, and boron are also essential for overall tree health and fruit quality. Additionaly, timing of fertilizer applications is critical to ensure that cherry trees receive nutrients when they need them most. Monitor cherry trees regularly for signs of nutrient deficiencies, such as yellowing leaves, stunted growth, or poor fruit set.

Irrigation

Cherry trees require regular and sufficient water throughout the growing season, especially during periods of active growth, flowering, and fruit development. Adequate irrigation is essential for maintaining soil moisture levels and preventing water stress, which can negatively impact tree health and fruit quality. Drip irrigation and micro-sprinkler systems are commonly used for irrigating cherry orchards. It delivers water directly to the root zone of the trees, minimizing water waste and optimizing water use efficiency. Developing an irrigation schedule based on the water requirements of cherry trees, taking into account factors such as tree age, canopy size, and soil moisture retention is cruical. Irrigate early in the morning or late in the evening to minimize water loss due to evaporation and maximize water uptake by the trees. Also, apply a layer of organic mulch, such as wood chips or straw, around the base of cherry trees to conserve soil moisture and reduce evaporation. Mulching also helps suppress weed growth, regulate soil temperature, and improve soil structure over time. By implementing effective irrigation practices, cherry growers can ensure that their orchards receive adequate water to support healthy tree growth, optimize fruit production, and achieve high-quality fruit yields.

Harvest

To determine the optimal harvest time for cherries, it is essential to consider the appropriate degree of ripeness, which is assessed based on the intended use of the fruit using specific indicators. The sugar content and firmness of cherries are particularly important for evaluating their quality. For example, cherries are considered of premium quality if their sugar content reaches desirable levels, often measured in Brix units. Unlike other fruits, where external appearance may indicate ripeness, cherries require more precise assessments. Factors such as skin colour and size vary between varieties, and environmental conditions can influence these, making it challenging to rely solely on visual cues to determine the ideal time for harvesting.

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CHAPTER 11

Strawberry (Fragaria x ananassa)

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WHAT WILL WE LEARN IN THIS CHAPTER?

We're going to learn about the intricacies of strawberry, diseases it is exposed to, followed by physiological disorders. this comprehensive exploration encompasses disease management strategies and best practices aimed at optimizing strawberry cultivation.

Keywords: strawberry, disease and Physiopathies, Post-Harvest care, Farming techniques

Summary

1 Overview

The strawberry, scientifically known as Fragaria × ananassa, holds significance within the Rosaceae family as a prominent fruit and is cultivated worldwide. It holds a key position among small fruit crops and finds diverse applications in the production of purees, juice concentrate, juice, jams, preserves, and rosé wine. However, it is exposed to many diseases, both fungal and physiological.

2 Field diseases and physiopathies

2.1 Powdery mildew (*Podosphaera aphanis)*

Powdery mildew, a fungal disease caused by the obligate parasite Sphaerotheca macularis f. sp. fragariae, is a significant threat to strawberry (Fragaria x ananassa) cultivation globally. This pathogen targets various parts of the plant, including leaves, petioles, stolons, flowers, and fruit, showing a particular affinity for this crop. Severe damage occurs as the dense mycelium covering foliage hampers photosynthesis, potentially leading to necrosis and eventual leaf loss.

Symptoms and signs

The most common indicators of strawberry powdery mildew typically manifest as small white colonies on the upper and lower surfaces of leaves. Nevertheless, the fungus has the capability to invade all aerial parts of the plant, including petioles, stolons, flowers, and fruits. Mature fruits that are heavily infected often exhibit reduced size, potential cracking, and a loss of their distinctive strawberry colour and shine.

Management

In strawberry cultivation, managing powdery mildew typically relies on fungicide application due to the limited disease resistance found in many varieties. Fungicides that act on fungal respiration, nucleic acid synthesis, sterol biosynthesis, and signal transduction are frequently employed to combat *P. aphanis* on strawberries. Fungicides are applied at consistent intervals of 7 to 10 days, starting from leaf emergence and continuing until harvest, to manage this disease. Nonetheless, the emergence of resistance to sterol demethylation inhibitor fungicides has presented hurdles in effectively controlling *P. aphanis*.

Identification tip

Infected strawberries will have white, powdery growth on leaves, stems and sometimes even fruit. The growth is dry and flour-like and unlike other fungal diseases – it does not soak water. Powdery mildew thrives in warm, dry conditions with high humidity.

*Figura 13: Powdery Mildew https://extension.umd.edu/sites/extension.umd.edu/files/styles/optimized/public/2021-09/VFN_Article_StrawberryPlug_Figure5.jpg?itok=bDWVJ7K_*

2.2 Anthracnose (*Azospirillum brasilense*)

Strawberry anthracnose, triggered by various species of the *Colletotrichum* fungus, stands as one of the most severe afflictions impacting strawberry cultivation. This disease infiltrates nearly all parts of the plant, resulting in significant economic setbacks in both fruit yield and plant productivity, whether in greenhouse or field environments.

Symptoms and signs

The fungus has the capability to invade fruit, runners, petioles, and the plant crown. On petioles and runner stems, dark elongated lesions emerge. These lesions can encircle affected petioles and stems, leading to wilting and death of individual leaves or entire daughter plants. In warm and humid conditions, salmon-coloured spore masses may develop on the surface of the lesions.

Management

The disease enters the field through contaminated plant material. The most effective preventive measure is to start with planting material that is free from the disease. While there are currently no nurseries that can provide certified disease-free plants, it is advised to inspect plants for signs of the disease before planting them. If the field has been infected before or if the disease is already present, reduce the use of overhead irrigation to minimize the spread of the fungus, which is propagated through water splashing. Plant parts that are infected act as a source of inoculum for the disease. It's important to remove as much old, infected plant debris as possible. Key actions that can be taken are:

- Trying to remove infected berries from the planting during harvest
- Avoiding the use of overhead irrigation and use drip irrigation if possible
- Applying fungicides before the disease develops.

Identification tips

Initially, whitish, tan, or light-brown water-soaked lesions, measuring up to 3 mm in diameter, form on the fruit. These lesions subsequently darken to brown or dark-brown, becoming sunken, and expand within two to three days to encompass most of the fruit. In humid conditions, the fungus might

extend its growth around the perimeter of the lesion or penetrate through it, resulting in a fuzzy appearance. Infected fruit ultimately desiccate to create firm, black, shrunken mummies.

Figura 14 Anthracnose https://content.ces.ncsu.edu/media/images/CastleHayne4-29-2014_AFR_Rangeofsymptoms.jpg

2.3 Verticillium wilt

Verticillium wilt (caused by *Verticillium dahliae)*, a prevalent soil-borne ailment affecting strawberry plants, infiltrates the roots and manifests symptoms visible at ground level. The signs of strawberry infection by this disease are intricate and typically require assessment and diagnosis by trained professionals.

Symptoms and signs

In cases of verticillium wilt infection in strawberries, the young leaves exhibit a yellow-green hue and contort into a boat-shaped form. The affected leaves lose their shine, with the paired lobes on compound leaves showing asymmetry. Often, one or two of the three lobes become misshapen, while the petiole adopts a tawny coloration. Gradually, the leaf begins to desiccate from its edges, ultimately leading to the demise of the entire plant.

Management

The most common strategy for managing this disease is crop rotation – strawberries should be rotated with non-host crops for at least 3 years in order to reduce fungal buildup in the soil. Solarization of soil before planting is also an effective way. In severe cases or when other management strategies are not sufficient, fungicides may be used to suppress it.

Identification tip

One of the hallmark symptoms of Verticillium wilt is wilting of foliage, especially during hot weather. You should look for yellowing, browning, or necrosis (death) of leaves and for smaller, misshapen, or underdeveloped fruit on infected plants.

Figura 15: Verticillium wilt https://strawberryplants.org/wp-content/uploads/Wilting-Strawberry-Plants-2.jpg

2.4 Red Stele Root Rot

This disease poses the greatest threat in dense clay soils that become waterlogged during cool periods, providing optimal conditions for the active growth of the fungus. The red stele fungus can persist in the soil for over 13 years once it establishes itself in a field or garden.

Symptoms and Signs

If plants in the lower sections of the strawberry patch begin to wilt and perish, red stele is likely the culprit. Affected plants exhibit stunted growth, dulling of their shiny green appearance, and minimal runner production. Younger leaves may display a metallic, bluish-green hue, while older leaves turn yellow or red prematurely. As soon as the initial hot and dry weather of early summer arrives, diseased plants swiftly wilt and succumb.

Management

As infective zoospores undergo substantial production and dispersion solely in periods of soil saturation, effective control hinges on proper drainage. Planting strawberries in low-lying or clay-rich soils prone to water accumulation or slow drainage should be avoided. Using fungicides is also recommended.

Identification tip

Red stele root rot primarily affects the roots of strawberry plants. When infected, the roots develop a characteristic reddish-brown discoloration, typically starting from the tips and extending along the length of the root.

Figura 16: Red Stele Root Rot https://cdn.mos.cms.futurecdn.net/8HW9CqwPBhPwv9BgumWzDJ.jpg

2.5 Bacterial Angular Leaf Spot

Angular leaf spot is a common disease of strawberry caused by the bacterium *Xanthomonas fragariae*. The disease primarily impacts the leaves and the calyx, resulting in the characteristic "black cap" symptom. Nevertheless, the pathogen has the capability to spread systematically through the plant's vascular system, leading to infection of not only additional leaf tissue but also crown tissue and emerging daughter plants.

Symptoms and Signs

Small, water-soaked lesions that appear angular and translucent initially, often surrounded by a yellow halo. These lesions typically develop on the upper surface of leaves but may also occur on stems and petioles. As the disease progresses, lesions may expand and merge, causing larger, irregularly shaped areas of necrosis (tissue death).

Management

Research has demonstrated that thermal treatments, such as immersions in hot water or exposure to hot air, are effective in eliminating or decreasing systemic pathogens. Buchner pioneered a hot water treatment method for strawberries, which involved submerging plants directly into a hot water bath for 5 to 7 minutes at temperatures ranging from 48°C to 49°C, but it was insufficient in killing that certain pathogen, so the hot water treatment has been modified in order to work – sealing plants in plastic bags and prioring them to HW treatment of either 48◦C for 2 hours or 44◦C for 4 hours.

Identification tip

To identify bacterial angular leaf spot, you need to look for angular, water-soaked lesions on the leaves that usually are surrounded by a yellow halo. In addition, this bacteria can also affect the fruit

by causing e.g. pits on its the surface.

Figure 5: Bacterial Angular Leaf Spot

https://fruitscout.ca.uky.edu/files/1c_strawberry_angular_ls_gauthier_img_2311.jpg?itok=el0r pZ8Z

2.6 Physiopathies

Physiological disorders, if it comes to strawberries, can arise from many environmental/cultural factors that later leads to abnormalities in plant growth, development, or fruit quality. There are 3 most common ones:

1. Blossom end rot:

It is similar to the one seen in tomatoes, and its occurrence has never been reported in wild species. It appears as dark, slightly sunken lesions at the blossom end of the fruit. It mostly is caused by moisture levels in soil that may lead to calcium deficiency and tissue breakdown. To manage it, soil moisture must be evenly maintained, mulching should be considered and high nitrogen fertilization ought to be avoided.

2. Misshapen fruit:

Different and "outrageous" shapes of fruit are factored mainly by damage caused to the flower at any point of development of a strawberry fruit, and if the damage is severe, no fruit will form at all. Since the process of development is long, the risks of damage are high, which is followed by change in a desired shape.

Figure 6: https://strawberryplants.org/wp-content/uploads/Deformed-Strawberries-fb.jpg

3. Yellowing leaves (chlorosis):

Chlorosis arises when nutrients are lacking or unable to be transported to the foliage, resulting in a yellowing of the leaves. In strawberries, iron chlorosis is induced by the alkaline nature of our soils, elevated levels of free lime in the soil, and excessive watering. To prevent it, strawberries should be watered only when the soil is slightly dry a few inches below the ground level. Also, an application of chelated iron in spring can be beneficial.

Figure 7: https://www.yara.co.uk/contentassets/8d7b77d131624010a8d41c1f38c996ed/11690/

3 Post harvest diseases

Strawberry plants are very susceptible to many pathogens, even after harvesting. Postharvest strawberry losses are largely caused by *Botrytis cinerea*, *Mucor* and *Rhizopus spp*.

3.1 Grey mould (*Botrytis cinerea)*

The necrotrophic fungus *Botrytis cinerea*, which causes grey mould disease, is notably harmful due to its apparent lack of host specificity. It is accountable for significant economic losses both before and after strawberry harvest. It causes soft, brown lesions on fruit, often covered in greyish mould growth.

Figure 8: https://drecampbell.com/wp-content/uploads/2022/12/gray-mold.jpeg

3.2 Mucor fruit rot (*Mucor spp.*)

That pathogen leads to a soft rot disease. It usually causes spoilage of stored fruit, mainly those harvested late. Its growth is influenced by abiotic factors like temperature, relative humidity, and water availability.

Figure 9: https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcRtPSs6C7kVA7ndLbeoPCDjyOkRiJkupIDvWavrz3K1g&s

3.3 Leather rot

Leather rot can impact fruit at any stage of development and can lead to substantial losses when weather conditions favour disease development. The management of leather rot involves integrating cultural practices with chemical control. Cultural methods include selecting suitable sites to prevent saturated soils, enhancing soil drainage, and minimizing pathogen spread by using straw mulches to reduce splashing.

Figure 10: https://content.ces.ncsu.edu/media/images/Lather_rot_fruit_SS-1.jpg

Management

Low temperature remains the primary and most effective method. Rapid and consistent cold storage is the crucial factor in ensuring the high quality of harvested fruits and vegetables. Humidity is the second factor to take into account during the cold storage of fresh produce. Low relative humidity can lead to fruit dehydration, while high relative humidity promotes fungal growth. Typically, the ideal relative humidity for storing strawberry fruit, as well as other fruits, ranges between 90% and 95%. During postharvest handling, strawberries are highly prone to mechanical damage, necessitating careful handling to prevent any damage that could provide an entry point for decay-causing fungi. Therefore, strawberries are typically harvested and packaged directly in the field. Some of the proper actions of management are:

• Harvesting fruit at the correct stage of growth

• Sorting fruit

• Using fungicides

• Monitoring stored fruit

4 Agronomic practices for crop protection

Choice of cultivation environment

Choice of the location can have a significant impact on crop quality and susceptibility to diseases. Climate must be suitable for strawberries as they thrive in places with cool winters and mild summers, but some of the varieties are adapted to more warmer or cooler climate. It must be ensured that the cultivation site receives enough amount of sun and irrigation water. Also, wind protection should be taken into consideration, since strong winds can lead to damage of plants and reduce its fruit quality. In addition, cultivation site ought to be checked for any pest and disease history.

Varietal choice

Main factor when it comes to choosing a right strawberry variety is local climate but also disease resistance. Another crucial thing is current market demand as long as one's planning on selling fruit

commercially connected with personal preferences, so that they align with one's goals. What also should be considered is the pollination requirements because some strawberries are self

pollinating, whilst others require cross-pollinating.

Rootstock selection

The choice of rootstock is crucial for achieving success as it provides resistance to a range of pests, diseases, and environmental stresses such as soil pH, salinity, and extreme temperatures. Rootstock selection profoundly influences tree vigour, time taken for fruit production, and both the overall yield and quality of the fruit.

Plant operations

Prior to planting, the site should be readied by removing weeds, rocks, and debris. Soil testing is essential to evaluate fertility and pH levels, and amendments such as organic matter and fertilizers should be added as necessary to establish ideal growing conditions for strawberries. They should be planted at the correct depth (4-6 inches) and have consistent moisture provided.

Plant operations may necessitate the utilization of diverse equipment and machinery, including tractors, irrigation systems, and pruning tools. They encompass the propagation of plants through methods like seeds, cuttings, grafting, or tissue culture. This procedure may entail tasks such as seed sowing, preparing cuttings, applying rooting hormone, and maintaining propagation structures like seed trays or propagation beds.

Planting techniques and distance

Various planting techniques are available for strawberries, such as matted row, plasticulture, and container gardening. In conventional matted row systems, rows are usually separated by a distance of 3 to 4 feet to ensure sufficient airflow and provide accessibility for cultivation and harvesting tasks. The spacing within rows varies based on the type of strawberry plants utilized and the desired plant density. For most June-bearing varieties, plants are typically spaced 12 to 18 inches apart within the row. However, for day-neutral or everbearing varieties commonly cultivated in plasticulture systems, plants are spaced 8 to 12 inches apart within the row. In raised bed systems, plant spacing should adhere to the row and within-row spacing recommendations

outlined previously. It's crucial to prepare raised beds properly with fertile soil and ensure good drainage to support healthy root growth and maximize plant growth.

Replanting

Before replanting, assessment of already existing plants is crucial. It should be determined, whether they are free from any diseases/pests and still productive. In order to grow replanted ones with lower risks of any soil-borne diseases, it is recommended to choose a new planting site. Selection of new plants is also advisable – healthy, disease-free strawberries. Soil in the new planting site should be loosened to the depth of approximately 8-10 inches.

Pruning

Pruning strawberries is a vital maintenance task that enhances healthy plant development, enhances air circulation, and maximizes fruit yield. During early spring, any dead or damaged leaves ought to be removed from plants and any unnecessary runners trimmed off. In the period of summer months strawberries must be monitored for any dead or yellowing leaves and runners that may disturb other plants or block pathways. After the growing season comes to an end, strawberry plants must be pruned more "aggressively" to prepare them for winter - all the remaining foliage has to be removed. When trimming strawberries, clean, sharp pruners or scissors have to be employed to make accurate cuts without causing undue harm to the plants. Disinfection pruning tools with rubbing alcohol or a bleach solution after each use is important to prevent the transmission of diseases.

Soil management

Soil should first be prepared by loosening it up, conducting soil tests for nutrient and pH level and incorporating organic matter into it. Already after planting, a layer of mulch ought to be applied around plants and fertilization should be taken into consideration (most likely fertilizer with higher potassium content). Strawberries must be provided with constant moisture that needs to be controlled not to increase the risk of e.g. fruit rot. It is important to steer clear of excessive tillage, as it can disturb soil composition and result in erosion.

Fertilization

A good practice is pre-plant fertilization, that increases successful growth. But before that, soil must be tested to assess its pH and nutrient levels to choose an appropriate fertilizer. Fertilization should be divided into multiple doses throughout the growing season – it is essential to apply fertilizer after the initial harvest and again in late summer or early fall to encourage robust root growth and the development of flower buds for the next year's crop. Another helpful practice is using a fertilizer that contains high potassium. Strawberries should be watered thoroughly after fertilization to dissolve the nutrients in the soil and make sure that they get to the roots. After those actions, plants must be monitored and depending on the plant responses and soil tests – adjusted.

Irrigation

Strawberries require constant and regular irrigation, especially during growing season when it is important to keep the soil moist, yet not waterlogged. The preferred method is the drip irrigation as it minimizes the water waste and reduces the risk of foliar diseases plus delivers water directly to roots. Watering should be frequent and monitored in case of needed adjustment. For optimal results, it's recommended to water strawberry plants in the early morning or late afternoon to minimize water loss due to evaporation and lower the risk of foliar diseases. It's crucial to refrain from irrigating during the hottest part of the day when evaporation rates are at their peak. Water should be distributed slowly and uniformly to enable it to permeate the soil to a depth of 6-8 inches, where the majority of strawberry roots are situated. It is crucial to pay close attention to irrigation during fruit development stages, as the moisture in the soil can affect the size of the fruit or its quality and flavour. Also, rainfalls must be considered to either reduce or increase irrigation. During rainy periods – suspending irrigation, and during dry periods – supplementing with additional irrigation.

Harvest

To be sure that the moment for harvest is perfect, its is needed to regularly observe plants to monitor the process of ripening. Ready strawberries will characterize by having vibrant colour with glossy sheen and firm texture. If it comes to the time of the day – early, cool morning is the best. Technique for a good harvest is starting by gently holding the stem of the ripe strawberry between thumb and forefinger, being cautious not to squeeze or bruise the fruit. Using a swift, upward motion, snapping or cutting the stem just above the fruit, ensuring the green calyx remains attached since preserving the calyx helps safeguard the fruit and extends its shelf life. Harvesting container should be shallow and flat (e.g. basket, tray) lined with clean and dry paper towels or cloth that will absorb excess moisture in order to prevent mould growth.

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CHAPTER 12

Conclusion

The comprehensive exploration of field diseases, physiopathies, and post-harvest management practices elucidates the intricate web of challenges and opportunities inherent in European fruit production. As evidenced throughout this educational material, the agricultural sector faces a myriad of threats, from climate variability and disease outbreaks to post-harvest losses and environmental degradation. However, amidst these challenges lie avenues for innovation, collaboration, and sustainable practices that can shape a more resilient and productive agricultural landscape.

Field diseases and physiopathies pose significant risks to crop health and yield. These pathogens, fueled by environmental factors and management practices, underscore the need for proactive disease management strategies. IPM emerges as a cornerstone approach, emphasizing the integration of cultural, biological, and chemical control measures to mitigate pest and disease pressures while minimizing environmental impacts. By adopting IPM principles, growers can enhance crop resilience, reduce pesticide use, and safeguard ecosystem health.

IPM is essential across diverse fruit crops, ensuring sustainable production while minimizing environmental impact and pesticide resistance. In Lemon cultivation, strategies focus on cultural practices such as avoiding mechanical injury and using copper fungicides preventatively. These practices not only mitigate Botrytis Rot but also enhance overall orchard health. Similarly, Grape Vineyards employ a multifaceted approach, combining drainage optimization and fungicide applications to combat Downy Mildew effectively. This proactive strategy minimizes disease pressure and maintains grape quality throughout the growing season.

Cherries benefit from rigorous IPM strategies like the removal of infected debris and targeted fungicide applications. By integrating these practices with monitoring and pest control measures, growers safeguard cherry orchards against devastating diseases like Brown Rot and Powdery Mildew. Meanwhile, Strawberry farming emphasizes the importance of regular monitoring and fungicide rotations to manage diseases like Powdery Mildew and Anthracnose effectively. These integrated approaches help maintain fruit quality and reduce economic losses due to disease outbreaks.

In Watermelon cultivation, IPM strategies involve the use of tolerant cultivars and strategic fungicide applications to combat diseases like Downy Mildew and Alternaria Leaf Blight. These efforts are complemented by cultural practices such as crop rotation and soil management, which contribute to sustainable disease control and long-term crop health. Orange orchards face unique challenges such as Citrus Greening (HLB) and Gummosis, which necessitate preventive measures like using disease-free propagation material and implementing strict sanitation practices. These methods minimize disease spread and ensure orchard longevity.

Both Plum and Peach cultivation prioritize proactive disease management through cultural practices and targeted fungicide applications. Practices like proper pruning and varietal selection play crucial roles in reducing disease incidence and ensuring fruit quality.

In Apple orchards, managing diseases like Fire Blight and Apple Scab involves planting resistant varieties, regular inspection, and pruning infected parts. Disinfecting tools and using copper fungicides are also critical practices. Raspberries benefit from IPM strategies like planting less susceptible varieties, ensuring good ventilation, and using drip irrigation to prevent diseases such as Anthracnose and Grey Mold.

Across all these fruit crops, the integration of IPM strategies underscores a holistic approach to pest and disease management. By linking preventive cultural practices with targeted chemical controls and biological interventions, growers enhance crop resilience and sustainability. This comprehensive strategy not only protects fruit quality but also promotes environmental stewardship and reduces reliance on chemical inputs. As agriculture continues to evolve, IPM remains a cornerstone of modern fruit production, aligning economic viability with ecological responsibility.

In parallel, post-harvest management practices are essential for maintaining fruit quality, reducing losses, and ensuring food safety throughout the supply chain. Key strategies include careful handling, sanitation, temperature control, and effective packaging, all aimed at extending shelf life and preserving freshness. The strategic application of fungicides and adherence to recommended pre-harvest intervals are crucial in combating post-harvest diseases such as Grey mold and Blue mold rot, ensuring that fruits remain safe for consumption.

A thermometer that illustrates the temperature
https://pixabay.com/photos/thermometer-temperature-celsius-2906817/

These practices are tailored to their specific needs of each fruit type. For instance, in the case of lemons, preventing physical damage to the rind and immediate post-harvest fungicide application are critical to mitigating green and blue molds. Managing grapevines involves rapid cooling upon arrival at processing facilities and storage under controlled environments with low temperatures and high humidity to maintain grape quality. Cherries benefit from rigorous sanitation, temperature, and humidity control to slow down pathogen growth, along with timely fungicide applications and IPM techniques.

Similarly, strawberries require immediate cooling and storage under high humidity levels to preserve quality and prevent fungal growth, along with preventive fungicide treatments and careful handling practices. Apples also require integrated management practices including pre-harvest fungicide applications to prevent diseases like apple scab and powdery mildew, and post-harvest fungicide treatments in cold storage to maintain quality and prevent storage diseases. Watermelons focus on preventing physical damage during harvesting and handling, supported by strict sanitation and proactive fungicide applications. Oranges, stored under optimal conditions, emphasize preventing physical damage and ensuring cleanliness to minimize infection risks.

Key to successful crop cultivation are agronomic practices, which form the foundational step in IPM. Implementing optimal methods for soil preparation, planting, pruning, and soil management is essential for attaining high-quality yields and promoting sustainable production.

Firstly, soil preparation is a foundational technique in fruit cultivation. For instance, in lemon cultivation, meticulous soil preparation ensures optimal nutrient uptake and growth. This involves

adjusting the soil pH, improving soil structure, and adding organic matter to enhance fertility. Similarly, strawberries require soil preparation techniques such as weed removal and nutrient enhancement to set the stage for successful planting and establishment. These practices not only create a conducive environment for the plants but also help in the long-term health of the orchard or field.

Soil Preparation
https://pixabay.com/photos/fields-field-landscape-agriculture-3442666/

Planting techniques are another crucial aspect of fruit cultivation. In cherry orchards, planting must focus on maximizing sunlight exposure, airflow, and nutrient availability. Proper spacing and depth during planting are essential to prevent overcrowding and ensure each tree has sufficient resources to thrive. Oranges also benefit from well-executed planting techniques that ensure the trees are established in well-drained soils within optimal temperature ranges, which is critical for disease resistance and fruit quality.

Pruning is an indispensable technique for managing tree size, structure, and health. For cherries, pruning practices are essential to enhance fruit yield and quality by ensuring that the tree structure supports good air circulation and sunlight penetration. Similarly, in lemon, apples and raspberries cultivation, pruning helps maintain tree health and fruit quality by removing dead or diseased branches, thus promoting vigorous growth.

Soil management practices, including mulching, fertilization, and irrigation, play a vital role in maintaining plant health and productivity. Effective soil management for plums involves integrated pest management strategies and balanced fertilization practices to combat pests and diseases and

maintain soil fertility. Watermelons, on the other hand, require efficient irrigation methods to meet water requirements and minimize stress, ensuring high-quality fruit production. Controlled irrigation and mulching are also critical in strawberry cultivation, helping to maintain soil moisture levels and reduce weed growth. For apples, maintaining soil pH and fertility through cover crops and organic amendments ensures optimal nutrient uptake. In raspberries, soil management techniques focus on weed control and maintaining soil structure to support root development.

A farmer irrigates the orchards with a tractor
https://pixabay.com/photos/tractor-fields-crops-irrigation-6546040/

Rootstock selection is a technique that significantly impacts tree vigor, disease resistance, and overall productivity. For example, in lemon and orange cultivation, choosing the appropriate rootstock is crucial for ensuring resilience against pests and diseases and optimizing fruit quality. The compatibility of rootstock with the chosen variety affects the tree's adaptability to soil and climate conditions, ultimately influencing yield and sustainability.

Therefore, each crop demands tailored agronomic practices that consider soil conditions, climate suitability, varietal selection, rootstock compatibility, planting techniques, pruning, soil management, fertilization, irrigation, and pest/disease control. Adhering to these practices not only optimizes crop yields and quality but also promotes sustainable agricultural practices essential for long-term productivity and environmental stewardship.

The significance of initiatives like the KICRO project, which is supported by the EU under the Erasmus+ Programme, are of paramount importance. By empowering stakeholders with advanced tools, knowledge, and skills, projects like KICRO contribute to environmental sustainability, climate resilience, and economic prosperity in the fruit growing sector. Through targeted training, capacity

building, and technology transfer, growers and packinghouse staff can enhance their ability to identify, manage, and mitigate crop diseases, thereby reducing reliance on chemical inputs and promoting sustainable farming practices.

Furthermore, the role of education and collaboration in driving agricultural innovation and resilience cannot be overlooked. Continued investment in research, extension services, and knowledge sharing platforms is essential for fostering a culture of learning and adaptation within the agricultural community. Resources such as the EPPO website offer valuable insights, guidelines, and best practices on IPM strategies, providing growers with the tools they need to navigate complex challenges and embrace sustainable solutions.

In conclusion, the insights gleaned from this educational material underscore the interconnectedness of climate, disease, and post-harvest management in European fruit production. By embracing integrated pest management principles, adhering to post-harvest management guidelines, and leveraging resources for continuous learning and improvement, stakeholders can forge a path towards a more resilient, sustainable, and productive agricultural future. As we confront the challenges of today and tomorrow, let us seize the opportunities for collaboration, innovation, and stewardship to cultivate a flourishing agricultural landscape for generations to come.

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