Hort4EUGreen

Strategic Partnership No. 2020-1-RO01-KA203-080398

CHEMICAL PESTICIDE-FREE HORTICULTURE

Agronomic techniques, physical and mechanical methods for crop pests, diseases and weeds management

Volume 2

USAMV BUCUREȘTI

ЛЕСОТЕХНИЧЕСКИ УНИВЕРСИТЕТ

MATE

Erasmus+

Bucharest, 2024

Hort4EUGreen

Intellectual output O2
Chemical pesticide-free horticulture

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ISBN 978-606-072-356-1
ISBN 978-606-072-358-5

Bucharest, 2024

Hort4EUGreen

Strategic Partnership No. 2020-1-RO01-KA203-080398

"Enhancing practical skills of horticulture specialists to better address the demands of the European Green Deal"

Bucharest, 2024

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Learning outcome descriptors

By the end of the module, the trainees should:

- Demonstrate proficiency in crop identification and classification of non-chemical methods for pest control.
- Apply integrated pest management (IPM) principles
- Utilize mechanical weed control methods
- Implement disease and pests management techniques
- Analyze soil health and fertility
- Interpret pest and disease monitoring data
- Develop crop protection plans
- Recognize and address ethical dilemmas related to crop protection, considering factors like pesticide safety, human health, and ecological impact.

Knowledge, understanding and professional skills

1	Gain knowledge on crop pest and diseases identification, weed biology and identification, IPM principles and methods
2	Have a deeper understanding on ecosystem dynamics, crop-environment interactions
3	Develop professional skills on crop protection planning and pest and disease diagnosis

General and transferable skills

1	Develp professional skills on crop protection planning and pest and disease diagnosis
2	Gain proficiency in identifying and addressing agronomic issues, such as pest outbreaks or disease epidemics, by applying a systematic problem-solving approach
3	Learn how to conduct research, gather information, and synthesize data to generate new insights and solutions in agronomy and plant protection.
4	Understand ethical principles and demonstrating ethical behavior in agronomic practices, particularly in pesticide use and environmental stewardship.

Agriculture is the cornerstone of global food production, providing sustenance and livelihoods to millions of people. However, the successful cultivation of crops is often challenged by pests, pathogens, and weeds, which can severely reduce yields and impact food security. In response to these challenges, agronomists, horticulturists, and biotechnologists have developed an array of techniques and methods to manage crop pests, pathogens, and weeds while promoting sustainable and eco-friendly practices.

Agronomic techniques are fundamental in pest, pathogen, and weed management. These strategies are holistic and environmentally sustainable, considering the entire ecosystem in which crops grow. They include practices like crop rotation, which disrupts the life cycles of pests and pathogens, reducing their build-up in the soil. Polyculture and companion planting create biodiversity that confuses pests and pathogens, while cover crops suppress weed growth and improve soil health. Biological control involves introducing beneficial organisms to control pest and pathogen populations, minimizing the use of chemical pesticides.

The effective management of crop pests, pathogens, and weeds is paramount to global food security and sustainable agriculture. Agronomic techniques, along with physical and mechanical methods, provide an arsenal of eco-friendly tools that farmers, horticulturists, and researchers can employ. These strategies not only reduce the use of chemical pesticides, preserving biodiversity and environmental health, but also contribute to sustainable and resilient cropping areas.

The application of these methods is further enhanced by advances in biotechnology, particularly in the field of plant propagation and the development of disease-resistant and pest-resistant plant varieties. In the pursuit of innovative and sustainable agriculture, the fusion of traditional and modern techniques promises to create a brighter future for food production and ecosystem preservation. By understanding and implementing these methods, we can move closer to a world where we cultivate more with less impact on the environment.

Unit 2.1 Selection of cropping area

Rumen Tomov, Viorica Lagunovschi,
Mădălin Radu, Florin Stănică

The selection of cropping area, also known as *Site isolation* and *Site selection*, refers to the process of choosing the land or area where crops will be grown. In context of pest management, the selection of cropping area refers to the process of choosing the area or land where crops will be grown, that is less likely to harbor pests and pathogens, reducing the need for pest and disease control measures. This decision is based on various factors, including the site conditions, history of pest infestation, the nature and severity of pest threats, and the potential for pest outbreaks under different cropping conditions.

Site selection practices can provide significant benefits for growers by reducing pest and disease pressures, minimizing the use of pesticides, and improving crop health. Farmers should be aware of their sites' physical characteristics, past infections, prone pest attacks and adapt measures to ensure the sustainability of production in the long-run. (Canny, et al. (2015), Gelder, et al. (2017), Köhl, et al. (2009), Zhang & Zhao (2016).

This practice is essential for organic farming and other low-input and sustainable methods of farming. The location's physical and biological characteristics can impact pest populations and ultimately determine the level of pest control measures needed.

Several site conditions are important for **vegetable and fruit growing** when it comes to pest management. These conditions can influence the type and severity of pests that affect crops, as well as the effectiveness and sustainability of pest management strategies. Some of the key site conditions to consider are:

Siting

This involves selecting a location for the crop that is isolated from potential sources of pest infestation. For instance, a greenhouse may be situated away from neighboring fields, or a garden may be planted in an area that is not near wild vegetation. Crop isolation is a technique used in crop management to prevent the introduction and spread of pests in a cultivated field or greenhouse.

The purpose of isolation is to physically separate or distance a crop from potential sources of infestation, such as neighboring fields, wild vegetation, or infected plants. This is usually achieved by planting crops in specific areas, or by creating barriers such as ditches, walls, or fences to prevent the movement of pests into or out of a crop. Another way to achieve site isolation is by **avoiding planting crops in sites** with previous pest infestations, as pests can survive in the soil or crop residues for extended periods. This approach reduces the likelihood of pest populations building up over time and reduces the need for pest control measures to manage them.

Soil quality

Soil quality is a critical factor in horticulture pest management. The quality of the soil influences not only plant growth, but also the presence and activity of soil-dwelling organisms, such as insects, nematodes, and microorganisms. These organisms can have both positive and negative effects on plants, and can either help or hinder pest management efforts.

Soil texture and structure can also affect the abundance and diversity of soil-dwelling organisms. For example, sandy soils may have fewer beneficial predators and parasites, while clay soils may harbor more pests and diseases.

Soil fertility is an important factor in controlling pest populations. Plants that are deficient in key nutrients may become more susceptible to pest damage, while plants that receive optimal nutrients may be better able to resist pests.

Soil pH can affect the survival and activity of beneficial soil microorganisms, such as bacteria and fungi, which can help to control soil-borne pests. Soil pH can also affect the uptake of nutrients by plants, which can impact their ability to resist pests.

The soil's physical properties can also impact pest management. For example, soils that are poorly drained can create conditions that favor certain pests and diseases, while soils that are too compacted can restrict root growth and reduce plant vigor, making them more vulnerable to pests. (Keeley & Fennimore (2012) Marrone, & Pfeiffer (2012) Niew et al. 2017). For more information please refer to the **Unit 2.4 Approaches for soil interventions.**

Microclimate

Microclimate refers to the climatic conditions, such as temperature, humidity, light, and wind, that exist within a particular area or ecosystem. It could have a significant impact on horticulture pests by shaping their behavior, development, and distribution. Temperature and moisture are essential factors that affect the survival and growth rate of many insect pests. High temperatures and drought conditions during plant growth stages may increase the severity of spider mite damage in some crops, such as tomatoes, strawberries, and flowers. High humidity and rainfall are conducive for the growth and spread of fungi, leading to foliage diseases such as powdery mildew. The microclimate can vary greatly in different growing areas, providing optimal conditions for particular pests than others.

Additionally, wind serves a critical role in regulating the pest's movement and abundance in a cropping system. Wind can impact pests by preventing insects or their natural enemies from reaching their host plants or decrease pest numbers with physical damage (e.g., abrasion, desiccation, or displacement). Other microclimate factors, such as the presence of shade, may create ideal conditions for pests that are notorious in love the vegetative growth stages of plants. The lack of sunlight may cause weak and leggy plants, which can encourage pests such as aphids, whiteflies, and thrips to feed on the lush foliage (Murray & Jenkins, 2017, Niew et al. 2017, Smith, 2015, Diaz & Fereres, 2013).

Vegetation diversity

Vegetation diversity refers to the variety of plants present within a particular ecosystem. It plays a crucial role in shaping pest populations in agricultural systems. Diverse vegetation can promote beneficial insects, such as natural enemies and pollinators, that can reduce pest populations and increase crop yield. It can also hinder the growth and development of specific pest species by disrupting their host-seeking and feeding behavior. For example, planting diverse crops or companion plants can support beneficial insects, such as predaceous ground beetles, lacewings, and parasitic wasps, which can help control harmful pests, such as aphids and caterpillars.

Studies have shown that interplanting insectary plants with main crop plants can increase the abundance and diversity of natural enemies and reduce the numbers of pest populations. In some cases, planting a trap crop to attract pests away from main crops and then killing them can reduce pest pressure. Vegetation diversity can also decrease the spread and severity of plant pathogens. Planting **cover crops**, **green manure**, or **crop rotations** can help reduce the incidence of soil-borne diseases by changing the soil microbial community, nutrient content, and pH. Likewise, crop diversification or intercropping can help reduce the risk of foliar diseases by breaking up the monoculture of host plants. Moreover, vegetation diversity can increase the plant's resistance to pest attacks. Research has shown that plants grown in diverse systems have better protection against pests and diseases. A mixture of plants offers a rich array of nutrients, secondary compounds, and other factors that can frustrate pests' ability to locate or digest their host plant. Altieri, (1999). Bugg & Waddington, (1994). Letourneau et al., (2011). Oerke, (2006) For more information please refer to the **Unit 2.2. Crop diversity**

Water management

Water management practices, including irrigation and drainage, can have a significant impact on horticultural pests. The availability of water can influence plant growth, fertility, and pest and disease incidence. Proper water management can reduce populations of certain pests and prevent the spread of diseases by creating suboptimal conditions for pest reproduction and development.

Proper irrigation management can affect the behavior of pests and natural enemies. Drip irrigation in plants has been shown to reduce the severity of aphid populations as a result of decreasing leaf surface moisture, whereas overhead irrigation can lead to increased fungal infection if the moisture is not managed correctly. Overhead water can accumulate on the plants and create moist conditions that can lead to the development of fungal pathogens that impact the growth and quality of crops. Drainage management can also contribute to pest management in horticulture.

Poor soil drainage can cause over-watering and root rot, which can weaken the plants and make them more susceptible to pest infestations. Drainage systems help to eliminate standing water and ensure proper soil aeration to reduce the risk of soil-borne pests and pathogens. Overwatering or poor drainage can create conditions that favor soil-borne pests and diseases, while drought-stressed plants may be more vulnerable to foliar pests. Pests found in wet or poorly drained soils like root-knot nematodes, and fungal diseases, including Verticillium wilt and Fusarium rot, are often less prevalent in well-drained soils. Additionally, pests that rely on high humidity levels, such as mildew or whitefly, are more common in high moisture soils.

Moreover, water management can impact the behavior of some insect pests. For instance, thrips can be induced to migrate to new plants if the soil is too dry, and spider mites populations can increase in drought conditions. Cloyd, 2019, Hadi et al., 2016, Kong & Lu, 2010. For more information please refer to the **Unit 2.7 Amelioration practices**

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Unit 2.2 Crop diversity

Milena Yordanova, Elena Delian,
Liliana Bădulescu

Crop diversity refers to the practice of growing a wide range of plant species and varieties. It involves cultivating various types of vegetables, fruits, herbs, and flowers to create a diverse and productive garden space.

Intensive agriculture with small crop rotations and monoculture cultivation led to the destabilization of agroecosystems. Their resistance to pest attacks and climate change is decreasing. One way to increase and improve the sustainability of agroecosystems is to increase biodiversity, and one of the key methods is to increase plant diversity. Crop diversity involves cultivating various types of vegetables, fruits, herbs, and flowers to create a diverse and productive garden space.

There are several key benefits to embracing crop diversity in the garden. Firstly, it promotes ecological balance and resilience. By growing different crops, gardeners can attract a variety of beneficial insects, birds, and other wildlife, which contribute to natural pest control and pollination.

This promotes ecological balance and contributes to the conservation of pollinators, which are essential for the reproduction of many plant species. Also, this helps create a harmonious ecosystem within the garden and reduces the reliance on chemical pesticides and fertilizers. Crop diversity in the garden enhances food security and self-sufficiency. Growing a variety of vegetables and fruits ensures a more reliable food supply, as different crops have varying growth requirements and are susceptible to different pests and diseases. Additionally, crop diversity in the garden improves soil health and fertility. Different crops have different nutrient requirements, and growing a diverse range of plants helps prevent nutrient depletion and encourages a balanced nutrient cycle. Some plants, known as "green manures," can also be grown specifically to improve soil structure and add organic matter when incorporated into the soil.

Preserving heirloom and heritage varieties is an important aspect of crop diversity in the garden. These traditional varieties often possess unique flavors, colors, and traits that may be lost in commercial agriculture. By growing and saving seeds from these varieties, gardeners contribute to the conservation of plant genetic diversity and maintain a link to the rich agricultural heritage of the past.

In conclusion, crop diversity in the garden offers numerous benefits, including ecological balance, food security, soil health, and aesthetic value. By cultivating a wide range of crops, gardeners can create a **resilient**, **sustainable**, and **rewarding** garden space that provides a diverse array of nutritious food, supports local ecosystems, and fosters a deep connection with nature.

Crop diversity includes temporal (crop rotation) and spatial diversity (e.g., intercropping, agroforestry, cultivar mixtures and cover crops) at field scale. (Li et al., 2021)

Farming systems can become more resource-efficient with fewer agronomic inputs by diversifying crops through rotation, multiple cropping, and species combinations. (Brannan et al., 2023; About the Crop Diversification Cluster, n.d.).

In this unit, several methods that can be used to increase plant diversity are discussed, namely: crop rotation; mixed cropping, cover crops, and others. Mixed cropping includes several methods for growing more than one species in one place - intercropping, companion cropping, trap cropping, under-sowing, etc.

By implementing these methods, you can enhance the diversity of crops in your garden, which not only improves the overall health and productivity of your garden but also contributes to biodiversity conservation and sustainable gardening practices.

2.2.1. Crop rotation

Milena Yordanova, Mihai Cosmin, Viorica Lagunovschi

Crop rotation alternates between different species in the same area at different times (seasons). A key point in the arrangement of crops is to alternate species from different families, as crops attacked by the same pests occupy the same place after a long period of time. Crop rotation is the key to controlling soil pests (weeds, diseases, and pests). (Frost, 2003).

Crop rotation is the process of planting several crops in succession on the same piece of land in order to enhance soil health, maximize nutrient content, and reduce insect and weed load. Crop rotation alternates between different species in the same area at different times (seasons) Frost (2003).

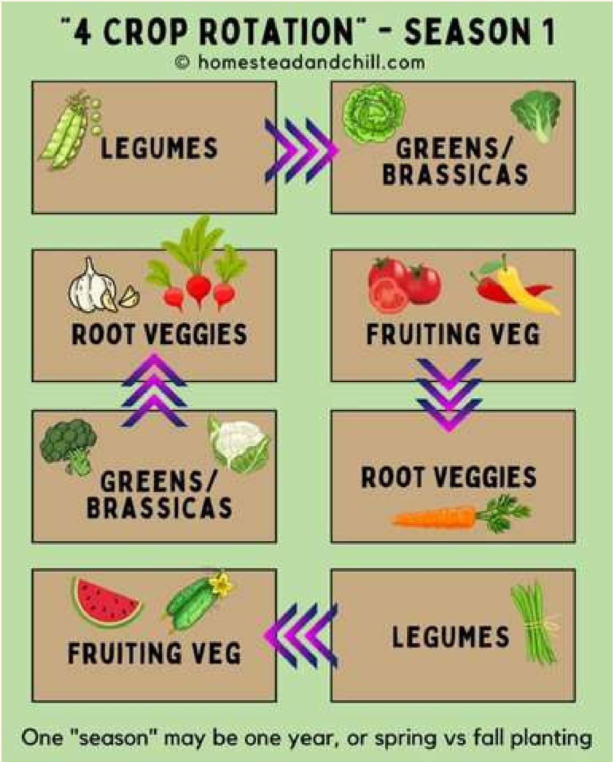
Crop rotation works by putting pests in a non-host habitat (crop) and interfering with their regular life cycles. By disrupting the pests' reproductive cycles, it lowers the pest pressure on all of the crops in the rotation. This approach is commonly used even when crop damage is anticipated to be small because it rarely has any negative economic or ecological effects (Herzog and Funderburk, 1986).

The foundation of many IPM systems and often compatible with biological controls is crop rotation. Grass, legume, and root crops are the most typical rotations. By replenishing plant nutrients, notably nitrogen, a leguminous crop in rotation typically lowers the rates of necessary chemical fertilizers. Additionally, rotation lessens the potential for chemical accumulation in the environment, reducing the risk of pests developing pesticide resistance (Reeves, 1994).

In some agricultural systems, crop rotation is the cornerstone of pest management because it separates insect populations from ongoing food supplies from one year to the next. Crop rotation can also impact populations of beneficial like ground-dwelling rove beetles, even if this is uncommon (Lubke-Al-Hussein and Al-Hussein, 2006).

Rotated crop placement in regard to the direction of the wind and crops from previous years may affect the capacity of parasitoids to find and colonize the current crop (Williams et al., 2007).

An effective rotation is one in which a crop of one plant family is followed by one from a different family that is not a host crop of the pest to be controlled.



https://homesteadandchill.com/crop-rotation-benefits/

An effective rotation is one in which a crop of one plant family is followed by one from a different family that is not a host crop of the pest to be controlled. **Grasses, legumes, and root crops** are the most typical rotational crops. Rotations are effective against pests that have a limited host-plant range and depressiveness and/or that cannot survive for more than one or two seasons without suitable host crops. Pests most subject to this type of control are poorly mobile, soil-inhabiting species with a restricted host range and a life cycle of 1 year or longer (Hills, 2004).

Table 1: An example of a crop rotation system

	Plot 1	Plot 2	Plot 3	Plat 4	Plot 5
Cycle 1	Leaf crops	Legumes	Brassicas	Root crops	*Solanaceae*
Cycle 2	*Solanaceae*	Leaf crops	Legumes	Brassicas	Root crops
Cycle 3	Root crops	*Solanaceae*	Leaf crops	Legumes	Brassicas
Cycle 4	Brassicas	Root crops	*Solanaceae*	Leafy crops	Legumes
Cycle 5	Legumes	Brassicas	Root crops	*Solanaceae*	Leafy crops

https://www.farmersweekly.co.za/farming-basics/how-to-crop/understanding-crop-rotation/

The application of crop rotation is to reduce the pressure of diseases, pests, or/and weeds. If the same crop is planted year after year on the same fields (monoculture), populations of certain pests and diseases can gradually increase. Crop rotation can be an interesting tool for reducing pest/disease pressure especially when long crop rotations are applied (>5 years).

In addition to significantly decreasing pest pressure, crop rotation has to be planned at a larger scale than just individual fields as pests/diseases easily move from one field to another. Therefore, crop rotation must be reasoned at the level of the farm or the area of production by considering the farming systems present under such area (FAO, n.d.)

	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5	Bed 6
Year 1	Alliums	Solanums	Legumes	Brassicas	Roots	Cucurbits
Year 2	Cucurbits	Alliums	Solanums	Legumes	Brassicas	Roots
Year 3	Roots	Cucurbits	Alliums	Solanums	Legumes	Brassicas
Year 4	Brassicas	Roots	Cucurbits	Alliums	Solanums	Legumes
Year 5	Legumes	Brassicas	Roots	Cucurbits	Alliums	Solanums
Year 6	Solanums	Legumes	Brassicas	Roots	Cucurbits	Alliums

https://localfoodconnect.org.au/community-gardening/crop-rotation/

Rotations that provide more organic material to the soil enhance the conditions for biological activity, which will speed up the breakdown of pesticides. One of the most effective and fundamental methods for reducing pests that overwinter in the soil as eggs or partially developed larvae is crop rotation.

Many soil pests, including arthropods, plant-parasitic nematodes, fungal diseases, and bacterial pathogens, have been successfully controlled with their use. It works best against arthropod pests with a small range of plant hosts, a long development cycle (at least a year), and little capacity to disperse. Depending on the feeding or ovipositional behavior, host selection may arise. Crop rotation is an effective method for reducing the number of key soil pest species. For instance, the white-fringed weevil complex has a limited ability to disperse since the adult cannot fly (Zehnder, 2007).

Whitefringed beetle, *Naupactus sp*.

Crop rotation aims to lessen the number of pests that are present in the soil. Some pathogens that cause diseases survive in the soil from year to year in one form or the other, usually as sclerotic, spores, or hyphae. Any soil-borne pathogens associated with that crop that may be present increase in population when the same crop is continuously harvested. Potentially, the population could increase to the point where it would be challenging to cultivate that crop without suffering production losses. However, by growing a crop that is not a host plant for that pathogen will lead to the pathogen dying out and its soil population levels lowering. Without a suitable host, the majority of pest populations will decrease in two to three years.

Rotating to non-host crops prevents the buildup of large populations of pathogens.

Crop rotation helps to reduce weeds and pathogens while enhancing the soil's fertility, moisture, and texture. The best crop rotations use intervals between the delicate crops that are longer than the known survival periods of the viruses. Rotations are most likely to be used to control the diseases *Gaeumannomyces graminis*, *Pyrenophora tritici-repentis*, several *Colletotrichum* and *Phoma species*, and some pathogenic bacteria that can only live in the presence of a particular host (or its residues) or as resistant propagules. They have a lower likelihood of being successful in preventing damping-off and root-rot caused by fungi such *Pythium* and *Aphanomyces*, *Fusarium spp*., including the vascular wilt pathogens, *Sclerotinia spp*., and *Plasmodiophora brassicae*, which can live for a long time in the soil as saprophytes.

Gaeumannomyces graminis

Pyrenophora tritici-repentis

Phoma blight

Pythium

The rotations that are employed to control cereal soil-borne diseases are perhaps the most common. These generally involve either a fallow period, during which volunteer plants and different weed hosts are eradicated or destroyed, or a non-host leguminous crop, which can boost soil fertility while lowering inoculum. In some areas, the removal of grass hosts, particularly during fallow seasons, has helped control the pathogens of wheat that cause take-all (*G. graminrs*), foot-rot (*Pseudocercosporella herpotrichoides*), *Ascochyta sp*., and other diseases. To control infections like *Streptomtyces scabies*, *Phymatotrichopsis omnivora*, and *Rhizoctonia solani* that survive in the soil as resistant spores or as sclerotia, long-term (long course) rotations are necessary. The worm *Heterodera schachtii* infection may cause sugar beet crop yields in some European nations to become unprofitable.

Pseudocercosporella herpotrichoides

Ascochyta sp

Phymatotruichopsis omnivora

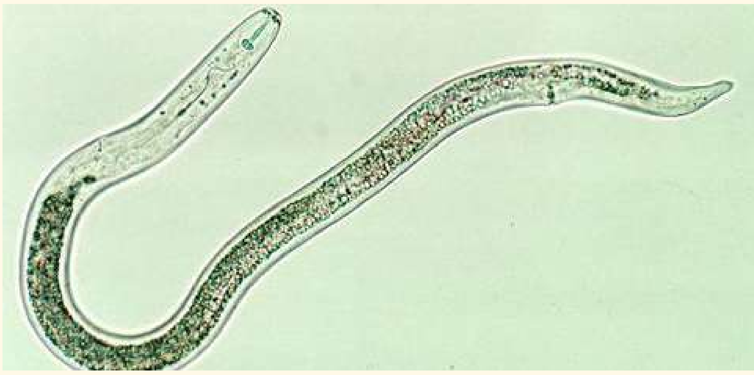
The populations of the nematode decrease to roughly half their initial level when non-host crops are grown or the area is left fallow. A further sugar beet crop cannot be planted until a "safe" population level has been reached. The length and composition of "beet-sick" soil rotation requirements are regulated by law. Because agricultural detritus is frequently brought to the soil's surface and exposed to the drying effects of the atmosphere, regular cultivation of fallow land during dry seasons can eradicate diseases like the bacteria *Ralstonia solanacearum*. However, because the land is unproductive, prolonged fallow periods have questionable utility.

Ralstonia solanacearum

Some crop rotations may contain a plant that prevents the growth of a particular disease. After crops including maize, sweet corn, and capsicum, root-knot nematodes (*Meloydogyne spp*.) are grown, high levels of these worms are found in the soil. However, only a few nematodes are supported by other crops, such as forage sorghum, pinto peanuts, watermelons, Rhodes grass, green panic, and cowpea. Following these crops, sensitive plant crops hardly exhibit any nematode damage.

Additionally, the nematode *Pratylenchus spp.* has been controlled in soil populations using legumes like *Crotalaria* and *Stylosanthes spp*. Similar to this, a variety of nematode species are prevented from growing by *Tagetes spp*. (marigolds). According to Ogle and Dale (1997), several brassica crops generate glucosinolates that degrade to become **isothiocyanates**, which are effective against a number of soil-borne diseases.

Pratylenchus spp



Crop rotation is crucial to the fundamental layout of an organic farm. It is not only the major weapon to prevent and control pests, diseases, and weeds but it is also the basis for maintenance and improvement of soil fertility. Crop rotation cannot be separately planned from nutrient management. (Wijnands, 1999).

Some pests are more common in some crops than in others. Thus, crop rotation in different places can isolate pests from their food source or may change the conditions that pests have to endure. When arranging plant species, members of the same family should not be grown in the same place in successive seasons. Eg. do not grow melons after cucumbers or pumpkins.

This also applies to crop rotations, which include green manure crops that add organic matter to the soil when plowed before flowering or insemination. (Hillock & Borthick, 2004; Bolluyt et. al, 2011).

Crop rotation is most effective against pests that do not spread over long distances, monophages by nature, and/or that overwinter in or near the fields of host crops.
(Frost, 2003)

For example, it is much less effective for the cabbage worm, Delia radicum, which travels long distances. (Poddar et al. 2019). Crop rotation also is the most effective indirect method for minimizing weed problems through different crop sequences, thus influencing the development of different weed species (Frost, 2003). Crop rotation can be used to efficiently manage a wide range of diseases and pests (HE et al., 2019); Frost, (2003) Improving knowledge of pest and weed control in organic crop production in Wales.

Crop rotation is the secret to eradicating pests from the soil and is crucial for eradicating potato cyst nematodes, white rot on alliums, and the club root in brassicas
(Frost, 2003)

Prevention and/or suppression of harmful organisms

A kind of crop isolation is also achieved through the crop rotation of vegetable crops, in which plants that are attacked by the same diseases are “isolated” by the spatial and temporal alternation of these species, which does not allow the emergence or multiplication of some pests. If there have soil pathogens in some cases the sensitive crops are excluded from crop rotation for certain periods, until the soil is cleared from pathogens.

2.2.2 Mixed cropping

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In the majority of emerging nations, traditional farming practices are characterized by multiple cropping or polyculture. Although Altieri (1987, 1991, 1999), Wratten and van Emden (1995), Landis et al. (2000), and others provide abundant observational evidence that the inherent increase in biodiversity of multiple cropping systems increases the quality and quantity of the natural enemy fauna, there is currently insufficient experimental evidence that multiple cropping has a beneficial effect for pest management.

The theory behind the advantage of different cropping systems for IPM is habitat diversification. Since they are agroecosystems that have been simplified, are unstable, and are frequently subject to pest outbreaks that necessitate ongoing human intervention, monocultures by their very nature lack biodiversity.

Cultivation of several crops in the same field known as mixed (multi, poly and inter) has long been practiced, with one of the main goals being to increase biodiversity.

Systems high in biodiversity tend to be more 'dynamically stable' because the variety of organisms provides more checks and balances on each other, thus helping prevent one species (i.e. pest species) from overwhelming the system. In IPM, biodiversity may create stability (but not always) within a crop season if employed as an area-wide approach.

The strategy may not work when used on a single field since pest species may spread from nearby areas. By offering concentrated resources and homogeneous physical circumstances that encourage insect invasions, monocultures facilitate pest infestations (Altieri, 1987). Due to limited alternative food, shelter, breeding places, and other environmental conditions, the abundance and efficacy of natural enemies are decreased in these environments. Contrarily, increasing crop diversity can be utilized to boost parasitic and predatory species' numbers or to hinder herbivores' capacity to locate and consume their host plants. In multiple cropping systems, some plants may fend off pests, restrict their food sources, and increase the population of natural enemies.

For instance, thrips and whiteflies avoid areas with full vegetation cover, such as a main crop and a cover crop between rows, and are drawn to green plants with a brown (soil) background (Sullivan, 2003).

Certain intercrops have a spatial configuration that results in a full vegetative cover that is unfavorable to thrips and whiteflies. Other insects can smell their host plant and identify it. Carrot flies' ability to smell carrots is masked by onions planted with carrots (Sullivan, 2003). In addition to the possible IPM advantages, multiple cropping may shield farmers from the dangers of crop failure; if one crop within the system fails, the other may live and partially make up in yield, giving the farmer a respectable harvest. Despite all the advantages it might have, much more research is required to understand the intricate relationships that exist between the various partnered crops and their pest/predator complexes before the technique can be extensively used to replace massive monocultures. The complexity of mechanical planting, growing, and harvesting is a significant disadvantage of multiple cropping.(Bajwa and Kogan, 2004)

https://www.ruralsprout.com/front-yard-vegetable-garden/

This element of agro-technology has a number of advantages, which contributes many benefits to the cultivation of crops. One of the great advantages of mixed cultivation is the protection of plants from pests by reducing their population in plantations.

The impact on pests is multifaceted, described in a number of publications, and from the analyzes and summaries made over the years, it is stated that the number of pests (weeds, diseases, and pests) is lower in mixed cultivation compared to monoculture development.

https://www.foodformzansi.co.za/intercropping-101-what-you-need-to-know/

The **reason** is the creation of crop diversity, attracting pollinators and predators, which reduces the population of pests and improves yields. Allelopathy can reduce weed populations. The increased number of plants per unit area, in addition to suppressing the development of weeds, also leads to a reduction in the number of vector insects that transmit infections to plants. On the one hand, the covered soil does not allow water droplets to hit the soil and spread soil pathogens, and on the other hand, different root secretions lead to the suppression of soil pathogens. (Boudreau, 2013; Maitra et al. 2021).

https://www.foodformzansi.co.za/intercropping-101-what-you-need-to-know/

Different types of mixed cultivation are as follows: Intercropping

Root (1973) suggested that the enhanced vegetational diversity offered by intercropping would be a way to lessen insect finding and retention in crops and to increase natural enemy populations and activity.

Intercropping - two, three and/or more species are selected, which are sown separately, at the same time, in the same place. It is used both to increase biodiversity per unit area and as an element of plant protection against pests.

When Andow (1991) analyzed intercropping research in the literature, he found that 56% of the time, pest densities were decreased, 16% of the time they increased, and 28% of the time they had no effect. According to Russell (1989), who examined natural enemy activity in intercropping experiments, natural enemies enhanced pest mortality in 70% of cases, decreased it in 15% of cases, and had no effect in the remaining 15%.

Because the underlying mechanisms at the behavioral level have not been thoroughly researched, the responses of both pests and beneficial insects to intercropping are not well understood (Bukovinszky et al., 2007). This level of comprehension is crucial for creating intercropping systems with more stable results.

It is anticipated that pest levels will be lower in polycultures. Row intercropping and strip cropping are two spatial configurations that are employed in multiple cropping. Row intercropping is a method where two or more crops are planted in rows at the same time throughout a single field. It is best to proceed cautiously while using this technique to control weeds. If there is competition for water or nutrients, intercropping may result in lower yields of the primary crop. On the plus side, interplanting the two crops can significantly reduce infestations of armyworm, *Spodoptera frugiperda* (J.E. Smith), in maize and leafhoppers, leaf beetles, and Empoasca spp. in beans (Altieri, 1987).

Spodoptera frugiperda

Intercropping could be:

Strip intercropping

when two or more crops are grown at the same time in strips alternating

https://www.enzazaden.com/news-and-events/news/2022/strip-cultivation-what-is-it-and-what-benefits-does-it-bring

Row intercropping

when two or more crops are grown at the same time in rows, alternating with each other

https://www.hobbyfarms.com/4-great-vegetables-for-intercropping

https://www.agupdate.com/tristateneighbor/news/crop/relay-cropping-helps-iowa-farmer-reach-a-lofty-goal/article_2bbb3d76-153b-11eb-9395-2fcca742ff32.html

Relay intercropping

Growing two or more crops at the same time during part of each life cycle. After the first crop has grown to its reproductive stage but before it is ready for harvest, a second crop is planted. In this way, there is no complete intercropping. It can be considered as a mixture of intercropping and alternation.

Intercropping could be:

https://www.agupdate.com/tristateneighbor/news/crop/relay-cropping-helps-iowa-farmer-reach-a-lofty-goal/article_2bbb3d76-153b-11eb-9395-2fcca742ff32.html

Mixed cropping

two or more crops are grown together, with no specific row ratio for each crop. The seeds of the selected species are mixed and sown simultaneously (for fodder mixtures, for cover crops, for green manure mixes, for flower stripes at the edges of the field). (Maitra et al. 2021).

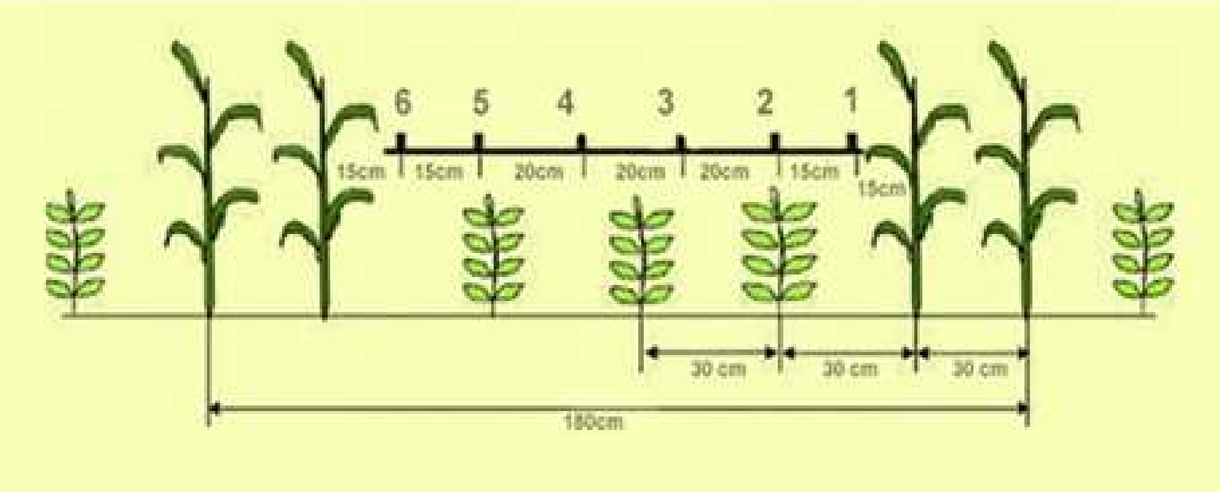
According to Hill (2012), increased ground cover, which is crucial for diurnal enemies, increased nectar and pollen sources, the greater temporal and spatial distribution of nectar and pollen sources, increased prey, which provides alternate food sources when the pest species are scarce or at the right time in the predator's life cycle, and increased ground cover all contribute to reduced phytophagous insect pests. By providing associational resistance and disguising the smells of the host plant, the non-host plant reduces the pest's ability to locate host plants.

Singh et al. (2013) add that when arranging the rows, it is good to determine the main crop. For example main crop capsicum, intercrop – beetroot, pea.

They point out that, depending on the choice of crops for intercropping, it can be:

Parallel intercropping

Under such a cropping system, both crops have different growth habits but zero competitiveness. e.g., Cowpea + Sweet corn. Cowpeas in this intercropping system reach their maximal nutrient need 30-35 days after sowing, whereas sweet corn does so 45–50 days after sowing.



https://www.agupdate.com/tristateneighbor/news/crop/relay-cropping-helps-iowa-farmer-reach-a-lofty-goal/article_2bbb3d76-153b-11eb-9395-2fcca742ff32.html

Multistoreyed/multitier cropping

Multistoreyed/multitier cropping: As the name indicates, under this system two or more crops of different heights grown simultaneously on a certain piece of land in any certain period. Cropping systems with many levels and storeys are designed to make more sustainable use of inputs like soil, water, air, radiation, and other resources.

Some of the examples of multi-storeyed cropping are:

Cotton + Radish + Beetroot + Coriander

https://www.researchgate.net/figure/Multistrata-agroforestry-system-at-the-study-area_fig4_257536715

Companion cropping

Companion cropping is one way to increase biodiversity in the garden. It is considered to be a type of polyculture (Franck, 1983; Parker et al., 2013), or variety of intercropping, but unlike intercropping the companion planting is designed for smaller areas or gardens (Wszelaki & Broughton, 2010).

Companion cropping (planting)", by most definitions, is the growing of two or more different crops together, on the same area, to benefit the main crop or all to be mutually beneficial.

The term "companion" comes from the idea that plants, like humans, have friends and enemies. Friends are those who help a plant in its development, while other plants harm them.

The help of companion plants can be summarized in several directions:

The help of companion plants can be summarized in several directions:

- increasing plant productivity
- improving the quality of the production
- pest control

Pest control can be accomplished in several ways:

- by attracting beneficial insects,
- by repelling pests,
- by using trap-crops,(for hosts plants for pest insects and confusing them - Potting, et al., 2005; to attract pest insects away from main crops)
- by suppressing soil-borne pathogens and improving soil health, by suppressing weed growth, etc.

In order to achieve the desired benefits, it is necessary to know the plants and to select those of them that possess the useful qualities, supporting the main culture or being of mutual benefit. In addition, vegetables, spices, flowers or other types of plants can be used as companion plants in gardening.

In this cropping system the production of both the intercrops is equal to the production of both the crops grown individually. e.g., potato + beans. If these two crops grown separately, the production is not much affected insignificant as compare to individual crop.

Many of the plants used in companion cropping possess different mechanisms against pests and thus protect the main crop or mutually protect each other. According to their **mode of action**, they are divided into the following groups:

Companions that **draw pests away from the main crop** (see trap crops);

Companion plants that **repel**;

Companion plants that **mask** - they may produce volatiles that conceal host plant scents, making it difficult to locate the host plant;

Companion plants that **camouflage or physically block** - According to the 'appropriate/inappropriate landing' theory, which postulated that green surfaces surrounding host plants may interfere with host plant discovery, companion plants may also physically and visually disguise or block host plants in addition to safeguarding crops with olfactory cues.

Main crop	Good companion	Bad companion	Examples
Asparagus *Asparagus officinalis L.*	Calendula, Petunias, Tomatoes, Parsley, Basil		Calendula, tomatoes, and petunias are thought to deter asparagus beetles. Basil repels Flies, Mosquitoes
Aubergine/Egg plant *Solanum melongena L.*	Marigold, Tarragon, Mints, Catnip,Beans, Bush Beans, Pole Beans,Peas, Peppers, Potato, Spinach	Pole beans Fennel	Marigolds will deter nematodes; Catnip will repel Flea Beetle, Ants
Beans	Most Vegetables & Herbs	Onion, Garlic, Gladiolus	
Beans, Bush	Beets,Borage,Cabbage, Carrots,Cauliflower, Celeriac,Celery,Chard, Corn,Cucumbers, Eggplant,Leek,Lettuce,Parsnip,Pea,Potato,Radish,Rosemary,Strawberry,Savory,Sunflower, Tansy, Marigold	Onion Basil, Fennel, Kohlrabi	
Beans, Pole	Carrots, Cauliflower, Chard, Corn,Cucumber,Eggplant, Lettuce,Marigold,Pea,Potato, Radish, Rosemary, Savory, Strawberry,Tansy	Basil, Beets, Cabbage, Fennel, Kohlrabi, Onion, Radish, Sunflower	
Broad bean	Basil, Savory		Both have deterrent effect and repellency against *Aphis fab*
Beetroot	Bush Beans, Cabbage family, Garlic, Lettuce, Lima Bean, Onion, Radish, Sage	Mustard, Pole Bean	Beetroot
Broccoli	Bush Beans, Beets, Carrot,Celery,Cucumber, Dill, Lettuce, Mint,Nasturtium, Onions, Rosemary, Sage, Spinach,Thyme, All Strong Herbs, Marigold, Nasturtium	Dill, Strawberries, Pole Beans, Tomat	Dill reduces egg laying by adult cabbageworms on cole crops Marigolds mask volatiles from the onions and cabbages, making it harder for the adult flies to find their host plants. Rosemary repels cabbage flies, Onion reduces host-finding ability of Brevicoryne brassica

Main crop	Good companion	Bad companion	Examples
Cabbage	Bush Beans, Beets, Carrot,Celery,Cucumber, Dill, Hyssop, Lettuce, Mint, Nasturtium,Onions,Rosemary, Sage, Spinach, Thyme, All Strong Herbs, Marigold, Nasturtium	Dill, Strawberries, Pole Beans, Tomato	Hyssop repels Cabbage Moth dill reduces egg laying by adult cabbageworms on cole crops Marigolds mask volatiles from the onions and cabbages, making it harder for the adult flies to find their host plants.Rosemary repels cabbage flies, Onion reduces host-finding ability of Brevicoryne brassicae
Carrots	Beans, Brussels sprouts, Cabbage, Chives,Lettuce, Leek, Onion, Peas, Radish, Rosemary, Sage, Tomato	Celery, Dill, Parsnip	Onions have repellent feature against various insects as aphids, mites, moths and cockroaches
Celery	Onion & Cabbage Families, Tomato,Bush Beans, Nasturtium Almost everythin	Carrot, Parsley, Parsnip	
Corn	All Beans, Beets, Cabbage, Cantaloupe,Cucumber, Melons, Parsley, Peas, Early Potatoes, Pumpkin, Squash	Tomato	
Cucumber	Bush Beans, Pole Beans, Cabbage family, Corn, Dill, Eggplant, Lettuce, Marigold, Nasturtium, Onions, Peas, Radish, Tomato, Savory, Sunflower, No Strong Herbs	Potato, Aromatic Herbs	
Garlic	Beets, Carrot, Lettuce, Cabbage Family, Summer Savory, Marigolds	Beans, English Pea	Marigolds mask volatiles from the onions and cabbages, making it harder for the adult flies to find their host plants.
Leek	Beets, Carrot, Lettuce, Cabbage Family, Summer Savory, Marigolds	Beans, English Peas	Marigolds mask volatiles from the onions and cabbages, making it harder for the adult flies to find their host plants

Main crop	Good companion	Bad companion	Examples
Lettuce	Carrot, Dill, Radish, Strawberry, Cucumber Everything, but especially Carrots, Garlic,Onion and Radish	None	
Melon	Corn, Nasturtium, Radish	Potato	
Onion	Dill, Beets, Cabbage family, Carrots,Celery, Cucumber, Lettuce, Parsnip, Pepper, Spinach,Squash,Strawberries ,Tomato, Turnip, Savory, Marigolds	Asparagus, Beans, Peas, Sage	Marigolds mask volatiles from the onions and cabbages, making it harder for the adult flies to find their host plants.
Parsley	Tomato, Asparagus	None	
Peas	Bush Beans, Pole Beans, Carrots, Celery,Chicory, Corn, Cucumber, Eggplant, Parsley, Early Potato, Radish, Spinach,Strawberry, Sweet Potato, Turnips	Onion Family, Gladiolus, Late Potato	
Pepper	Basil, Onions, rosemary, lavender	Fennel,beans, kale (cabbage, brussels sprouts, etc)	Onions, basil, rosemary and lavender mask volatile chemicals from peppers to hide them from Green peach aphids
Potatoes	Bush bean, Cabbage family, Carrot, Corn, Garlic Horseradish, Marigold, Onion, Parsnip, Peas	Tomato,Cucumber, Kohlrabi,Parsnip, Pumpkin,Rutabaga, Squash family, Sunflower, Turnip, Fennel	Horseradish increases the disease resistance of potatoes; garlic repels and reduces the attractiveness of hosts against *Myzus persicae Aphis gossypii*
Pumpkin	Corn, Marigold	Irish Potato	
Radishes	Beet,BushBeans, Pole Beans, Carrots,Cucumber,Lettuce,Melons,Nasturtium, Parsnip,Peas,Spinach,Squash family	Hyssop	
Spinach	Strawberry,FabaBean, Celeriac,Celery,Corn,Eggplant, Cauliflower		

Main crop	Good companion	Bad companion	Examples
Spinach	Strawberry,FabaBean, Celeriac,Celery,Corn, Eggplant, Cauliflower		
Squash	Borage, Nasturtium, Corn, Marigold, Corn,Onion, Radish	Potato	Nasturtiums reduced squash bug numbers in test plots, perhaps through volatile masking.
Strawberry	Borage, Bush Beans, Lettuce, Nasturtium,Onion, Radish, Spinach	Cabbage, Potato	
Tomatoes	Asparagus, Basil, Bean, Borage,Cabbage family, Carrots, Celery, Chive, Cucumber, Garlic, Head lettuce, Marigold, Mint, Nasturtium, Onion, Parsley, Pepper, Marigold	Cabbage Family, Pole beans, Corn, Dill,Fennel, Potato	Volatiles from basil mask the volatiles from tomatoes and lead to reduced egg laying behaviors in both pests: tomato hornworm and striped armyworm;**Basil** repels trips;Basil repels Flies, Mosquitoes; **Borage** repels Tomato Worm
Turnp	English Pea	Potato	

Trap cropping

Trap crops are plant grown to attract insects or other organisms to protect field crops from pests' attack. Pests can be contained in a specific area of the field or prevented from accessing the crops in order to provide protection.

Trap cropping is the process of luring pests to early plantings of a crop on a small area, tiny plantings within or around a major crop, or both. In general, target pests prefer trap crops to the primary crop as hosts.

The pest might never leave a trap crop if it is kept in a healthy state. The main crop can be protected by mowing or spraying the trap crop if the insect population increases and starts to depart. The actions of helpful species in the main crop are unaffected by this action. When the nearby crop field is treated, trap crops frequently act as refugia or additional reservoirs for beneficial predators and parasitoids. (Bajwa and Kogan 2004)

Trap crops are composed of one or more plant species that are grown to attract insect pests in order to protect the cash crop. Protection may be achieved either by preventing the pest from reaching the crop or by concentrating the pests in a certain part of the field, where they can be managed. Trap crops can be manipulated in time or space, so they attract insects at a critical period in the pest's and/or the crop's life cycle. Depending on the insect's biology and the available management practices, the population on the trap crop can be managed in several ways. In some cases, the plants can simply withstand the damage, and no further action is necessary.

Trap crop works as an alternative host that draws away invading insects, giving the main vegetable crop protection. The primary benefits of trap cropping are reduced use of pesticides on valuable crops and low-cost control of insects for the producer. Zehnder et al. (2007) summarized that trap cropping is a strategy that has clear potential in organic systems. The trap crop must be more desirable to the pest as a source of food or a place to lay eggs than the main crop. Indeed, the relative attractiveness and size of the trap crop in a landscape are important factors in arresting the pest and the consequent success of a trap cropping system. Trap cropping varies according to factors such as plant characteristics, the basis of deployment, and the use of combined approaches.

Shelton and Badenes-Perez (2006), in their review, summarized different trap cropping modalities and classified them according to trap crop plant characteristics or the deployment of the trap crops. According to plant characteristics of trap crops, they divided trap cropping practices into three groups:

- conventional, they are live trap plants that are grown close to the main crop and are more attractive to pests;
- a dead-end trap: plants that become attractive to pests after they die plants that insects find very alluring but on which they or their offspring cannot live Pests can't travel from dead-end trap crops to the main crop later in the season because they act as a sink for them;

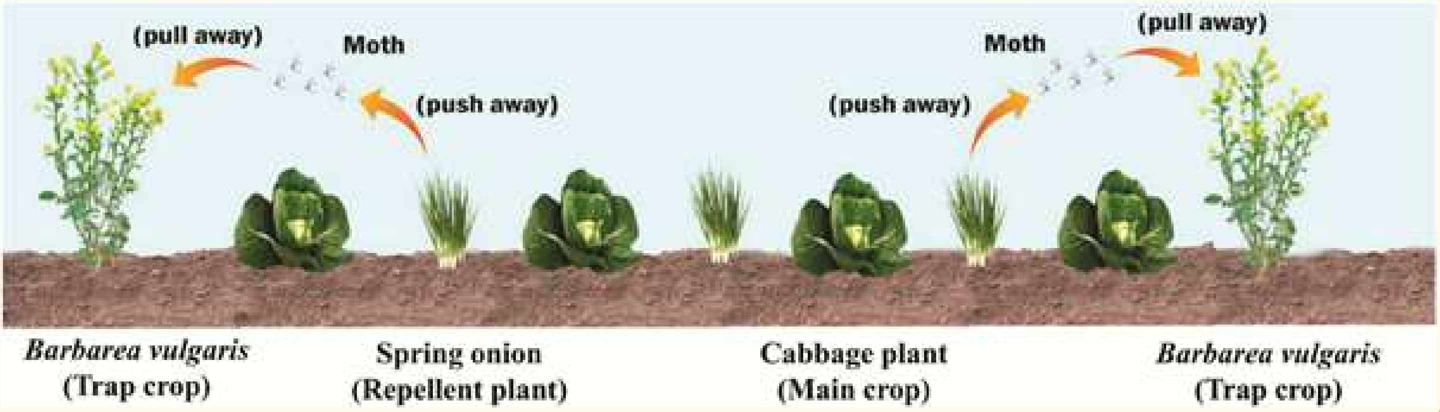
genetically engineered trap cropping This not be considered unique because it can produce plant characteristics that fit other modalities.

https://drecampbell.com/trap-crops/

Shelton and Badenes-Perez, (2006), classified trap crops on their deployment on four groups:

- **perimeter trap cropping** - the use of a trap crop planted around the border of the main crop;
- **sequential trap cropping** - trap crops that are planted earlier and/or later than the main crop to enhance the attractiveness of the trap crop to the targeted insect pest;
- **multiple trap cropping** - planting several plant species simultaneously as trap crops with the purpose of either managing several insect pests at the same time or enhancing the control of one insect pest by combining plants whose growth stages enhance attractiveness to the pest at different times.

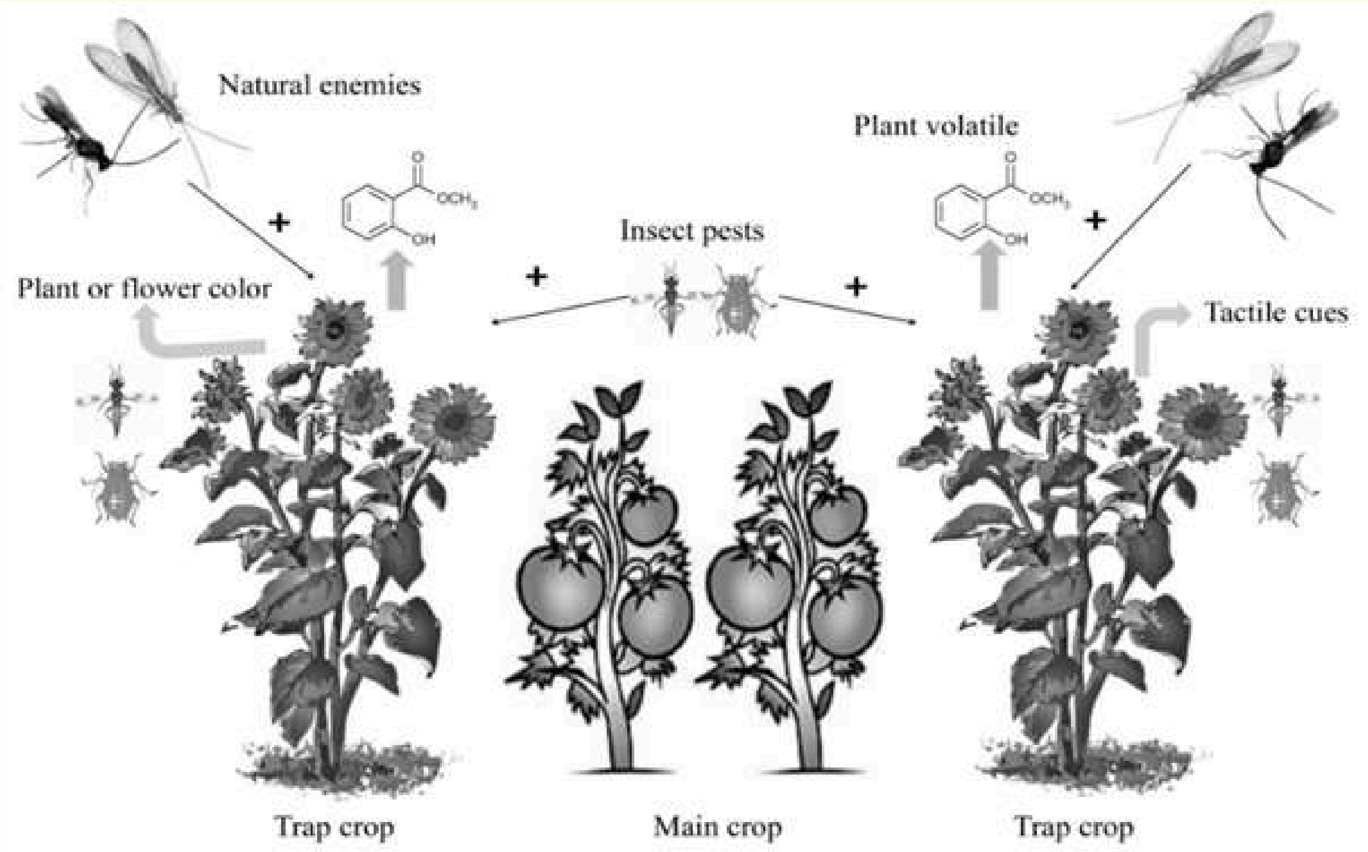
push-pull trap cropping - the push-pull strategy is based on a combination of a trap crop (pull component) with a repellent intercrop (push component). The trap crop attracts the insect pest and, combined with the repellent intercrop, diverts the insect pest away from the main crop



Source: Mayanglambam, S., Singh, K. D., & Rajashekar, Y. (2021). Current biological approaches for management of crucifer pests. Scientific Reports, 11(1), 1-9.

Trap cropping can significantly lessen the damage caused by the *Cerotoma trifurcata* (Forster) and *Epilachna varivestis* (Mulsant) Mexican bean beetles and bean leaf beetles. Planting early-maturing cultivars is possible two weeks before the main soybean crop. These early-maturing trap crops attract adult beetles, which are then eliminated by tillage or insecticide spraying (Newsom and Herzog, 1977). According to Hokkanen (1991), early-planted potatoes may serve as a trap crop for Colorado potato beetles that emerge in the spring. The beetles will congregate on these plants, where they can be more easily handled because the early potatoes are the only food source available. (Bajwa and Kogan 2004)

Trap plants are effective for some insects, such as flea beetles on cole crops (cabbage family). Plant a species or variety of plant that the insect prefers to feed on near or within the crop to be protected. Insect damage to the gardener's primary crop will be minimized because the insects will mostly feed on the trap plants. Remove and destroy trap crops if they become severely infested so the insects do not move over onto the desired crop.



Sarkar, S. C., Wang, E., Wu, S., & Lei, Z. (2018). Application of trap cropping as companion plants for the management of agricultural pests: a review. Insects, 9(4), 128.

In the vegetable garden, trap cropping is a very simple and effective organic pest management technique. According to Loebenstein (2014), traps crops are effective in reducing populations of whiteflies, and therefore reducing the level of virus infection. In tomatoes in the south-eastern USA, squash planted around tomatoes acted as a trap crop, since whiteflies were more attracted to the squash plants than they were to the tomatoes.

In Finland, the rape-blossom beetle, *Meligethes viridescens* (Fabricius), has been captured using mixed stands of trap plants, including Chinese cabbage, oilseed and turnip rape, sunflower and marigold. Up to one-third of the entire harvest is frequently destroyed by this insect. Due to the beetle's great mobility, numerous strips of trap plants are produced in the direction where infection is expected to occur. Insecticide applications for trap cropping should be timed appropriately to suppress the beetle and stop it from spreading to the cauliflower plants. The strategy has shown to boost the crop's marketable yield by about 20% (Hokkanen, 1991). Even though some of these methods still use insecticidal control, the treated area is significantly smaller (Hokkanen, 1991). The cost of growing and discarding a crop that yields no profit could be a drawback of trap cropping. However, melon fields with a few small squash plantings around the perimeter usually do not need insecticides. The method lowers the cost of production for the primary crop, preserves natural enemies, and lessens the possibility of subsequent pest outbreaks. As a crop with added value in this instance, the squash trap crop improves sustainability for the producer.

Sales of squash generate additional revenue while covering the cost of the seed and insecticide. (Bajwa and Kogan 2004)

Source: https://www.researchgate.net/publication/285189207_Companion_planting_and_insect_pest_control/figures?lo=1

Since the trap crop will be most effective when it begins to flower or seed, it is important to establish it earlier than the desirable crop. A good starting point is to plant the trap crop two weeks prior to the desirable crop. To provide an extended control session, it also suggested that the grower continue to stagger new plantings of the trap crop every two to three weeks. Trap crops work best when planted at least 2 to 3 m away from the desirable vegetables.

Since the trap crop will be most effective when it begins to flower or seed, it is important to establish it earlier than the desirable crop. A good starting point is to plant the trap crop two weeks prior to the desirable crop. To provide an extended control session, it also suggested that the grower continue to stagger new plantings of the trap crop every two to three weeks. Trap crops work best when planted at least 2 to 3 m away from the desirable vegetables. Each trap crop should be planted in two to three rows at once. Scouting trap crops frequently is essential in order to stop the pest population from out of control before any control measures are implemented. When it comes to fertilizer and irrigation, trap crops will require identical care as your ideal crops. Weed infestation should also be managed with mechanical or chemical methods. One tool that commercial and individual growers can utilize to combat pest pressure is trap cropping. Research has shown that it can assist in providing some relief of insect pressure to desirable crops. Trap cropping may not work for everyone, but it is a possible solution for those preferring to use fewer chemicals in their garden.

The number of practical trials of trap cropping has increased rapidly in recent years. Caldwell, et al., 2013 summarized that studies have analyzed different trap-cropping situations, such as early planting of single rows of trap crop potatoes between current and previous year fields for Colorado potato beetle control and perimeter trap cropping against pepper and cucurbit pests.

Altieri & Liebman, (2014) described that the concept of crop diversification for the management of nematode populations has been applied mainly in the form of decoy and trap crops. Decoy populations has been applied mainly in the form of decoy and trap crops. Decoy crops are nonhost crops which are planted to make nematodes waste their infection potential. This is effected by activating larvae of nematodes in the absence of hosts that would enable them to continue their development. Trap crops are host crops sown to attract nematodes but destined to be harvested or destroyed before the nematodes manage to hatch. This has been advocated for cyst nematodes, sowing crucifers to be plowed in before the nematodes of beets can develop fully.

Additionally, the trap crop can keep the pest population high so that it can be used as a resource by natural enemies to grow. Natural enemies may control the pest population and stop it from migrating to the cash crop, or they may start out in the trap crop and move to the cash crop. (Caldwell et al., 2013)

Main crop	Trap crop	Pest	Method
Cabbage (Cabbage family)	Chinese cabbage, Mustard, Radish	Cabbage webworm, Flea hopper, Mustard aphid	Planted in every 15 rows of cabbage
	Collards	Diamond black moth	Border crops
	Indian mustard	Cabbage head caterpillar	Strip intercrop between cabbage plots
	Nasturtium	Aphid, Flea beetle, Cucumber beetle, Squash vine borer	Row intercrop
	Radish	Flea beetle, Root maggot	Row intercrop
	Tomato	Diamond black moth	Intercrop
Carrot	Medic (*Medicago litoralis*)	Carrot root fly	Strip intercrop in between carrot plots
	Onion and garlic	Carrot root fly; Thrips	Border crops
Cowpea	Tick clover (*Desmodium*)	Stemborer; Striga	Row intercrop

Main crop	Trap crop	Pest	Method
Corn	Beans and other Legumes	Leafhopper; Leaf beetles; Stalk borer; Fall armyworm	Row intercrop
	Tick clover (Desmodium)	Stemborer; Striga	Row intercrop
	Soybean	Heliotis sp.	Row intercrop
	Sudan grass (*Sorghum*)	Stembore	Intercrop Border crops
	Vetiver	Corn stalk bore	Perimeter crop
Cucumber	Blue Hubbard squash	Cucumber beetles; Squash vine borer; Squash bugs	Border crops
Cucurbita family	Buttercup squash, Cucurbita maxima Duchesne (Cucurbitaceae)	*Acalymma vittatum* (Coleoptera: *Chrysomelidae*);*Diabrotica undecimpunctata L*. (Coleoptera: *Chrysomelidae*);*Acalymma vittatum*(Coleoptera: *Chrysomelidae*)	
Garlic	Basil, Marigold	Thrips	Border crops
Lettuce	Alfalfa, *Medicago sativa L*(Fabaceae)	*Lygus rugulipennis Hahn* (Hemiptera: Miridae)	
Melon	Buttercup squash, Cucurbita maxima Duchesne; (Cucurbitaceae)	*Acalymma vittatum* (Coleoptera: *Chrysomelidae*); *Diabrotica undecimpunctata L.* (Coleoptera: *Chrysomelidae*) *Acalymma vittatum* (Coleoptera: *Chrysomelidae*	
Onion	Buckwheat,Carrot	*Thrips*	

Main crop	Trap crop	Pest	Method
Bean	Eggplant, Summer squash, Cucurbita pepo	*Bemisia argentifolii* Gennadius (Hemiptera: *Aleyrodidae*)	
Bell pepper	Hot cherry pepper	Pepper maggot	Border crops
	Sunflower	*Halyomorpha halys* Stål (Hemiptera: *Pentatomidae)*	
Tomato	Dill, Lovage	Tomato hornworm	Row intercrop
	African marigold, *Tagetes erecta L.* Marigold, *Calendula officinalis L.*	*Helicoverpa armigera Hübner* (Lepidoptera: Noctuidae)	
	Arugula, *Eruca sativa* Mill. (Brassicaceae);	Lygus spp. (Hemiptera: *Miridae*)	
Potato	Horseradish, Tansy	Colorado potato beetle	Intercrop
Zucchini	Blue Hubbard squash	Cucumber beetles, Squash vine borer, Squash bugs	Border crops
Solanaceous, Cucurbits, Legumes, Crucifers	French Marigold, African Marigold	Nematodes	Row/strip intercrop

Source: https://www.gardenia.net/guide/trap-cropping-to-control-pests

Hort4EUGreen

Barrier plants

They are used to protect against some airborne pests. Poddar, et al. (2019) summarized that the barrier plants are used within or bordering a primary crop for the purpose of disease suppression and/or interception of pests and/or pathogens. Barrier plants or barrier crops may reduce the spread of diseases spatially by intercepting pests and/or pathogens. The barrier crop is planted in field margins. The barrier crop hypothesis or physical obstruction hypothesis bases its effectiveness on the use of taller non-host plants to obstruct the movement of the pest insect within the cropping system. Barrier plants act on viruliferous aphids, and reduce their potential to transmit and spread viruses to the protected crop close by. However, other authors suggest that tall barrier crops may simply act as mechanical barriers that decrease the total number of aphids landing on the protected crop. Sometimes, instead of using the barrier crop as a border, a non-susceptible crop can be mixed with the crop to be protected, so that the intercrop provides camouflage, decreases the movement and spreading. It may also act as a source of natural enemies.

Examples of barrier plants are sunflower, sorghum, sesame, and pearl-millet used to protect pepper crops or wheat, Swiss chard exploited to further muskmelon crops.

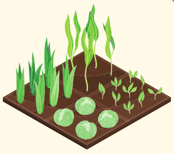
In the 1950s, the idea of utilizing one crop as a border to shield another crop from viral infections was initially put forth. Since then, this strategy has been explored by several authors and a wide range of diverging conclusions in the prospects have been reached. Despite the potential success of using barrier plants for vector management, this concept has received little research attention compared with other management strategies.

Hooks and Fereres (2006) considered barrier cropping to be any form of plant diversification (e.g. mixed cropping, cover crops, border plants, intercrops, trap crops, flower strips, organic mulch, etc.). These may be used to protect a primary crop from insect-transmitted viral diseases. However, apart from disease suppression, they can have additional functions such as restricting dispersal of airborne pests and reducing the effects of wind on natural enemies.

As a barrier for insects – pests and vectors of diseases, are used and border crops, but they offer partial isolation and therefore this method is not combined with the release of predatory insects. (Damicone et al., 2007).

2.2.3 Cover crops

Milena Yordanova, Oana Crina Bujor,
Ivona Dimitrova, Vera Petrova



Cover crop: HE, et al (2019) described that a cover crop is defined as any living ground cover that is planted with or after the main crop, and usually killed before the next crop is planted. Introduced before 1945, it includes double cropping into one main crop to increase organic matter and reduce weeds, pests and soil erosion.

Moreover, relay cropping, overseeding, and interseeding are also types of cover cropping. This kind of cropping strategy, which aids in weed suppression, can also be advantageous to vesicular-arbuscular mycorrhizae. Herbicides and artificial fertilizers were introduced, drastically reducing the need for these systems. To be achieved the effect of suppression sowing density is also important in weed and voluntary plant management. In agricultural practice, it is very important the influence of cover crops on the number and the biomass of weeds and volunteer plants. The long-term experimental research shows that the number of weeds and volunteer plants in the sustainable farming system without cover crops was in most cases higher compared with the farming systems with cover crops in soils with low and moderate humus content, but it largely depended on meteorological conditions during vegetation. (Masilionyte et al. 2017)

Due to its short growing season, capacity to outcompete many weeds, resistance to damage from insects and diseases, and the necessity for only modest soil fertility, buckwheat (*Fagopyrum esculentum*) is a useful cover crop in the production of vegetables. (Björkman and Shail, 2013)

When comparing five cover crops in raspberry plantations with nematodes, it was found that three of them (*Avena sativa L.*; *Festuca rubra L.* and *Agrostis alba L.*) suppressed the multiplication of nematodes, although this did not lead to an increase in raspberry vitality. (Vrain et al., 1996)

Properly selected and managed, cover crops can enhance the soil and field environment to favor beneficial. Success depends on properly managing the cover crop species matched with the cash crops and anticipated pest threats.

https://jooinn.com/img/get

https://jooinn.com/img/gethttps://www.growbetterveggies.com/growbetterveggies/2008/11/adding-fertility-sow-a-winter-cover-crop.html

Benefits of cover crops are:

- increasing biodiversity;
- protecting the soil from erosion;
- increasing soil fertility;
- improving soil structure; improving the water-air soil capacity;
- improving soil health; plant protection (against soil pathogens, incl. and nematodes, weed suppression);

https://jooinn.com/img/gethttps://www.growbetterveggies.com/growbetterveggies/2008/11/adding-fertility-sow-a-winter-cover-crop.html

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Cover crop	Pest management Weed control	Soil structure Soil erosion	mulch Biomass	N fixation Improve nutrients nitrogen scavengers	Planted season		
					spring	summer	Late summer/ autumn
Brassicas:							
Arugula *Eruca sativa*	good biofumigation properties suppresses weeds,	improves soil structure and aggregates	moderate mulch for winter beds				✓ cool-season plant
Canola *Brassica napus*	some allelopathic and biofumigant properties, good weed suppression				✓		✓
Forage Radish/Daikon *Raphanus sativus*	strong biofumigation properties, allelopathy deter weeds	breaking up hard soils, aerate soils, increase water infiltration and retention, give excellent erosion control		nitrogen scavenger	✓		✓
Mustard species *Brassica* spp.	high levels of glucosinolates producing biofumigant effects have allelopathic properties for effective weed control	good erosion control.	moderate winter mulch		✓		✓
Grasses:							
Rye *Secale cereale L.*	blocks out weeds allelopathy Reduces soil-borne diseases and root-knot nematodes	Erosion control		N recovery			✓
Barley *Hordeum vulgare* L.	good for weed control	Erosion control	green manure crop	N recovery,			✓
Oat *Avena sativa* L.	blocks out weeds	controls erosion	green manure, winter mulch		✓		✓
Annual ryegrass *Lolium multiflorum* Lam.	suppresses weeds	prevents compaction, loosens soil reduce erosion	winter mulch	controls nitrogen	✓	✓	
Sorghum/Sudangrass *Sorghum bicolor* (L.) Moench / *S. sudanense* (Piper) Stapf	good biofumigation properties allelopathy		Summer biomass production	nitrogen scavengers		✓	
Legumes:							
Alfa alfa *Medicago sativa*		good erosion control improve soil structure	providing mulch for the dormant roots green manure	add nutrients			
Hairy vetch *Vicia villosa* Roth Avoid planting other legumes right after vetch, as this can increase the chance of root rot, nematode infestation, and white mold in those plants				N production			
Woollypod vetch *Vicia dasycarpa* L.				N production			
Austrian winter pea *Pisum sativum* ssp. *sativum* var. *arvense* (L.) Poir.				N production			
Crimson clover *Trifolium incarnatum* L.	attracts important pollinators like bees and butterflies			N production,	✓		
Subterranean clover *Trifolium subterraneum* L.	Effective weed suppression allelopathy			N production,			

Berseem clover *Trifolium alexandrinum* L.			Summer biomass production	as a nitrogen fixer			
Cowpea *Vigna unguiculata* (L.) Walp	good weed control			as a nitrogen fixer		✓ Heat tolerance	
Fava beans (*Vicia faba*)				as a nitrogen fixer		in cool and warm seasons	
Fast-growing field peas (*Pisum sativum*)	good weed control	effective erosion control		as a nitrogen fixer	✓		✓
Other:							
Buckwheat *Fagopyrum esculentum* Moench	suppresses weeds, allelopathy Supports large populations of beneficial insects and pollinators.	good erosion control improves soil structure and tilth	form a light mulch	nutrient fixer		✓	✓

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Biological crop protection – an effective natural support
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Biological Control Agents
Predators
Feed & kill many individual prey during their lifetime.
Many feed on a variety of insects and mites, as well as pollen, nectar, and honeydew
Green lynx spider
Share
2-spot spider mite and Predatory mite
Pirate bug
Lady beetle larva
Lady beetle
Mealybug destroyer
Lacewing larva
Syrphid larva
Assassin bug
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Unit 2.3. Disease or pest resistant and tolerant cultivars

Rumen Tomov, Roxana Ciceoi, Beatrice Iacomi, Oana Venat, Cornel Baniță

2.3.1 Disease or pest resistant and tolerant cultivars produced through conventional breeding

Plant breeders use a variety of methods to create new cultivars (EPRS, 2021) as:

- Traditional breeding, including Selection breeding, Crossbreeding, Hybrid breeding;
- Mutagenesis
- Marker-assisted selection
- Cisgenesis
- Intragenesis

Disease and pest resistant and tolerant cultivars are those that have been developed through conventional breeding methods to have genetic traits that make them less susceptible or resistant to specific diseases and pests. Conventional breeding involves selecting and crossing plants with desirable traits over several generations to develop a cultivar with specific attributes. These cultivars are developed to exhibit natural resistance or tolerance to specific pests or diseases, reducing the need for chemical pesticides and enhancing overall crop health.

Plant breeding has resulted in the development of a large number of varieties that are resistant to several kinds of diseases. Wild cultivars have low economic benefits in most cases, but often show resistance to locally occurring biotic and abiotic stresses; and cross-breeding of these varieties can result in the development of varieties that can perform better, by out-competing weeds, without the application of large doses of pesticides.

In addition to resistance, cultivars can be developed with tolerance to specific pests or diseases. For example, the cabbage cultivar 'Kilaton' was developed with tolerance to clubroot, which is a soil-borne disease that affects cabbage and other brassica crops. Tolerance means that the plant can still grow and produce a yield even when affected by the pest or disease, compared to susceptible cultivars that may have stunted growth or reduced yields when attacked. The most effective, practical, and cheapest method of managing pests and diseases is probably by the use of resistant cultivars Reddy (2017).

Disease and pest resistant and tolerant cultivars produced through conventional breeding are a major tool in the control and management of pests and diseases in horticulture production system.(Smith 2005, 2021, FAO, 2022).

Examples

Tomato

'Ferline' (resistant to tomato leaf mould and verticillium wilt);
'Fandango' (resistant to tomato mosaic virus, fusarium wilt, verticillium wilt, and nematodes);
'Robusta' (resistant to verticillium wilt, fusarium wilt, and nematodes);

Pepper

'Golubka' (tolerant to aphids and whitefly);
'Belcanto' (resistant to tobacco mosaic virus and cucumber mosaic virus);
'Jalapeno' (resistant to bacterial spot);

Cucumber

'Dasher II' (resistant to powdery mildew);
'Korsor' (resistant to cucumber mosaic virus and powdery mildew);
'Corinto' (resistant to downy mildew and powdery mildew);

Cabbage

'Groninger' (resistant to clubroot);
'Kilaton' (tolerant to clubroot);
'Richi F1' (resistant to alternaria leaf spot);

Carrot:

'Resistafly' (resistant to carrot fly);
'Tirion' (resistant to cavity spot);
'Autumn King' (tolerant to cavity spot);

Apple

'Pinova' (resistant to scab and powdery mildew);
'Resi' (resistant to scab and mildew);
'Elstar' (tolerant to apple scab);

Plum

'Czar' (resistant to black knot);
'Valor' (resistant to bacterial spot);
'Oullins Gage' (tolerant to plume moth);

Cherry

'Griotte de Kleparow' (resistant to cherry leaf spot);
'Regina' (tolerant to brown rot);
'Gisela 5' (resistant to cherry leaf spot and tolerant to powdery mildew);

The list of examples is not exhaustive. Additional information about disease and pest resistant and tolerant vegetable cultivars produced through conventional breeding available in Europe, could be found in seed companies and agricultural research organizations that specialize in plant breeding and variety development.

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Companies involved in resistance breeding in horticulture

Several companies around the world have been actively involved in resistance breeding in horticulture. These companies are dedicated to developing horticultural crop varieties with resistance or tolerance to pests, diseases, and environmental stresses the most known for their contributions being:

Syngenta has a significant presence in the horticulture industry and is known for its research and development efforts in developing crop varieties with resistance to various pests and diseases. They work on a wide range of horticultural crops, including vegetables and fruits.

BASF Vegetable Seeds (formerly Nunhems) focuses on developing vegetable varieties with improved resistance traits. They offer a range of resistant vegetable varieties for various pests and diseases.

Sakata Seed Corporation is a global seed company that has been involved in breeding horticultural crops for resistance to pests, diseases, and environmental stresses. They have a strong emphasis on vegetables and ornamental plants.

Monsanto (now part of **Bayer**) has historically been involved in resistance breeding for various crops, including horticultural crops. They have worked on genetically modified (GM) varieties with resistance traits.

HM.CLAUSE is a company that specializes in vegetable seeds. They have breeding programs focused on developing resistant vegetable varieties, including those with resistance to diseases and pests.

Rijk Zwaan is a global vegetable breeding company that invests in developing resistant vegetable varieties. They work on crops like tomatoes, cucumbers, and lettuce.

Seminis (a brand under Bayer) specializes in vegetable seeds and has breeding programs for developing resistant vegetable varieties.

Bejo Zaden is a Dutch vegetable breeding company known for its efforts in developing disease-resistant vegetable varieties, particularly in the onion, carrot, and brassica crops.

Enza Zaden is another Dutch vegetable breeding company that focuses on developing innovative and resistant vegetable varieties for various markets.

East-West Seed specializes in tropical vegetable seeds and is actively involved in developing resistant varieties suitable for tropical and subtropical regions.

All these companies recognize the importance of resistance breeding in horticulture to reduce the reliance on chemical pesticides and promote sustainable and environmentally friendly crop production.

Resistance breeding aligns with the principles of sustainable agriculture, benefiting both the environment and growers. By developing plant varieties with built-in resistance to pests and diseases, horticulture can achieve a more balanced and sustainable approach to crop protection.

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2.3.2 Disease or pest resistant and tolerant cultivars produced through genetic engineering and new genomic techniques

Ivona Dimitrova, Oana Venat, Elena Ivan, Liliana Bădulescu, Arzu Aydar

Genetic modification of living organisms is a thriving activity used for agricultural research and development. A genetically modified organism (**GMO**) is an organism whose genes have been purposefully altered by humans. The term **transgenic organism** is also used as a synonym. Genetically modified organisms are artificially subjected to genetic change without this occurring under natural conditions.

The genomes of plants and animals used in agriculture have been modified by humans for many centuries through the application of traditional breeding techniques. In recent decades, advances in the field of molecular techniques allow precise control over the genetic changes carried out in the organism. Through genetic engineering techniques, today it is possible to introduce a gene from one species into another, completely distant species, in order to improve agricultural results or produce valuable pharmaceutical substances. Crop plants, farm animals and microorganisms are most often the object of such experiments (Phillips, 2008).

Agricultural plants are most often subjected to genetic modification. The expected benefits of genetic engineering in agriculture are increased yields, reduced costs of food and drug production, reduced need for pesticides, improved nutritional composition and food quality, resistance to pests and diseases.

Progress has also been made in the development of crops that mature faster and tolerate the presence of various harmful substances (including metals - such as aluminum, boron), salinization, drought, freezing and other environmental factors, which allows these plants to survive in conditions in which they would not normally develop (Takeda & Matsuoka, 2008). The potential of genetically modified (GM) crops and other organisms can also be used for the current efforts developed to address the challenge of climate change. Other applications of molecular techniques include the production of non-protein (bioplastic) products or ornamental plants (Rozas et al., 2022). Many animals have also been genetically modified to increase their productivity and disease resistance. For example, salmon for increased size and faster reproduction, and cattle have been modified to gain resistance to mad cow disease (US Department of Energy, 2007).

Transgenesis is spreading rapidly in world agriculture in terms of cultivated area. According to the latest reports of the International Office for the Acquisition of Agro-Biotechnology Applications, in 2019, an area of 190.4 million hectares was cultivated with GMOs in a total of 29 countries, with the Americas being the continent with the largest cultivated area in the world. The most widely cultivated GM crops are soybean, maize, cotton and canola, which account for about 99% of the world's GMO-cultivated area (ISAAA, 2019; Rozas et al., 2022).

Along with the process of transgenesis, new technologies have been developed in the last decade that allow editing the genome or modifying its expression in the target organism in a precise, rapid and relatively cheaper way than other techniques coined under the acronym "NBT" ("new cultivation techniques") (Xu et al., 2019). Currently, the three most widely used NBTs are zinc ring domain-associated nucleases (ZFN), transcription activator-like effector nucleases (TALEN), and the bacterial system of clustered regularly interspaced short palindromic repeats (CRISPR) related nucleases Cas9, Cas12, or Cpf1 (Zhang et al., 2020).

In the European Union, genetically modified organisms (GMOs) and genetically modified microorganisms (GMMs) are defined respectively under **Directives 2001/18/EC** on the deliberate release of GMOs and **2009/41/EC** on the operation of GMMs under controlled conditions. European Union (EU) regulations set high standards of biosafety for human and animal consumption, environmental impact and consumer interests as set out in the first article of **Regulation 1829/2003 EU** and provide a framework for citizen participation. Levels of control in the EU regarding GMO cultivation applications are such that in more than two decades only two biotech cultivation events have been approved, and in recent years only one has been cultivated in Spain and Portugal (insect-resistant maize MON810) (Rozas et al., 2022).

In accordance with the legislation

a GMO/GMM is defined as "an organism/microorganism in which the genetic material has been altered in a way that does not occur naturally through mating and/or natural recombination".

This definition is an integral part of a series of applications which list techniques: which result in genetic modification; which are not considered to result in genetic modification; or which result in genetic modification but produce organisms that are excluded from the scope of the directives.

Therefore, a new organism will only fall within the scope of the GMO regulation if it has been developed using certain techniques. With the advancement of scientific knowledge, techniques have emerged that are applied to the genetic modification of organisms that may challenge the current regulatory definition of GMOs, as it is not always clear whether products obtained through these techniques are subject to the prevailing European GMO legislation or no - for example, the new genome editing techniques that open up new avenues for the development and use of genetic modification. At the European level, several initiatives have been taken to evaluate some of these new techniques in the context of the existing legislative framework.

The Biosafety and Biotechnology Division (SBB) actively contributes to this work. Countries' regulatory frameworks, despite their differences, can be classified as process-oriented or product-oriented (Ishii and Araki, 2017; Turnbull et al., 2021; Rozas et al., 2022). Alongside each country's regulations, the Cartagena Protocol, signed by more than 140 countries, represents an example of international law with binding legal principles for countries that have ratified it.

A comprehensive review of different aspects related with the transgenic plants is made by Orr (2009).

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Unit 2.4 Approaches for soil cultivation

Vera Petrova, Ovidiu Jerca

Introduction

Soil cultivation practices play a crucial role in agricultural systems as they directly impact soil health, fertility, and overall crop productivity. These practices involve various techniques and methods used to prepare, manage, and nurture the soil to create optimal conditions for plant growth. By implementing good soil cultivation practices, farmers can improve soil structure, nutrient availability, water-holding capacity, and biological activity, leading to healthier plants and higher yields. The introduction of good soil cultivation practices is essential for sustainable agriculture and the long-term viability of farming systems. It involves a combination of approaches that aim to preserve soil integrity, minimize erosion, maintain soil organic matter, and promote beneficial soil organisms.

Soil cultivation, also known as **soil tillage** or **soil preparation**, is a fundamental practice in agriculture that involves manipulating the soil to create favourable conditions for plant growth. It plays a crucial role in preparing the soil for seeding or planting and promoting optimal crop development.

These practices are not only environmentally friendly but also economically viable, as they contribute to improved crop performance and reduced input costs.

Implementing techniques to prevent soil erosion, such as contour plowing, terracing, and strip cropping, helps retain topsoil and protect against water and wind erosion. By preserving soil structure and preventing nutrient loss, these practices maintain the long-term fertility and productivity of the soil.

Adopting reduced tillage or no-till practices helps minimize soil disturbance, preserve soil structure, and reduce erosion. By leaving crop residues on the soil surface, these practices protect against water runoff and maintain organic matter levels. Conservation tillage also promotes water infiltration, enhances soil moisture retention, and reduces fuel and labour requirements.

By incorporating these and other best practices into their farming systems, farmers can enhance soil health, promote sustainable crop production, and preserve the long-term productivity of their land. Good soil cultivation practices not only benefit farmers by improving yields and reducing input costs but also contribute to environmental stewardship and the conservation of natural resources for future generations.

2.4.1 Tillage

Vera Petrova, Dorel Hoza

Tillage refers to the process of preparing agricultural soil through mechanical agitation, which involves activities like digging, stirring, and overturning. Human-powered tilling methods rely on hand tools and include practices such as shoveling, picking, mattock work, hoeing, and raking. On the other hand, draft-animal-powered or mechanized work involves techniques like ploughing (which includes overturning with moldboards or chiseling with chisel shanks), rototilling, rolling with cultipackers or other rollers, harrowing, and cultivating with cultivator shanks (teeth).

Tillage is the mechanical manipulation of soil to prepare it for crop cultivation by creating a favorable enabling environment for proper plant growth (Rahman, 2018).

Different kinds of organic matter, such as crop leftovers, manure, green manure, weeds, and stray crop plants, are incorporated into the soil through tillage. Despite the fact that some types of inoculum can be widely dispersed by implements, tillage methods often have indirect effects on the spread of plant infections. Tillage reduces populations of weeds and volunteer crop plants that harbor pathogens between crops.

It also buries plant pathogens from the top soil into deeper layers of the soil where they cause less or no disease. Practices involved in the preparation of seedbeds can greatly modify physical properties of soils such as moisture characteristics, bulk density, aeration and temperature profiles, which in turn influence the incidence of disease. Forming the soil into hills, ridges or raised beds provides better drainage and irrigation.

Tillage may also influence nutrient release mechanisms and the total effect is often expressed as increased crop vigor. Healthy plants may be more resistant to some pathogens but the more humid microclimate within the crop can be conducive to the spread of other pathogens. Through exposure to solar desiccation, subsequent tillage activities can lower the inoculum levels of several diseases. The practice of routinely cultivating the land in between crops has been replaced by limited tillage or even no-tillage in modern agriculture. Minimum tillage is a method of planting crops that involves no seedbed preparation other than opening the soil to place the seed at the intended depth.

Typically, soil cultivation is not done during crop production, and weed control is done using herbicides. Because mechanical tillage and hand weeding lessen damage to agricultural plant roots, opportunistic diseases have less opportunity to spread. It also reduces the spread of pathogens by tillage practices.

However, it may favor the development of some diseases such as those that can be controlled by burying inoculum too deep for infection of plant roots to occur. Crop leftovers are left on the soil's surface in no-tillage systems. The residues may become a food source for pathogens or alter the physical environment occupied by both the host and its pathogens.

The effect of tillage practices on the soil microflora is often overlooked. Many of these organisms are competitors or antagonists of soil-borne pathogens. Minimum tillage practices was thought to promote greater microbial antagonism near cereal roots than normal cultivation practices.

However, little is known about the influence of cultivation on these activities although incorporation of organic matter (e.g. green manure crops) is known to reduce the incidence of some diseases. Plant residues intensive the microbial activity of the soil, which may result in the formation of fungi toxic or even phytotoxic compounds (Ogle, 1997).

This website about physical control recommended the following practice of tillage (https://www.alberta.ca/physical-control-of-pests.aspx).

Pre-seeding tillage

Most weed seeds germinate more readily in early spring when there is just shallow tillage (less than 7.5 cm). The seedlings will be eliminated and a seedbed will be created by a second shallow tillage. If there is a lot of crop residue, use a disc-type implement. Less residue means that a cultivator or rod weeder will work. For weeds like wild oats, mustards, and hemp nettle that sprout in cool soils, this method works best.

Post-seeding tillage

Weeds that emerge concurrently with or shortly after grain crops, sunflowers, and potatoes will be controlled by this method.

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Post-seeding tillage should sometimes be avoided because it can seriously harm crops. For instance, **maize and vegetable inter-row cultivation** causes less damage than blanket cultivation when used as post-seeding tillage. However, it is a relatively safe technique to use a rod weeder to remove early emergent weeds from cereal crops when the crop sprouts are still below the depth of the weeder. With a harrow that destroys delicate, shallow-rooted weed seedlings, well-established cereals, sunflowers, and potatoes will sustain cultivation. On somewhat deep, hard soil where deeper seeding took place, tillage will be most successful.

Crop damage will differ depending on the kind of soil, the climate at the time of tillage, the crop being grown, and the depth of sowing.

Before crop emergence, cereal crops can be cultivated with a harrow or a rod weeder to manage newly emerged weed seedlings by sowing them 8 to 10 cm deep and at rates 25% higher than usual. This procedure should only be carried out as a last option because it is dangerous. Deep sowing raises worries about crop damage and an increase in disease. Fungicide use on cereal seed is recommended to reduce seedling disease. Before crop emergence, tillage must be done at a depth of no more than 5 cm and before crop sprouts are 2 cm long. Typically, this happens three to four days after seeding.

When the soil's surface is dry, weeds are most effectively controlled. If post-seeding tillage is used, some crop loss is unavoidable and should be acknowledged by the producer.

Post-emergence tillage

After emergence, 8 to 10 cm deep seeds of wheat and barley that are up to 25% heavier than usual can be harrowed. Before tillers form, till at the one to four leaf stage. You can move light harrows slowly and parallel to the seed rows. Crop maturity may be postponed by at least two or three days using post-emergent harrow tillage. During tillage, inspect the crop plants. Crop roots that are loosened, broken, or injured will sustain irreparable damage. If the crop is under stress, avoid tillage. This procedure will inflict more harm than the potential harm the weeds could do in a dry spring. Barley is typically more prone to damage than wheat. In fields with thick trash cover, post-emergent harrowing is not advised because the straw will jam the harrows and significantly harm the crops.

Inter-row tillage

In row crops like potatoes and sugar beets, tillage can lower weed levels. The first tillage should be early and shallow. Subsequent passes can be made if required. Take care to avoid **crop injury**.

Fall tillage

With early fall tillage, winter annual seedlings and some permanent weeds can be managed. To keep stubble in the Brown soil zones, use a blade cultivator. In the other soil zones, field cultivators can be utilized.

Avoid fall tillage and till early the following spring if the stubble is sparse. The timing of fall tillage varies depending on the type of weed. Fall tillage often takes place between crop harvest and soil freeze-up. Most weed management plans should include both fall tillage and a fall herbicide treatment because they are both particularly effective against winter annuals.(https://www.alberta.ca/physical-control-of-pests.aspx)

Conservation tillage is used primarily for soil and water conservation, but tillage can significantly affect arthropod pest and natural enemy abundance and diversity. Tillage can be used to control weeds, and is most successful when done on a warm day when weeds will wilt and die quickly. Annual and biennial weeds without extensive tap roots and perennial seedlings are readily destroyed by tillage. The ease of control increases with the age of the weed. Tilling also can be used to bring larvae and pupae of some insect pests onto the soil surface, where they may be exposed to desiccation, predation or freezing. The habitat for many overwintering insects and plant pathogens is destroyed by tilling under crop trash in the fall, which also serves to lower their populations the following year Prevention 2019.

Tillage can be also effective not only for the weeds control but it is an effective way to control pests.

Bajwa & Kogan (2003), recommended soil tillage as a part of field sanitation, it can be an effective direct means of pest control by itself.

Tilling the soil destroys life-cycle stages that occur in the soil or in crop residues. It destroys pests by mechanical action, starvation through debris destruction, desiccation and exposure to predators or adverse environmental conditions. Tillage may modify the soil microclimate, which will influence pest behavior and plant growth. Often tillage timing and depth are the major considerations for the management of soil-inhabiting animal pests and critical factors in weed management. Timing is usually determined when pests are in an immobile stage (pupation or dormancy), and depth is recommended by the location of this stage in soil. Generally, tillage may be conducted in the autumn or early winter and in the spring before planting. Soil-inhabiting pests such as rootworms, white grubs, wireworms and the overwintering larvae and pupae of *Lepidoptera* and *Coleoptera* may be exposed to desiccation or bird predation by ploughing. The pests that feed on stubble after harvest may starve if the ground is tilled. Deep ploughing after harvest buries infested plant parts and stubble and destroys the larvae of pests such as army worm, *Pseudaletia unipunctata* (Harworth) (Capinera, 2001); wheat-stem sawfly, *C. cinctus*; maize earworm, *Helicoverpa zea* (Boddie); European corn borer, *Ostrinia nubilalis* (Hübner); grape berry moth, *Endopiza viteana* Clemens (Herzog & Funderburk, 1986).

Curled larva of the armyworm, *Mythimna unipuncta* (Haworth). Photograph by Lyle J. Buss, University of Florida.

Wheat-stem sawfly, *C. cinctus*
Source: https://blog-crop-news.extension.umn.edu/2017/08/wheat-stem-sawfly-causing-problems-in_14.html

Larva of corn earworm, *Helicoverpa zea* (Boddie), darker form.
Credit: John L. Capinera, UF/IFAS

Larva of corn earworm, *Helicoverpa zea* (Boddie), light-colored form.
Credit: John L. Capinera, UF/IFAS

Mature larva of the European corn borer, *Ostrinia nubilalis* (Hübner). Photograph by John L. Capinera, University of Florida.

Endopiza viteana Clemens
Source:
https://www.virginiafruit.ento.vt.edu/GBM.html

In the case of the European corn borer, the ploughing of stubble may result in a 90% reduction of hibernating larvae (Horn, 1988). Shallow autumn tillage may provide up to 90% sawfly control (Steffey et al., 1992). If only spring tillage operations are performed, approximately 25% of larvae may be destroyed, depending upon the tillage implements used (Steffey et al., 1992). Reduced- or conservation-tillage practices may increase soil surface residues. These residues may have an impact on populations of certain pests. The presence of such residues repels the colonizing of a field by greenbugs, *Schizaphis graminum* (Rondani) in wheat and sorghum (Burton et al., 1987), but attracts black cutworms in maize (Steffey et al., 1992). Greenbugs prefer fields with more bare ground visible, while black cutworm prefers crop residue for oviposition. Reduced tillage systems may have higher soil moisture and be slower to warm up in the spring, thus reducing crop growth. This may add to damage from soil pests (wireworms, white grubs and other seed and seedling pests) by increasing their feeding time on young plants (Steffey et al., 1992). Biological control agents are often affected by tillage practices. Discing or harrowing has fewer negative impacts on the parasitoid population than does ploughing (Herzog and Funderburk, 1986). Parasitoids of the cereal leaf beetle, *Oulema melanopus* (Linnaeus), can be severely affected by tillage operations, which has little effect on the pest. Reduced-tillage systems may increase populations of various predatory arthropods by increasing populations of their prey, such as other insects, mites and organisms that feed on decaying organic matter. Increased levels of predatory insects and predation on black cutworms, *Agrotis ipsilon* (Hufnagel), and maize earworm, H. zea, have been observed in reduced-tillage systems. Tillage is not always advantageous and can actually aggravate some pest problems. For example, in some areas the soil surface tends to form a crust; keeping this crust intact can inhibit weed germination and/or prevent the penetration of soil-inhabiting pests. Serious side effects of tillage are loss of organic matter, especially in warm soils, and accelerated loss of soil to wind and water erosion if the soil is left bare for an extended period.

Schizaphis graminum (Rondani)
Source: https://www6.inrae.fr/encyclopedie-pucerons_eng/Species/Aphids/Schizaphis/S.-graminum

Agrotis ipsilon (Hufnagel)
Source:https://entnemdept.ufl.edu/creatures/veg/black_cutworm.htm

Oulema melanopus (Linnaeus)
Source:https://www6.inrae.fr/encyclopedie-pucerons_eng/Species/Aphids/Schizaphis/S.-graminum

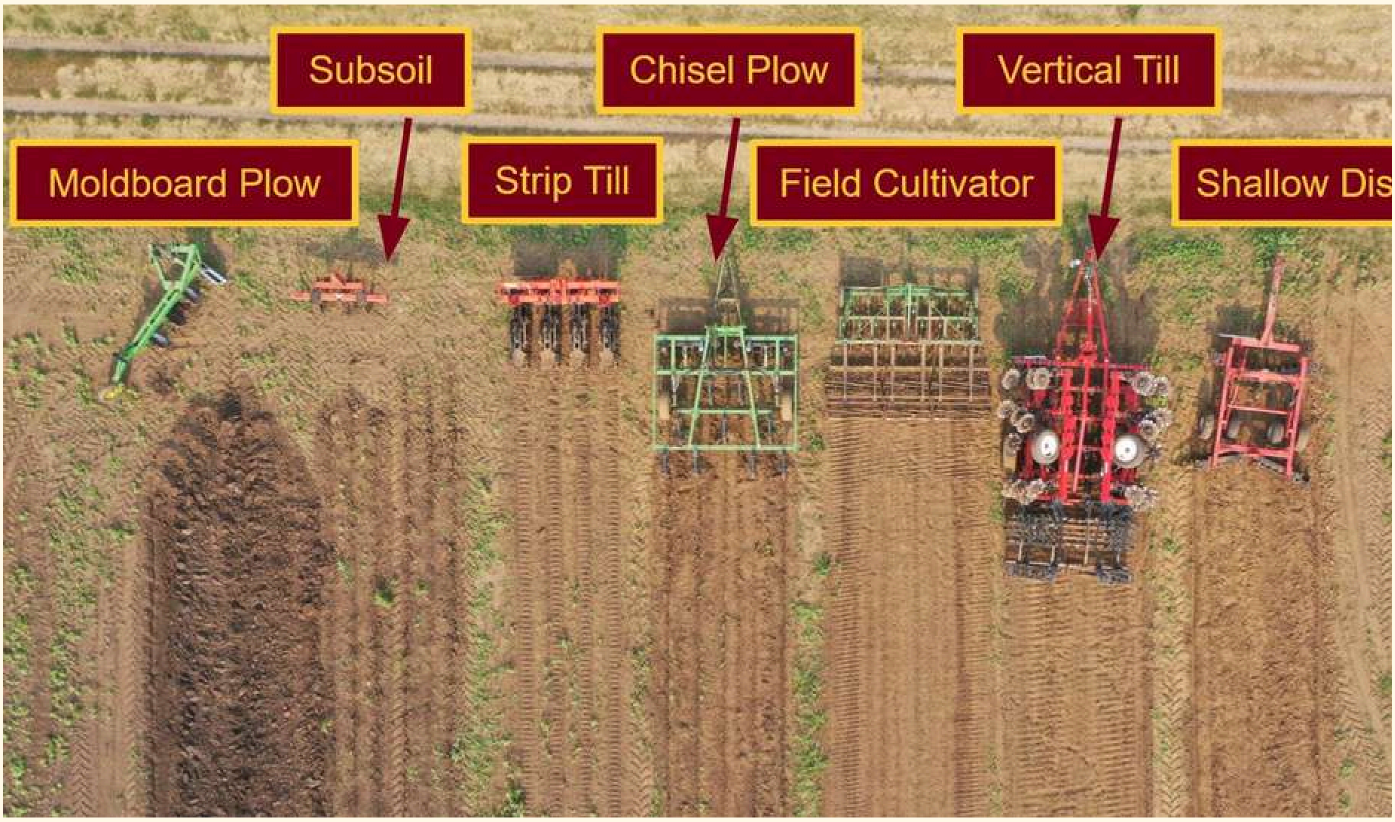
Caldwell et al., (2013) advice that maintaining untilled refuge strips may help sustain predator populations against Delia antiqua. Important predators of eggs, larvae, and pupae include many species of rove beetles (Coleoptera: *Staphylinidae*) and ground beetles (Coleoptera: *Carabidae*).

Tillage practices can have significant influences on arthropod populations, including natural enemies, and in turn pest management. A significant amount of research has been directed toward understanding the influence of reduced tillage systems on arthropods, including natural enemies. In some cases, conservation tillage has been shown to increase natural enemy populations, while in others they were either not affected, or reduced. Much of the work dealing with soil-dwelling insect natural enemies has focused on carabid beetles (Coleoptera: *Carabidae*), which are significant generalist predators in annual row-crop agricultural.

Tillage affects carabid populations through direct mortality from tillage events, or indirectly through loss of prey resources and changes in microclimate. Shearin et al., (2007) reported that entomophagous carabid beetles were more sensitive to tillage than herbivorous carabids. While diversity and abundance of carabids appears to be favored by reduced tillage, there are examples where entomophagous beetles are significantly more abundant in conventional tillage systems (Menalled, 2007). Interpretation of results of these studies is complicated by the sampling method employed.

Populations of carabids are usually sampled with pitfall traps with trap catches expressed as activity-density. However, there are significant constraints to using this method and care should be taken when designing studies and interpreting results. In addition, dispersal of beetles between experimental plots may mask treatment effects (Shearin et al., 2007).

More work appears to be needed to gain a clearer understanding of the effects of tillage on ground-dwelling arthropod natural enemies. What is less clear, and needs even more work perhaps, is the link between population changes in enemies from tillage practices and suppression of target insect pest populations.



Tillage has also been found to affect foliage dwelling arthropod predators either directly from soil disturbance, or indirectly by altering weed communities. This is especially important where natural enemies pupate in soil. For example, an outbreak of cereal leaf beetle, Oulema melanopus (Coleoptera: Chrysomelidae), in Canada was linked to a change in tillage practices that killed parasitoids of the beetle overwintering in the soil. In addition to tillage, other practices used to manage crop residues can affect natural enemies.

Several studies have shown that leaving crop residues behind, in cases where there is no good pest management (or other) reason to remove them through tillage or other means, can conserve populations of parasitoids and predators.

2.4.2 No till farming

Vera Petrova, Ana Butcaru, Marin Stoian, Mădălin Radu

No-till farming, also known as zero tillage or direct drilling, is an agricultural practice that involves cultivating crops or pasture without disturbing the soil through traditional tillage methods. By eliminating tillage, no-till farming minimizes soil erosion, particularly in sandy and dry soils found on sloping terrains. Additionally, this approach offers potential benefits such as increased water infiltration into the soil, retention of organic matter, and improved nutrient cycling. While conventional no-till systems rely on herbicides to manage weeds, organic systems employ alternative strategies like using cover crops as mulch to suppress weed growth.

In recent years, there have been successful demonstrations of growing small fruits and various vegetable crops without disturbing the soil. This non-cultivation approach has shown that crop yields are often unaffected and sometimes even slightly increased compared to traditional cultivation methods, particularly on different soil types.

Non-cultivation offers several advantages, including the potential for increased crop uniformity and yield by utilizing narrower row spacing's and innovative crop production techniques. It also avoids damage to surface-feeding roots, reduces the risk of frost, and facilitates mechanical harvesting of certain crops. In small-fruit plantations, the problem of weeds has significantly decreased after approximately three years of non-cultivation. This is because non-disturbance of seeds beneath the germination zone and the absence of a seedbed hinder weed growth. Although a surface crust may form on undisturbed soil, which could potentially affect plant growth in specific situations, recent experiments in Britain have not provided evidence that such a crust is detrimental to the growth of established plants.

Non-tillage, also known as no-till or zero-till, is a soil management practice where the soil is left undisturbed or minimally disturbed during the cultivation of orchard and vegetable crops.

However, there are some drawbacks to consider. Water infiltration on bare non-cultivated soil can sometimes be slowed, and increased runoff may occur on sloping sites. The effects of eliminating cultivation vary depending on soil types, climatic conditions, and crop responses, making it challenging to generalize the overall impact. Nonetheless, given the considerable advantages and the potential to overcome disadvantages, it is likely that non-cultivation practices will become more widespread in horticultural crop production in the future (Robinson, 1964).

Here's a description of non-tillage practices:

Soil Conservation

Non-tillage aims to conserve the soil by minimizing soil erosion and preserving soil structure. Instead of tilling the soil, crop residues from previous seasons are left on the surface. These residues act as a protective layer, reducing the impact of raindrops and preventing soil erosion. The undisturbed soil structure promotes the formation and stability of soil aggregates, which helps improve water infiltration and nutrient retention.

Reduced Soil Compaction

By avoiding mechanical tillage operations, non-tillage helps prevent soil compaction. Compaction can occur when heavy machinery compresses the soil, reducing pore space and impeding root growth and nutrient uptake. Non-tillage preserves the natural soil structure, allowing roots to penetrate more easily and facilitating better nutrient and water absorption.

Moisture Conservation

By avoiding mechanical tillage operations, non-tillage helps prevent soil compaction. Compaction can occur when heavy machinery compresses the soil, reducing pore space and impeding root growth and nutrient uptake. Non-tillage preserves the natural soil structure, allowing roots to penetrate more easily and facilitating better nutrient and water absorption.

Weed Management

Non-tillage can have implications for weed management. Without disturbing the soil, weed seeds are not brought to the surface, reducing weed germination and emergence. Additionally, crop residues on the soil surface can suppress weed growth by blocking sunlight and creating a physical barrier. However, additional weed control measures such as the use of herbicides or cover crops may be necessary in conjunction with non-tillage practices.

Nutrient Management

Non-tillage can impact nutrient management in orchard and vegetable crops. Crop residues left on the soil surface gradually decompose, returning organic matter and nutrients to the soil. This organic matter improves soil fertility and enhances nutrient cycling, benefiting crop growth and reducing the need for synthetic fertilizers. However, careful nutrient management practices, including appropriate fertilizer application techniques, are essential to ensure optimal nutrient availability for the crops.

Energy and Cost Savings

Non-tillage practices often require less energy and labor compared to conventional tillage methods. The reduced use of machinery and fuel leads to cost savings for farmers. Additionally, time saved from reduced tillage operations can be allocated to other farm management activities.

Non-tillage practices offer several advantages in orchard and vegetable crop production, including improved soil conservation, reduced soil compaction, moisture retention, and potential cost savings. However, successful implementation requires careful planning, adaptation to specific crop and soil conditions, and consideration of integrated weed and nutrient management strategies.

Source: https://www.pennington.com/all-products/agriculture/resources/why-use-a-cover-crop

Non-tillage practices in agriculture can have implications for pest control. This practices, such as zero tillage or direct drilling, involve minimal disturbance of the soil, which can preserve the natural habitat and microenvironments for beneficial organisms. This can create a favorable environment for natural predators and parasites that help control pest populations.

Non-tillage often involves leaving crop residues on the soil surface, which acts as a physical barrier and impedes the movement and establishment of certain pests.

Crop residues can make it more difficult for pests to access plants, reducing the risk of infestations. By minimizing soil disturbance, non-tillage practices can inhibit the emergence of certain pests from the soil. For example, some insect pests overwinter in the soil, and non-tillage can disrupt their life cycle by maintaining undisturbed soil conditions.

Non-tillage systems may require alternative weed management strategies compared to traditional tillage. While conventional no-tillage systems often rely on herbicides for weed control, organic non-tillage systems may utilize practices like cover cropping, crop rotation, and mulching to suppress weeds naturally. Effective weed management is essential to minimize competition between weeds and crops, which can indirectly reduce pest pressures.

It's important to note that certain pests may adapt to non-tillage systems. For example, some insects and diseases may find refuge in crop residues or undisturbed soil, potentially leading to localized pest outbreaks. Monitoring and implementing integrated pest management (IPM) strategies are crucial to address such situations and maintain pest populations at acceptable levels.

Overall, non-tillage practices can have both direct and indirect effects on pest control. By promoting a balanced ecosystem and minimizing disturbances to the soil, non-tillage can contribute to natural pest suppression and reduce the reliance on chemical interventions. However, proper monitoring and adaptation of pest management strategies are necessary to address potential challenges and optimize pest control in non-tillage systems.

2.4.3 Non-inversion tillage

Vera Petrova

Non-inversion tillage refers to a specific type of tillage practice in agriculture that involves minimal disturbance of the soil structure. Non-inversion tillage aims to preserve the natural arrangement and layers of the soil. This technique is characterized by shallow tillage or surface disturbance, typically limited to the top few inches of soil. It may involve methods such as strip-tilling, minimum tillage, or reduced tillage, where only specific areas or zones of the field are tilled while leaving the remaining soil undisturbed.

Non-inversion tillage, also known as conservation tillage or minimum tillage, is a soil management practice that involves reducing or eliminating deep soil inversion and disturbance during the cultivation of orchard and vegetable crops.

Here are some key points about non-inversion tillage:

Soil Conservation

Non-inversion tillage aims to minimize soil erosion and promote soil conservation. By reducing the intensity of tillage operations, soil structure and organic matter content are preserved, helping to prevent soil erosion and maintain soil health.

Water Conservation

Non-inversion tillage can contribute to water conservation by improving water infiltration and reducing runoff. The presence of crop residues or cover crops on the soil surface helps to retain moisture, enhancing water-holding capacity and reducing water loss through evaporation.

Weed Management

Non-inversion tillage can have implications for weed management. By minimizing soil disturbance, it can help to prevent the germination and emergence of weed seeds. The use of cover crops or mulching in non-inversion tillage systems can further suppress weed growth and competition.

Soil Structure and Aeration

Non-inversion tillage practices contribute to maintaining soil structure and porosity. The reduced disturbance preserves soil aggregates and pore spaces, promoting better root penetration, nutrient uptake, and soil aeration. Improved soil structure enhances the soil's capacity to retain water and nutrients.

Organic Matter Management

Non-inversion tillage can help preserve and increase soil organic matter content. Crop residues left on the soil surface decompose slowly, adding organic matter to the soil. Higher organic matter levels enhance soil fertility, nutrient cycling, and microbial activity, benefiting overall plant growth and soil health.

Energy and Cost Savings

Non-inversion tillage often requires less machinery and fuel compared to conventional tillage practices, resulting in energy and cost savings for farmers. Additionally, reduced tillage operations can lead to time savings and increased efficiency in farm operations.

It's important to note that the applicability of non-inversion tillage practices may vary depending on factors such as soil type, crop type, and specific regional conditions. Successful implementation requires careful consideration of the crop's specific needs, weed management strategies, and adaptation to local conditions.

Non-inversion tillage systems can offer sustainable alternatives to traditional tillage practices, promoting soil conservation, water management, and overall agroecosystem health in orchard and vegetable crop production.

2.4.4 No-dig gardening

Vera Petrova, Viorica Lagunovschi

No-dig gardening, also known as no-till gardening or no-tillage gardening, is a gardening method that emphasizes minimal disturbance to the soil. The no-dig gardening method is one employed largely by growers of organic vegetables, though it applies to ornamental plants, too.

Rather than using traditional digging methods to remove weeds, the no-dig gardening approach involves applying organic matter, such as garden compost or well-rotted manure, directly onto the soil surface. This mimics natural decomposition processes, where plants naturally die back and leaves naturally fall to the ground. Instead of being incorporated by digging, the organic matter is left on the surface to be broken down and incorporated into the soil by plants, fungi, and soil organisms.

By adopting this method, the soil structure remains undisturbed, avoiding disruption to worms and other organisms that make up the soil ecosystem. This preserves the overall health and integrity of the soil. Additionally, growing vegetables in no-dig soils often leads to higher yields. This makes it an attractive option, especially for busy gardeners who have limited time and prefer not to spend hours digging beds and borders.

Trials have shown that no-dig beds generally yield larger vegetable harvests compared to those that are regularly dug over. However, it's important to note that this may not always be the case, as certain crops like potatoes often perform better in traditionally dug soils. Embracing the no-dig gardening method offers the advantage of saving time on digging, weeding, and watering, which is particularly beneficial for busy growers. Digging can inadvertently bring weed seeds and roots to the surface, allowing them to germinate and grow.

By avoiding digging, these weeds remain undisturbed. Additionally, applying a layer of organic matter, such as well-rotted manure or garden compost, on the soil surface acts as a mulch that suppresses weed growth, making it more challenging for weeds to emerge. While no-dig gardening doesn't completely eliminate weeds, the mulch weakens perennial weeds, and regular removal of emerging weeds can help keep them in check.

Mulching the soil through the no-dig approach helps retain moisture, reducing the need for frequent watering. Furthermore, it can contribute to improved drainage. Digging, especially on heavy soils, can lead to soil compaction, hindering water permeation and resulting in water pooling or runoff. By mulching instead of digging, water can reach where it's needed more effectively.

Digging causes the carbon stored in the soil to oxidize and release as carbon dioxide. By avoiding digging, carbon remains sequestered in the soil, providing a positive contribution to limiting climate change.

In areas with clay soil, heavy rain can turn the garden or allotment into a muddy mess, making gardening difficult. However, compost mulch doesn't become sticky like cultivated soil, allowing for easier gardening as soon as the surface dries out a bit. No-dig beds have a firm yet open structure, enabling walking on them without compacting the soil or getting boots covered in mud.

Not only does adopting a no-dig approach save time by eliminating extensive digging, but it also leads to earlier planting and sowing. Undug soil retains higher temperatures during winter and early spring compared to dug or forked soil. This early warming is particularly advantageous in colder regions with shorter growing seasons. It also benefits by enabling the cultivation of crops that require a longer growing season, helping to prevent issues like blight and allowing for successive crops in the same space once the ground is cleared. By refraining from digging, you protect the diverse organisms residing in the soil, including mycorrhizal fungi. These fungi form a symbiotic relationship with plant roots, assisting in nutrient and moisture uptake. The majority of soil life is concentrated near the soil surface, facilitating easy access for new roots. However, when you dig, there is a risk of displacing these organisms deep into the soil, making them inaccessible to your plants. Applying garden compost as a mulch nourishes these organisms, ensuring their abundance. This practice mimics natural processes, where worms and other soil life consume organic matter on the surface and release it into the soil through their excrement. As a result, seedlings planted in undug soil establish themselves more rapidly and thrive, developing into robust and healthy plants.

How to get started tricks and tips:

Remove the unwanted weeds from your garden plot either by using a hoe to cut them or by pulling them out manually. Certain persistent weeds such as brambles and docks may require digging to completely eradicate them. In cases where there is a significant presence of established weeds, you can employ a method by covering the soil surface with cardboard and then applying a layer of compost mulch. Alternatively, if the weed growth is minimal, a 5cm layer of well-rotted compost directly on the soil will suffice.

Apply composted garden waste, composted wood chips, leaves, or well-rotted manure as a mulch on your garden soil. These materials are beneficial for improving soil fertility and structure. However, it is advisable to avoid using un-decomposed mulches like straw, as they can create a favorable environment for slugs and snails to thrive.

Create distinct beds within your vegetable plot, leaving pathways in between for convenient access. By mulching the planting areas, the beds will naturally become slightly elevated and clearly defined. Another option is to cultivate your vegetables in raised beds, which provide additional benefits.

Sow or plant directly into your compost mulch – seedlings love it.

Maintain weed and grass-free paths by using cardboard as a barrier. Lay down cardboard sheets to cover the path areas, preventing weed growth and minimizing the need for frequent weeding. This method helps to keep your paths tidy and reduces the competition between plants and unwanted vegetation.

Nourish the soil organisms by applying an additional layer of mulch once a year, preferably in late autumn after the last harvest. Spread a 3-5cm thick layer of compost over the beds, without the need for sieving. Simply use a fork to break up any larger lumps and evenly distribute the compost across the surface. This replenishes the organic matter in the soil and provides a nutrient-rich environment for the soil life to thrive

Source: https://www.gardenersworld.com/how-to/grow-plants/no-dig-gardening-guide/.

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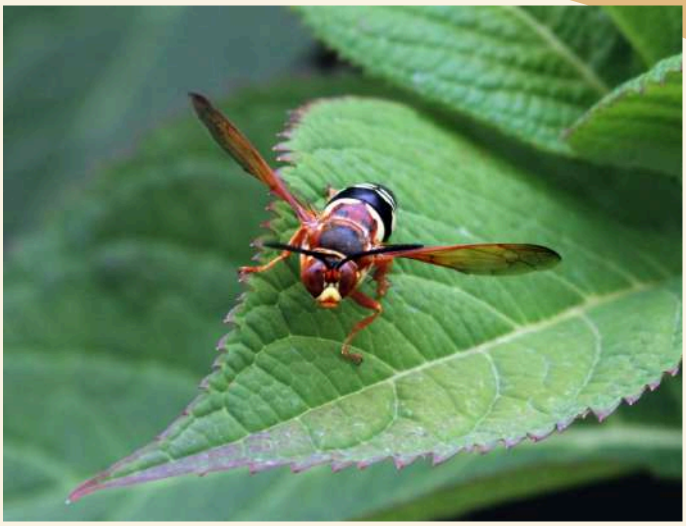













Unit 2.5. Soil disinfestation

Rumen Tomov, Ovidiu Jerca, Lilyana Koleva

2.5.1 Soil solarization

Soil solarization is a term that refers to disinfestation of soil by the heat generated from trapped solar energy (DeVay et al. 1991). According to DeVay et al. (1991) The Soil solarization is a hydrothermal process that takes place in moist soil which is covered by plastic film and exposed to sunlight during the warm months. The process of solar heating of the soil is known as soil solarization, and encompasses the entire complex of physical, chemical, and biological changes in soil associated with solar heating and has value as an alternative to the use of certain agricultural chemicals that will be phased out of agricultural usage.

Soil solarization is a non-chemical method for control of certain soil-borne pests, pathogens, and weed seeds. Solar-heating of soil requires the capture of incoming solar radiation beneath clear plastic sheeting laid out on the soil surface and it is usually enhanced by moistening the soil either before the plastic sheets are rolled out or by using drip irrigation lines beneath the plastic. While this is not a new technology, with the gradual elimination of methyl bromidethe frequency and scale of its use is growing (Weintraub, 2009).

A review of development and practice of this method is presented by Katan (1981). The process involves covering moist soil with clear plastic during the hot summer months when temperatures are high and leaving it in place for several weeks creating high temperatures within the soil.

Soil solarization can be effective in controlling several horticulture pests in Europe, particularly those that are sensitive to high temperatures. The limitations of this method stem from its dependence on climate and it can therefore be used only in certain climatic regions and during limited periods of the year. Gamliel and Katan (2005). This technique is particularly suitable for the Mediterranean climate, where the occurrence of high summer temperatures can ensure an effective control of fungi, nematodes and weeds (Shlevin et al., 2003; Oka et al., 2007; Roe et al., 2004).

Solarization repeated for two or more consecutive years could improve the effectiveness of thermal treatment on heatresistant weed species or on root-knot nematodes (Meloidogyne spp.), that easily survive and reinfest the soil after a single solarization treatment (Rubin & Benjamin, 1983; Stapleton & DeVay, 1995).

In addition, during solarization, the soil remains without a crop for several weeks (Gamliel &Katan, 2005).

Some pests and pathogens that can be controlled by soil solarization in Europe include:

Soil-borne pathogens
Soil solarization can help reduce populations of various soil-borne pathogens, such as fungi, bacteria, and nematodes.

Aitkenhead, & Moody, (2017). Katan, et al. (1987). Pathogen and disease control are attributed to microbial, chemical, and physical processes in addition to the thermal killing. These occur in the soil during the solarization treatment and even after its termination. (Katan & Gamliel 2014). Under appropriate conditions, many soilborne pathogens such as fungi (e.g., *Verticillium*, *Fusarium*, *Phytophthora*, *Pythium*, *Pyrenochaeta*), are controlled by soil disinfestation and consequently yields are increased Gamliel & Katan (2005).

It is particularly effective against soil-borne diseases like *Pythium*, *Fusarium*, *Phytophthora* and *Verticillium*. This heating has a profound impact on soil microbial communities, and can cause the death of plant pathogens, especially those that cannot endure temperature above 37–40 °C. (Mohammadiani & Bakker 2022). An effective integration of solarization treatment with a variety of organic amendments, such as composts, crop residues, green manures, and animal manures, was reported for the control of soilborne pathogens (Kodama & Fukui 1982; Freeman & Katan 1988; Gamliel & Stapleton 1993; Chellemi et al. 1997).

Weeds

Soil solarization can suppress weed growth by heating the soil and killing roots and weed seeds near the surface. This can reduce weed pressure in horticultural crops. According to Candido et al., (2008) Repeated solarization treatments also resulted in a high reduction of emergence of most weed species in all crop cycles. A single soil solarization treatment was shown to be effective for a long-term sustainable management of weeds.

Nematodes

Root-knot nematodes (*Meloidogyne spp.*) and other plant-parasitic nematodes can be affected by exposing the soil to high temperatures, which can kill the nematode eggs and larvae.

Soil-dwelling insect pests

Some soil-dwelling pests, such as wireworms and cutworms, onion maggot (*Delia antiqua*), can be controlled to some extent by soil solarization, especially in the upper layers of the soil (Seo et al. 2015).

Soil solarization is most effective in warm and sunny regions, where the heat generated under the plastic sheets can reach lethal levels for pests and pathogens. It is typically performed during the hottest months of the year to maximize the effectiveness of the treatment. However, its efficacy may vary depending on factors such as the duration and intensity of solarization, soil type, and pest species.

It's important to note that soil solarization is a preventive method and may not be suitable for all pest control scenarios. It is most effective in situations where pest pressures are localized and the soil can be adequately covered with plastic sheets. Integrated pest management practices, including crop rotation, resistant cultivars, and other cultural and biological control methods, should be combined with soil solarization to achieve sustainable pest management in European horticulture.

Gamliel & Katan (2005) summarize the principles of soil solarization as follows:

- Solarization heats the soil through repeated daily cycles. At increasing soil depths, maximal temperatures decrease, are reached later in the day, and are maintained for longer periods
- The best time for soil mulching, i.e., when climatic conditions are most favorable, can be determined experimentally by tarping the soil and measuring the temperatures.
- Adequate soil moisture during solarization is crucial to increase the thermal sensitivity of the target organisms, improve heat conduction in the soil, and enable biological activity during solarization.
- Proper preparation of a soil ready for planting is essential. This is the case because, after plastic removal, the soil should be disturbed as little as possible to avoid recontamination;
- The soil is mulched with thin, transparent polyethylene sheets or other plastic material. Another method of solarization involves a closed glasshouse (or plastic house), provided climatic conditions are suitable and the soil is kept wet. Novel technologies such as the use of **sprayable plastics** can replace plastic mulching of the soil;

- Successful pathogen control in various regions of the world is usually obtained within 20–60 days of solarization. Extending the solarization period enables control in deeper soil layers, as well as of pathogens that are less sensitive to heat;
- Solarization causes chemical, physical, and biological changes in the soil that affect pest control, plant growth, and yield.

Detailed description of the method is presented by D'Addabbo et al. (2010) and Ali et al. (2018). Soil solarization can be an effective and environmentally friendly method for pest control in horticulture. However, its effectiveness may vary depending on factors like the duration of solarization, soil type, and pest species.

Agrochemical remediation of farm soils by combining solarization and ozonation techniques is studied in the framework of LIFE17 ENV/ES/000203 | Acronym: LIFE AgRemSO3il
https://webgate.ec.europa.eu/life/publicWebsite/project/details/4930#eu-legislation

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Additional reading
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https://eos.com/blog/soil-solarization/
https://ipm.ucanr.edu/PMG/PESTNOTES/pn74145.html
https://cordis.europa.eu/article/id/429360-helping-farmers-to-keep-their-land-fertile
https://www.climate-policy-watcher.org/soil-solarization/conclusion-qyr.html

Hort4EUGreen

2.5.2 Soil heating

Rumen Tomov, Roxana Ciceoi, Lilyana Koleva

Soil heating is a method of controlling soil-borne pests using heat generated by machines or electrical elements that raising the soil temperature to lethal levels.

Soil heating can be achieved through various methods, including steam sterilization, using soil heating cables or mats, or using hot water. This type of soil treatment can be useful for controlling certain pests in greenhouse production or in areas where other control methods are unsuccessful. Soil heating has been shown to be effective against several horticulture pests in different regions worldwide, and some pests in Europe that can be controlled or managed by soil heating include:

Soil-borne pathogens

Soil heating can effectively control various soil-borne pathogens, such as fungi, bacteria, and nematodes. It can reduce the incidence of diseases caused by pathogens like Pythium, Fusarium, and Verticillium. Some examples for reduction of pest population are as follows:

- reduced Verticillium wilt (*Verticillium spp.*) severity and increased tomato yield in steam-treated plots. (Matlack et al., 2016);

- reduced Fusarium wilt (*Fusarium oxysporum f. sp. radicis-lycopersici*) severity and improved tomato yield in steam-treated plots. (Aichinger et al., 2015);
- reduced clubroot (*Plasmodiophora brassicae*) severity and improved the growth of cabbage and cauliflower in steam-treated plots. (Kalinina et al., 2018).

Weeds

Soil heating can help suppress weed growth by killing weed seeds near the soil surface. This can reduce weed pressures in horticultural crops. Some examples for reduction of pest population are as follows: soil heating at 60-70°C for two hours significantly reduced field bindweed (*Convolvulus arvensis*) populations and improved lettuce yields in treated plots. (Gelsomino et al., 2006); soil heating at 55°C for four hours significantly reduced blackgrass (*Alopecurus myosuroides*) seed viability and reduced the emergence of blackgrass plants. (Ritz et al., 2008); soil heating at 70-85°C for two hours reduced the growth of amaranth plants (*Amaranthus spp.*) and improved the growth of lettuce in treated plots. (Gelsomino et al., 2014); soil heating reduced knotweed (*Fallopia japonica*) populations by up to 99%, with no regrowth observed in the treated areas. (Preston et al., 2015); soil heating at 60°C for six hours significantly reduced black medick (*Medicago lupulina*) populations and improved lettuce yield in steam-treated plots. (Huiting et al., 2014).

https://www.first-nature.com/flowers/convolvulus-arvensis.php

https://www.ncl.ac.uk/press/articles/archive/2018/06/blackgrass/

https://plantvillage.psu.edu/topics/amaranth/infos

https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.23875

https://plantsam.com/medicago-lupulina/

Soil-dwelling insect pests

Some soil-dwelling pests, such as root maggots and wireworms, can be controlled by soil heating, especially in the upper layers of the soil. Some examples for reduction of pest population are as follows: soil heating at 55-60°C for one hour significantly reduced wireworm (*Agriotes spp.*) populations and improved lettuce yields in treated plots. (McCaffrey et al., 2012); soil heating at 50-60°C for one hour significantly reduced frit fly (*Oscinella frit* and *O. pusilla*) populations in treated areas, resulting in reduced crop damage. (Cloquell-Ballester et al., 2020); soil heating at 45-60°C for one hour significantly reduced carrot fly (*Psila rosae*) emergence from treated soil, resulting in reduced crop infestations. (Andrews et al., 2013)

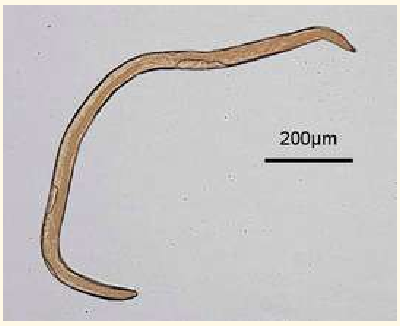
Agriotes spp.
Source here

Oscinella frit
Source here

Psila rosae
Source here

Nematodes

Soil heating can effectively reduce populations of plant-parasitic nematodes, which can cause damage to various horticultural crops. Some examples for reduction of pest population are as follows: Soil heating at 50-60°C for one hour reduced root knot nematode (*Meloidogyne spp.*) populations and improved cucumber yields in treated plots. (Ploeg et al., 2009); soil heating at 45-50°C for one hour reduced citrus nematode (*Tylenchulus semipenetrans*) populations and improved the growth of citrus trees in treated plots. (Schmutterer et al., 1985)



Meloidogyne spp.
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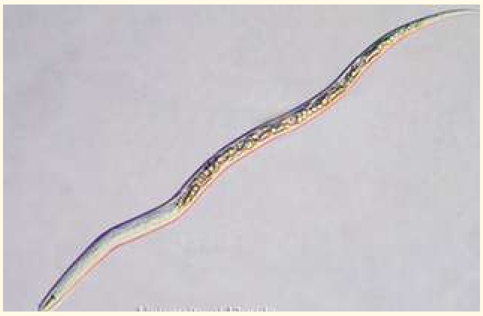

Tylenchulus semipenetrans
Source here

Soil-dwelling insects in diapause

Soil heating can disrupt the diapause (dormancy) of certain soil-dwelling insect pests, preventing them from completing their life cycle. Some examples for reduction of pest population are as follows: soil heating at 55°C for two hours significantly reduced western flower thrips (*Frankliniella occidentalis*) pupae populations and improved chrysanthemum yield in treated plots. (Barbosa Bellini et al., 2017); soil heating at 50-70°C for four hours significantly reduced onion fly (*Delia antiqua*) pupae populations and improved onion bulb yield in treated plots. (Miyazawa et al., 2014); soil heating at 60-80°C for two hours reduced carrot fly (*Psila rosae*) pupae populations and improved carrot yield in treated plots. (Knight et al., 2007).

Frankliniella occidentalis
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Tylenchulus semipenetrans
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Soil heating has been found to be effective in controlling thrips larvae in potted plants and greenhouse production. Lee & Shin (2021) and whitefly larvae and pupae population, reducing adult populations and damage levels (Oliveira et al. 2013).

While soil heating can be effective in controlling certain pests in horticulture production systems in Europe, it is not a commonly used method since it has limitations in certain settings, it can be expensive and the high temperature required for effective control can cause damage to beneficial microorganisms in the soil as well as root damage to some crops.

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2.5.3 Soil steaming

Rumen Tomov

Soil steaming is a method of controlling soil-borne pests and diseases by exposing the soil to high temperatures using steam generated by boilers or electrical elements.

This type of soil treatment can be useful for controlling certain pests and diseases in horticultural production systems with limited effects on soil microorganisms. While soil steaming can be effective for controlling various pests and pathogens, its specific effectiveness in European horticulture may vary depending on the pest species, soil type, and environmental conditions.

Here are some examples of pests that can be managed through soil steaming in horticultural production systems in Europe:

Soil-borne pathogens

Soil steaming can effectively control various soil-borne pathogens, such as fungi, bacteria, and nematodes. It is particularly effective against diseases caused by pathogens like *Pythium*, *Fusarium*, and *Verticillium*. Soil steaming has been found to effectively control the populations of *Verticillium dahliae* and reduce the disease damage. (Kabir, 2019). Soil steaming can be effective against several soil-borne plant pathogens such as *Rhizoctonia solani*, *Pythium spp*., *Fusarium solani*, and *Phytophthora spp*., that affect a variety of horticultural crops including vegetables and ornamental plants (Harrewijn et al. 1991, Karim et al. 2019).

Weed seeds

Soil steaming can help suppress weed growth by killing weed seeds near the soil surface. This can reduce weed pressures in horticultural crops. Soil steaming can also help control weeds, as it kills weed seeds and seedlings in the top layer of soil. Some examples for reduction of pest population are as follows: reduced weed populations by up to 90% in a carrot field. (Van Os et al., 2001); reduced annual meadow grass (*Poa annua*) populations by 99% compared to non-steam-treated plots (Bloemhard et al., 2018); significantly reduced chickweed (*Stellaria media*) populations and allowed for the successful cultivation of lettuce with minimal weed interference. (Riemens et al., 2007); reduced field bindweed (*Convolvulus arvensis*) populations and allowed for improved growth and yield in strawberry fields. (Svendsen et al., 2002)

Poa annua
Source here

Stellaria media
Source here

Nematodes

Soil steaming can effectively reduce populations of plant-parasitic nematodes, such as root-knot nematodes (*Meloidogyne spp.*) and and lesion nematodes (*Pratylenchus spp.*) especially during the early growth stages of the crops (Scholberg & McSorley 2014, Kabir, 2019).

Soil-dwelling insects in diapause

Some soil-dwelling pests, such as root maggots and wireworms, can be controlled by soil steaming, especially in the upper layers of the soil. Some examples for reduction of pest population are as follows: reduced the population densities of carrot rust fliy (*Psila rosae*), by up to 90%, resulting in significantly higher carrot yields. (Van Os et al., 2001); soil steaming has been used to control the pupae of western flower thrips in soilless production systems in Europe; reduced western flower thrips (*Frankliniella occidentalis*) populations and improved plant growth in potted chrysanthemums. (Ruijven et al., 2004); reduced population densities of onion maggots (*Delia antiqua*) in onion crops by up to 63%, resulting in significantly higher onion yields. (Duchene et al., 2010)

It's important to note that while soil steaming can effectively control pests and pathogens, it may also affect non-target organisms, including beneficial soil microorganisms and natural enemies of pests. While soil steaming can be effective in controlling certain pests and diseases in horticulture production systems in Europe, it is a costly and energy-intensive process that can affect the soil structure and organic matter.

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Unit 2.6 Sowing, Planting

Vera Petrova,
Claudia Grigoraș

Sowing and planting are two essential processes in agriculture and gardening that involve the placement of seeds or young plants into the soil to initiate growth.

These practices mark the beginning of the crop production cycle and require careful consideration to ensure successful establishment and optimal plant growth.

Sowing refers to the process of placing seeds into the soil at the appropriate depth and spacing to promote germination and plant establishment. It is commonly used for crops that reproduce through seeds. The sowing method can vary depending on the crop, farming system, and equipment available. Some common sowing techniques include:

Broadcasting

This method involves scattering the seeds uniformly over the soil surface by hand or using mechanical seed spreaders. Broadcasting is suitable for small-seeded crops or those that require minimal precision in seed placement.

Drill Seeding

Drill seeding involves using a mechanical seed drill or planter to create furrows or rows in the soil and place seeds at a specific depth and spacing. This method allows for more precise seed placement and facilitates better seed-to-soil contact.

Hill Dropping

Hill dropping is commonly used for crops like vegetables or vine plants. It involves placing multiple seeds in small mounds or hills spaced at regular intervals. Once the seedlings emerge, they are thinned to leave only the strongest plant in each hill.

Transplanting

Transplanting involves starting seeds in a separate nursery or greenhouse and then moving the seedlings to the field once they have reached a certain size. This method allows for better control over plant spacing and reduces competition among seedlings.

Planting typically refers to the process of placing young seedlings or vegetative parts of plants (such as cuttings, bulbs, or tubers) into the soil for growth and development. It is commonly used for crops that reproduce asexually or when starting with pre-grown seedlings. Planting techniques vary depending on the crop and the type of plant material being used. Some common planting methods include:

Direct Planting

Direct planting involves placing young seedlings or vegetative parts directly into the soil at the desired planting distance. This method is commonly used for crops like vegetables, fruits, and trees. It is important to handle the plants carefully to minimize damage to the roots or stems during planting.

Plug Planting

Plug planting involves using pre-grown seedlings or rooted cuttings that are grown in individual containers or cells.

These seedlings are transplanted into the field by placing them directly into the prepared planting holes. Plug planting allows for efficient use of space and ensures uniform plant spacing.

Division

Division is a planting method used for perennial plants that naturally produce clumps or clusters. It involves dividing the plant into smaller sections, each with its own set of roots, and replanting them in separate locations. This method is commonly used for herbaceous perennials and ornamental plants.

Bulb/Tuber Planting

Bulb and tuber planting involves placing bulbs, tubers, or corms directly into the soil at the appropriate depth. These specialized plant structures contain stored nutrients and buds that will develop into new shoots and roots. Examples of crops planted using this method include tulips, potatoes, and dahlias.

Proper sowing and planting practices consider factors such as soil conditions, weather, crop requirements, and recommended planting depths and spacing. By following appropriate techniques, farmers can ensure good seed-to-soil contact, promote uniform emergence and growth, and establish a strong foundation for successful crop production.

Conversely, late planting can also have benefits for managing specific pests. Delaying wheat planting until after the lifespan of adult Hessian flies, the vectors of Hessian fly infestations can prevent damaging infestations. Late planting of crops can interfere with colonization patterns of certain pests, such as soybean thrips and the bud-blight virus. Furthermore, adjusting harvest time can reduce pest populations or damage. Early harvesting of sorghum removes a significant portion of stem borer populations, while early clipping of lucerne at specific growth stages can minimize damage from potato leafhoppers and lucerne weevils.

In summary, manipulating the timing of planting and harvest can be an effective strategy to disrupt pest phenology, reduce damage, and enhance crop management. However, it's important to consider the specific pests, crops, and ecological factors in each situation, as the effectiveness of these practices may vary (Bajwa and Kogan 2004).[L1]

2.6.1 Sowing time

Rumen Tomov,
Ana Butcaru

Sowing time refers to the specific period or season during which seeds are planted or sown in the soil to initiate the growth of crops or plants. It is an important factor in agricultural and horticultural practices as the timing of sowing can significantly influence the success and productivity of the crop.

The optimal sowing time may vary depending on the geographical location and local conditions. Farmers and gardeners often rely on local agricultural extension services, climate data, and their own experience to determine the best sowing time for their specific region and crop.

By choosing the right time for sowing, transplanting and planting, control over certain pests can be achieved. In order to determine the appropriate time, monitoring is needed, and it is good to keep a diary and record dates of unfavorable periods - falling frosts, multiplication of enemies and more.

Zehnder et al. (2007) describe four phases in the strategy for arthropod pest management in organic crops. The timing of sowing, planting and transplanting is one of the practices that are indicated for prevent or avoid pests as make the crop unavailable to pests in space and time through knowledge of pest biology.

The timing should be chosen so that the most sensitive phases of plant development do not coincide with the peak periods of spread of infection, flying vector insects, development and multiplication of a pest. For example, plant cabbage in late spring to avoid infestation with larvae.

The choice of timing should be in line with crop requirements - eg heat-loving species should be sown after the soil has warmed to speed up germination and reduce problems with seed rot, seedling blight and root rots. On the other hand, many crops can be sown or planted earlier to miss severe pest infestations. In the cultivation of vegetables, earlier sowing or planting than normal can be achieved by using cold frames or hot hats to protect plants. Thus, the crop will develop earlier and will have a competitive advantage over pests (Hillock & Borthick, 2004). But for this purpose it is necessary to know the time of emergence and life cycle of pests that need to be controlled (Hillock & Borthick, 2004).

According to Caldwell et al. (2013), delaying planting until soils are warmer can be a smart strategy to avoid peak spring emergence because the seed corn maggot prefers early spring and chilly soils. If infestation has been a persistent issue.

Delayed planting should be done with caution because onions must have good size by the long days of June in order for bulbs to reach proper size.

Earlier planted tomatoes are far less likely to be infested by the tomato fruitworm, *Helicoverpa zea*, than those planted later in the season. Early sweet potato planting and harvesting is useful in white-fringed beetle, *Naupactus spp.*, management programmes. These pests cause damage to roots late in the season, therefore, harvesting the crop before larvae reach sufficient size to cause serious feeding damage reduces the proportion of damaged and unmarketable roots at harvest.

Timing of seeding and planting cant be used largely to:

- avoid invasion by migrants, or the oviposition period of particular pests, and the introduction of disease in the crop by insect vectors;
- to synchronize the pest attack with its natural enemies, with weather conditions that are adverse for the pest or with the abundance of an alternative host;
- to make it possible to destroy the crop before the pest enters diapause.

Timing can be used to allow young plants to establish to a tolerant stage before attack occurs, to reduce the susceptible period of attack, to mature the crop before a pest becomes abundant, to allow it to compensate for damage and to fill gaps where plants have been damaged or killed, and to avoid the egg-laying period of a particular pest.

2.6.2 Seed/plant density

Rumen Tomov,
Roxana Ciceoi

Seed/plant density refers to the number of seeds or plants present within a given area of land. It is a measure of how closely spaced the seeds or plants are in a specific planting arrangement. Seed/plant density is an important consideration in agriculture and gardening as it can affect crop productivity, resource utilization, and overall plant growth.

Plant density is a straightforward but crucially significant factor that connects people to crops. Simply put, plant density is the number of people per square meter of ground (Benjamin, 2017).

Planting density and distances between plants is an element of agricultural technology and is from the so-called preventive measures against pests. The density of a plantation depends on the distances of the plants between the rows and inside the row, on the way the plants grow - how fast they grow, whether they form a large vegetative mass, etc.

It has been noted that crop planting density affects the dynamics of insect populations. (Akinkunmi, 2012). According to authors, the severity of insect infestation increased with increase in plant spacing.

The experiment with sunflowers show that introducing planting space will reduce the population of insects as well as reduce damage, which will increase the yield of the crop.

The relative rate of growth of the plant and its pest population per unit of time, as well as the behavior of the insect pest when looking for food or a place to lay its eggs, can all be impacted by spacing. The effectiveness of planting density based on Hills (2004) observation, shows that close spacing may add to the effectiveness of natural enemies and result in greater control of a pest population. Low-density planting attracts some insect pests because they are silhouetted against the bare ground, e.g., at low-density brassicas attract more aphids. Some populations of pests can increase on high-density crops. Because of the variety of existing responses to crop spacing, detailed knowledge of the pest's biology is of extreme importance.

Plant spacing is also used to promote vigorous and strong plants, which in itself can be a good cultural control measure, e.g., good protection for corn against corn stalk borer. Indeterminate blooming plants' crops may be encouraged to fruit and be harvested early by using plant spacing that promotes quick crop maturation. This has been used in the south against bollweevils and pink bollworms.

Nowatzki et al. (2002) conducting the experiment with corn including sweet corn, to find out if maize rootworm, *Diabrotica virgifera virgifera* LeConte and *D. barberi* Smith & Lawrence, adult emergence, larval harm to the roots, and plant tolerance to injury were impacted by row spacing and plant density. We investigated plant populations of 64,500 and 79,600 plants per hectare with row spacing's of 38 and 76 cm. Adult emergence was 31% greater in 38 cm compared with 76-cm rows. However, root injury was not significantly different between row spacing's or plant populations. Row spacing by itself had no discernible effect on the amount of root regrowth or the size of the roots as indicators of injury tolerance. The plants in 38-cm rows, however, produced 25% more regrowth than the plants in 76-cm rows in one environment with little precipitation. At the high plant population, root dry weight and regrowth were reduced by 16 and 32%, respectively. Although lodging was 51% lower in the 38-cm rows compared with the 76-cm rows, grain yields were not significantly different between row spacing. Reducing the row spacing of field corn from 76-38 cm should not increase the potential for injury from corn rootworm larvae.

By changing sowing or planting rates, farmers can control plant densities. They may also employ higher rates to make up for anticipated pathogen-caused crop losses. Crop density can also been manipulated by pruning, thinning, trellising, and fertilization, water management, staking and harvesting plants or plant parts, depending on the types of crop.

The influence of density is mainly on the microclimate of the crop, but this is not unambiguous and depends on a number of factors: season, growing system, plant species, pests and others.

In the conditions of humid climate or season, the higher than the optimal density increases the humidity in the plantation, which creates conditions for the development of diseases. In addition, the higher density contributes to the spread of a number of diseases by infecting the diseased leaves of the plants that touch the neighboring healthy ones.

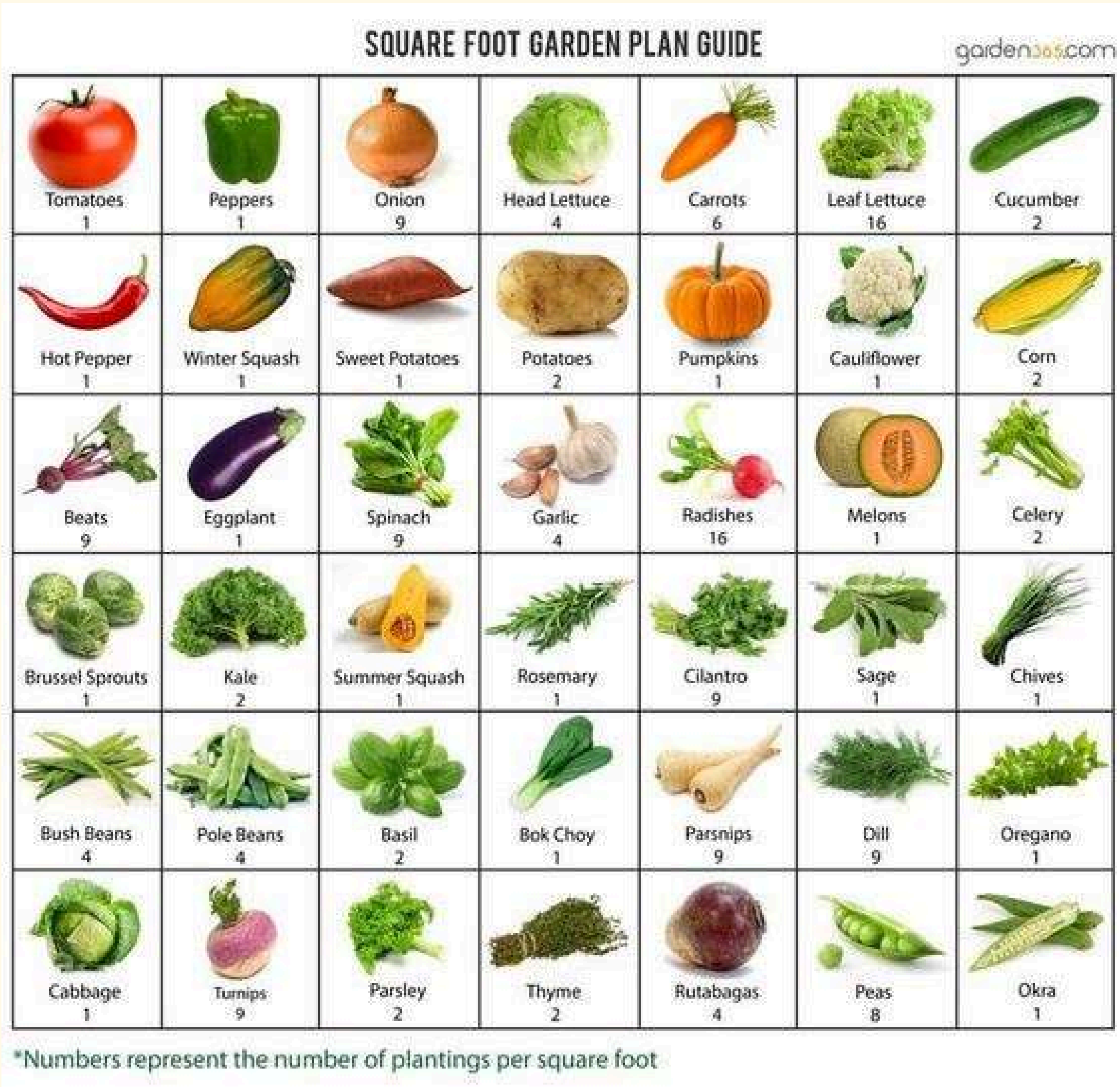
In fruit species and vines, the density can be adjusted by pruning. Some vegetable species are also pruned, but they are relatively few, while other species, especially when the plants have large leaf masses, poor ventilation and damp leaves are a prerequisite for the development of pathogens. Therefore, it is important to observe the optimal density of vegetable crops. This prevents the appearance and multiplication of pathogens that grow in a humid environment. (Davis, 2007; Gomez & Thivant, 2015).

On the other hand, higher densities can prevent the development and spread of some vector-borne diseases (spread by cicadas, aphids, etc.) that multiply in lower-density crops. They do not multiply in higher density crops. However, in some tree species the inverse relationship has been found - in young plantations with lower density of planted trees there is less multiplication of aphids than in those planted more densely, because the studied species reproduces by females (Van Emden & Harrington, 2017).

Crop density also affects the multiplication of other pests. But the cultivation system must also be taken into account here. In monoculture, the multiplication of pests in cucumbers is established. When grown in a polyculture, the population is smaller, although the number of plants is larger. Here the diversity of species has an impact and in fact the number of cucumber plants is smaller and this helps to reduce pests (Altieri & Liebman, 2014).

Crop density also affects weeds - less frequently sown crops than optimal allows them to multiply. The optimal crop density will limit the development of weeds, leaving them no space for their development.

This graph represents the number of plants, which can be plant per square foot. For more clearness about square foot you may use this: 1 square foot = 0.09290304 m 2 (1 m2 ≈ 10,76391 sq.ft).



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Various cultural control practices can be employed to manage pests and optimize crop growth. Here are the paraphrased points from the provided text:

- Adjusting plant density can have benefits, but it may increase production expenses.
- Damage caused by soil pests like cutworms to seedlings can be mitigated by using higher seeding rates.
- Closing the canopy early by reducing row spacing creates favorable conditions for the establishment of natural predators in numerous crops.
- Opting for narrow row spacing in soybean cultivation reduces the attractiveness of open-canopy fields to maize earworm moths, decreasing their inclination to lay eggs (Speight et al., 1999).

2.6.3 Standard/certified seed and planting material

Rumen Tomov,
Adrian Asănică

Standard/certified seed and planting material refer to seeds or vegetative propagules that have undergone a certification process to ensure their quality, genetic purity, and adherence to specific standards set by regulatory authorities or certification agencies.

This certification process is designed to maintain and improve the overall quality of seeds and planting material used in agriculture, horticulture, and forestry.

Here are some key points about standard/certified seed and planting material:

Quality Assurance

Standard/certified seeds and planting material undergo rigorous quality control measures to ensure they meet certain standards regarding genetic purity, physical purity, germination capacity, and freedom from diseases, pests, and weed seeds. This quality assurance process helps ensure that farmers and growers have access to reliable and high-quality planting material.

Genetic Purity

Certified seeds and planting material are produced from parent plants that have been carefully selected and maintained to preserve their desirable traits and genetic characteristics. This helps maintain the uniformity and consistency of the crop or plant variety, ensuring that it performs as expected.

Traceability

Certified seeds and planting material are typically accompanied by proper documentation, including tags or labels that provide information about the variety, origin, production methods, and certification details. This traceability helps farmers and regulatory authorities track the source and quality of the planting material, facilitating transparency and accountability.

Compliance with Standards

Standard/certified seeds and planting material are produced and handled in accordance with specific regulations and standards established by national or international certification bodies. These standards cover various aspects, such as seed production practices, field inspections, post-harvest handling, storage, labelling, and packaging.

Increased Productivity and Performance

By using standard/certified seeds and planting material, farmers and growers can benefit from improved crop performance, higher yields, and better resistance to pests and diseases, and enhanced adaptability to specific environmental conditions. This can contribute to increased agricultural productivity and profitability.

Access to New Varieties

Certified seed and planting material often include newly developed or improved crop varieties that have undergone extensive research and breeding programs. By using certified material, farmers can access and adopt these improved varieties, which may offer better traits such as higher yield potential, improved disease resistance, or tolerance to specific environmental conditions.

Legal Requirements

In some jurisdictions, the use of certified seeds and planting material may be mandatory for certain crops or varieties, particularly for commercial production. This helps ensure adherence to quality standards, protect intellectual property rights of breeders, and prevent the spread of pests or diseases through infected or low-quality planting material.

It is important for farmers and growers to source standard/certified seeds and planting material from reputable suppliers or authorized outlets to ensure their authenticity and adherence to the required standards. Local agricultural authorities or certification agencies can provide guidance on the availability and procurement of certified planting material in a specific region.

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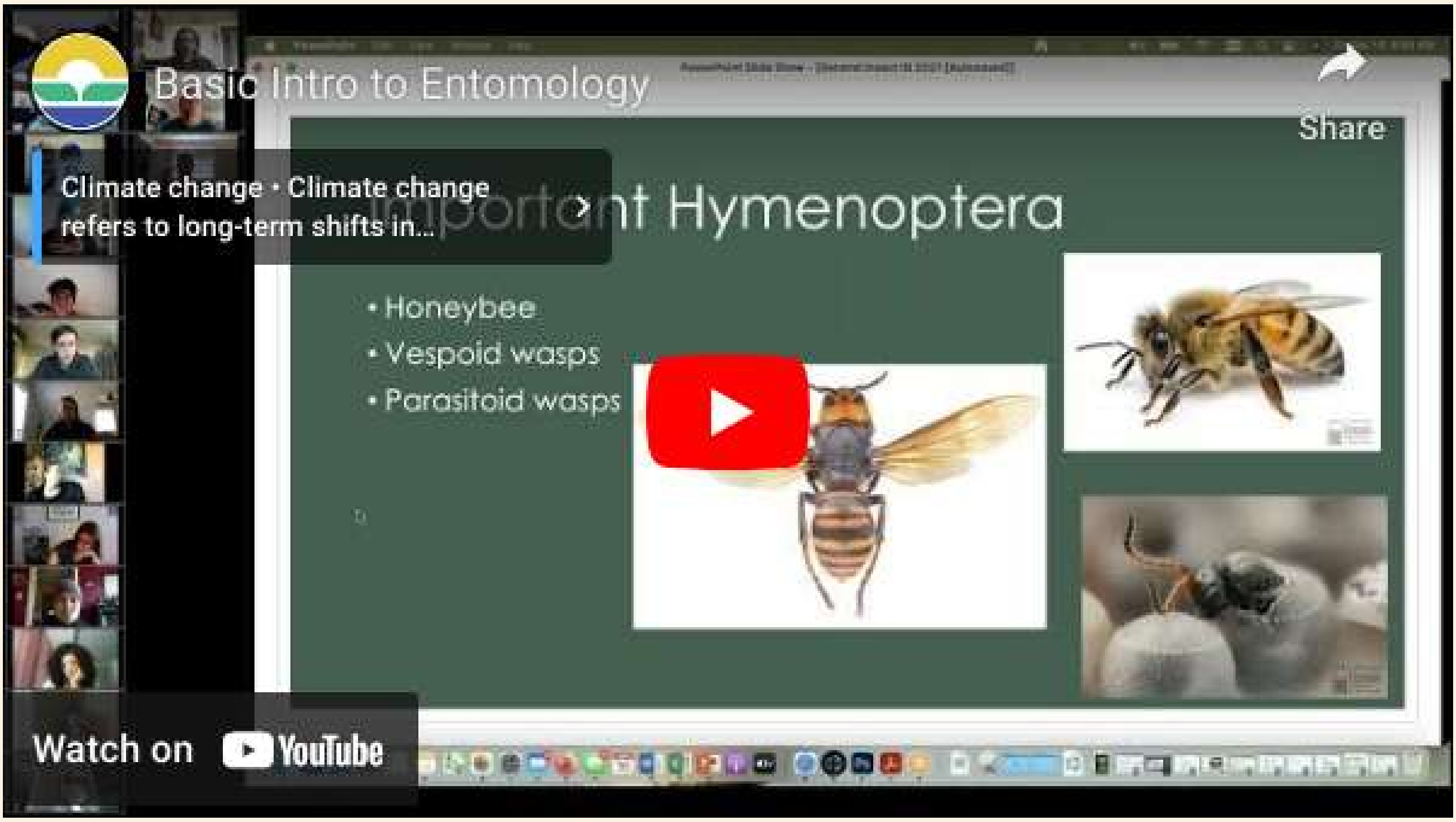
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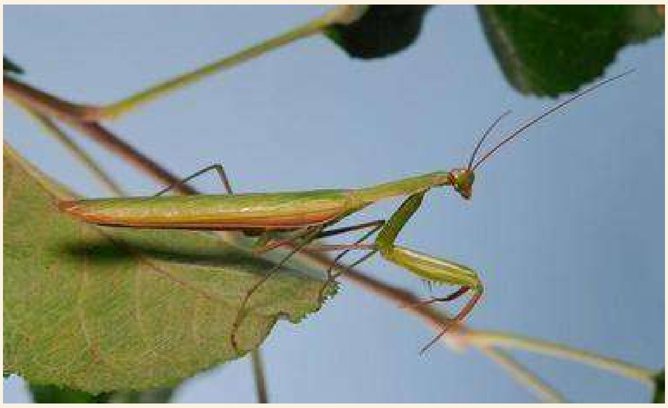


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Unit 2.7 Amelioration practices

Vera Petrova, Oana Crina Bujor,
Lavinia Iliescu

The productivity of agriculture relies heavily on the quality of soil, which serves as the primary source of agricultural output. Land improvement, also known as amelioration, has been recognized as a crucial aspect of agricultural labor since the early stages of agricultural development in ancient civilizations such as Egypt, Greece, Rome, and China. Unlike regular annual agricultural practices like plowing and harrowing, amelioration entails comprehensive and long-lasting effects on the soil. It can be defined as a set of measures aimed at radically improving unfavorable hydrological, soil, and agroclimatic conditions to maximize the efficient utilization of land resources. In addition to enhancing land productivity, amelioration enables the cultivation of poor and unused lands such as swamps, wastelands, and degraded areas of human origin. It also contributes to the improvement of soil and environmental health, leading to an overall enhancement in living standards and quality of life for individuals.

Amelioration practices refer to the techniques and methods used to improve the quality and productivity of agricultural land. These practices aim to enhance soil fertility, structure, and overall conditions for better crop growth and yield.

Amelioration practices encompass various approaches including engineering reclamation (such as irrigation, drainage, filling, and flood protection), chemical interventions, anti-erosion measures, and agronomic techniques. Specific methods of land reclamation involve utilizing sea and lake bottoms (known as polders), developing desert soils, and optimizing soil heat regulation (referred to as thermal amelioration). Soil amelioration has proven indispensable in areas where unfavorable agricultural conditions exist, and over thousands of years, significant experience has been gained, the theory of amelioration has been developed, and methods have been refined.

In present times, developed countries have established specific laws and regulations governing land reclamation policies. The effectiveness of amelioration is closely tied to the level of field management, emphasizing the importance of efficient and responsible agricultural practices.

Good amelioration practices, also known as **land improvement practices**, are essential for enhancing the quality and productivity of agricultural land. Amelioration involves the systematic application of various techniques and measures to improve the physical, chemical, and biological properties of the soil, as well as the overall environmental conditions of the land. These practices aim to create a favorable environment for plant growth, optimize water and nutrient availability, prevent soil erosion, and promote sustainable land management.

By implementing good melioration practices, farmers and land managers can achieve several benefits. These include increased crop yields, improved soil fertility, enhanced water retention, reduced nutrient leaching, minimized soil erosion, and better resilience to climate change impacts. Additionally, adopting these practices can contribute to the conservation of natural resources, preservation of biodiversity, and mitigation of environmental degradation associated with agricultural activities.

Source: https://www.mdpi.com/2073-4395/11/10/1970

Hort4EUGreen

2.7.1. Fertilization

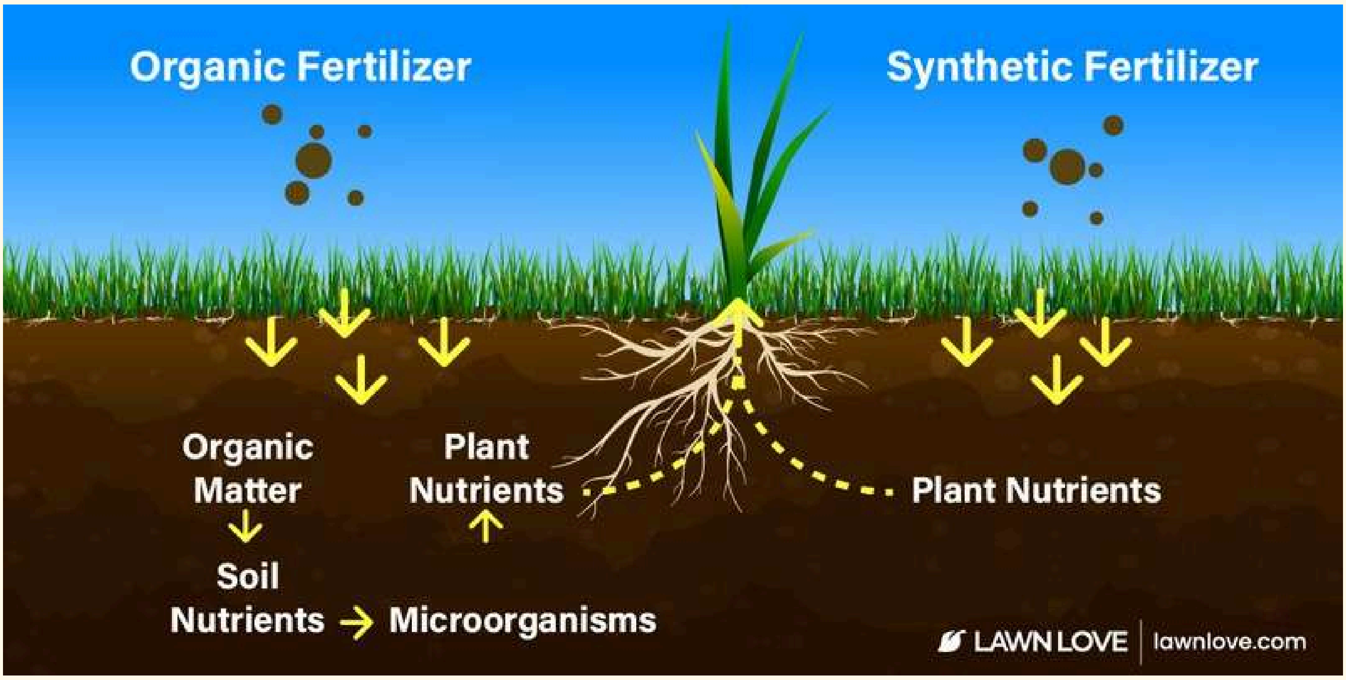
Vera Petrova, Ovidiu Jerca, Liliana Bădulescu

Fertilization is the process of supplying essential nutrients to plants to promote healthy growth and maximize crop yields. Fertilizers are substances that contain specific nutrients, such as nitrogen (N), phosphorus (P), and potassium (K), along with secondary and micronutrients needed for plant development.

The utilization of manure as a fertilizer offers numerous advantages for the well-being of plants and soil. Nevertheless, due to the imperfect distribution of macro and micronutrients in manure for crop requirements, there is a risk of excessive phosphorus build up when attempting to fulfil the nitrogen needs. Such imbalances in nutrients can potentially intensify the presence of weeds and insect pests, resulting in unforeseen and undesirable expenses for growers.

Based on the Hill (1987) plant nutrition can influence the feeding, longevity and fecundity of phytophagous pests; the common fertilizer elements (nitrogen, phosphorous and potassium) can have direct and indirect effects on pest suppression. In general, nitrogen in high concentrations has the reputation of increasing pest incidence, particularly of sucking pests such as mites and aphids. On the other hand, phosphorous and potassium additions are known to reduce the incidence of certain pests, e.g., in low phosphorous soils wireworm populations often tend to increase.

Fertilization promotes rapid growth and shortens the susceptible stages. It gives better tolerance to, and opportunity to compensate for, pest damage. Trace mineral and plant hormones sprays (e.g., from seaweed extracts) have been found to reduce damage by certain pests, particularly sucking pests such as some aphids and mites.



Source: https://lawnlove.com/blog/blog-landscaping-organic-lawn-fertilizer/

According to Ogle (1997) soil nutrient status may influence the susceptibility of plants to attack by pathogens. Farmers try to offer a well-balanced supply of nutrients to their crops. The resultant healthy, vigorous plant should have a greater chance of withstanding attacks by pathogens. However, this is not always the case. The same conditions that favor the growth of the plant may also encourage development of biotrophic pathogens. For example, many viral diseases of crop plants are promoted by fertilizer applications. Deficiencies of nutrients in soils increase the susceptibility of many crops to certain pathogens. In this context, fertilizer applications are sometimes recommended as a control strategy. The influence of the major nutrients nitrogen, phosphorus and potassium, as well as calcium, on disease development will be discussed further.

Applications of some of the minor nutrients can also decrease host susceptibility to disease. Applications of zinc reduce the incidence of maize downy mildew, while sulphur fertilization inhibits the occurrence of cercospora leaf spot in groundnuts and copper applications reduce take-all (*Gaeumanonomyces graminis*) in wheat. Hearty applications of nitrogenous fertilizers are commonly thought to predispose plants to disease. This assertion is supported by the frequently noticed rise in infection by obligate parasites such the powdery and downy mildews and rusts. However, it is unlikely that such an apparently direct interaction promotes disease and the effect of a nutrient is probably more indirect.

Nitrogen applications tend to delay crop maturity by prolonging vegetative development. Increased risk of infection may result because plants are susceptible to attack for longer periods. However, by promoting vegetative growth, plants may be able to "outgrow" an infection and repair any harm. High nitrogen levels are also thought to influence the production of host metabolites, which can either inhibit or promote infections by various pathogens.

For instance, on plants cultivated in high nitrogen soils, rice blast (*Pyricularia oryzae*) and scald (*Rhynchosporium oryzae*) typically rise, whereas maize head smut (*SphaceLotheca reiLiana*) typically decreases in severity. Nitrogenous fertilizers also indirectly affect the spread of disease by modifying crop environments. *Rhizoctonia solani* is hypothesized to become less common after nitrogen fertilizer as a result of the stimulation of specific soil microbes that compete for resources. There will be a microclimate that favors specific foliage infections as crop canopy density rises.

Pyricularia oryzae
Source here

Rhynchosporium oryzae
Source here

SphaceLotheca reiLiana
Source here

Rhizoctonia solani
Source here

Rank (overly lush) growth in cereal crops resulting from liberal fertilizer applications can lead to lodging (breaking, bending over or lying flat on the ground of the above ground parts of plants) which is often associated with increased disease incidence (e.g. rice blast). The form of nitrogen available to the host (and not total soil nitrogen) probably has most influence on disease susceptibility. Nitrogen is absorbed as either nitrate or ammonium ions and their effects have to be largely assessed in relation to specific host/pathogen relationships. In addition, other cultural factors such as rate, time and method of fertilizer application, soil properties including texture, pH and microbial populations and previous cropping history require consideration.

The effects of phosphorus fertilizers on disease incidence are not well understood. Phosphate fertilization can lower the incidence of potato scab (*Streptomyces scabies*) and delay the onset and severity of take-all in barley, but it can also enhance the occurrence of cucumber mosaic virus in spinach and decrease the incidence of potato scab.

The effects of phosphorus fertilizers are attributed to correction of phosphorus deficiency in the soil resulting in healthier plants more able to resist attack by pathogens. In addition, phosphorus hastens the maturity of the crop so young susceptible tissues are not exposed to the inoculum of obligate parasites for long periods of time.

Streptomyces scabies
Source here

For example, *Fusarium oxysporum*, bacteria (*Corynebacterium rnsidtosum* and *Xanthomonas spp*.), certain viruses, and worms cannot grow in the presence of adequate potassium levels. Application of potassium fertilizers also seems to reduce some of the disadvantages of excessive nitrogen applications. The effect depends on the nutrient status of the soil, the rate of application and the buffering effect of potassium on other elements, especially nitrogen. Through direct stimulation or inhibition, potassium affects the pathogen's ability to multiply, survive, be aggressive, and establish a foothold in the host. It also indirectly influences aspects of disease development. For example, potassium promotes wound healing, reducing infection by wound parasites such as *Botrytis*. Potassium fertilization also heightens resistance to frost injury and delays maturity in some crops, postponing the strain of senescence and reducing the risk of infection by facultative saprophytes.

Another vitamin that may affect the occurrence of disease is calcium. Its main impact is on the make-up of the host's cell walls. Adequate supplies of calcium make cell walls more resistant to penetration by facultative pathogens such as *Rhizoctonia*, *Sclerotium*, *Botrytis* and *Fusarium*. However, soils high in calcium favor the development of diseases such as black shank of tobacco (*Phytophthora parasitica var. nicotianae*). Alternatively, high levels of calcium (lime) in soils can raise their pH to the detriment of pathogens such as *Plasmodiophora brassicae*, which are favored by acid soils.

By modifying the nutrient composition of crops, fertilizer practices can influence plant defenses. A review of 50 years of research identified 135 studies showing more plant damage and/or greater numbers of leaf-chewing insects or mites in nitrogen-fertilized crops, while fewer than 50 studies reported less pest damage. High nitrogen levels in plant tissue have been shown to reduce resistance and increase susceptibility to pest attacks (Altieri & Liebman, 2014).

Plant nutrition can influence pest damage. Fertilizer elements (nitrogen, phosphorous, and potassium) can have direct or indirect effects on pest incidence. High nitrogen levels can make people more susceptible to illness and make mite and aphid infestations more common. Proper, balanced fertilization promotes healthy plants that will be better able to withstand pest harm and have more chances to recover from it. [1]

Hsu et al. (2009) conducted research on the impact of the butterfly *Pieris rapae crucivora*, a pest of cabbage, and found that it preferred to lay its eggs on the foliage of plants that had received synthetic fertilization. The authors contend that proper organic fertilization can increase plant biomass production and reduce pest incidence. Additionally, according to Alyokhin et al. (2005), Colorado potato beetle (*Leptinotarsa decemlineata*) densities were typically lower in plots receiving manure soil amendments combined with lower rates of synthetic fertilizers than in plots receiving full rates of synthetic fertilizers but no manure. A more complex relation between soil fertilization and crop pest has been found by Staley et al. (2010). The authors report that two aphid species showed different responses to fertilizers: the Brassica specialist *Brevicoryne brassicae* was more abundant on organically fertilized plants, while the generalist *Myzus persicae* had higher populations on synthetically fertilized plants.

Pieris rapae crucivora
Source here

Leptinotarsa decemlineata
Source here

Brevicoryne brassicae
Source here

Myzus persicae
Source here

The crucifer-specific diamondback moth *Plutella xylostella* preferred to lay her eggs on synthetically fertilized plants, where she was more prevalent. The scientists discovered that while nitrogen content was maximum on plant foliage under higher or synthetic fertilizer treatments, glucosinolate concentrations were up to three times more on plants grown under organic treatments.

Here are some key points about fertilization:

Nutrient Requirements

Different plants have varying nutrient requirements, and understanding these requirements is crucial for effective fertilization. Soil testing is often conducted to determine nutrient deficiencies or imbalances, helping determine the appropriate fertilizer formulation.

Macronutrient

The primary macronutrients required by plants are nitrogen (N), phosphorus (P), and potassium (K). Nitrogen is essential for leaf and stem growth, phosphorus promotes root development and flower/fruit production, while potassium contributes to overall plant health and disease resistance.

Secondary and Micronutrients

Secondary nutrients, such as calcium (Ca), magnesium (Mg), and sulfur (S), are also important for plant growth. Micronutrients, including iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), and chlorine (Cl), are needed in smaller quantities but are equally vital for plant functioning.

Fertilizer Types

Fertilizers come in various forms, including granular, liquid, and slow-release formulations. Granular fertilizers are commonly applied to the soil surface and incorporated into the root zone, while liquid fertilizers are often applied as foliar sprays or through irrigation systems. Slow-release fertilizers release nutrients gradually over an extended period, providing a steady supply to plants.

Fertilizer Application

The timing and method of fertilizer application depend on crop type, growth stage, soil conditions, and climate. Fertilizers can be applied before planting (pre-planting), during planting (starter fertilizers), or after planting (topdressing). Precision agriculture techniques, such as soil mapping and variable rate application, help optimize fertilizer use and minimize environmental impact.

Environmental Considerations

Proper fertilizer application is essential to prevent nutrient runoff and minimize environmental pollution. Applying fertilizers at recommended rates, avoiding over-application, and considering factors like soil type, water availability, and nutrient uptake by plants are crucial for sustainable fertilization practices.

Organic Fertilizers

Organic fertilizers, such as compost, manure, and plant-based materials, provide nutrients in a slow-release form and also improve soil structure and fertility. They are commonly used in organic farming systems and contribute to long-term soil health.

Fertilizer Management

Monitoring plant growth, soil nutrient levels, and crop response to fertilization helps adjust fertilizer programs and optimize nutrient uptake. Regular soil testing and nutrient management planning assist in maintaining balanced nutrient levels in the soil.

Balanced fertilization practices, tailored to specific crop needs and soil conditions, play a vital role in sustainable agriculture by promoting healthy plant growth, optimizing resource use, and minimizing negative environmental impacts.

2.7.2 Composting

Vera Petrova, Milena Yordanova,
Oana Crina Bujor, Cosmin Mihai

Composting is a process of converting organic waste into nutrient-rich compost, which can be used as a natural fertilizer for soil and plants.

In the FAO terminology section, one definition of composting is that it is "a controlled process in which organic materials are assimilated aerobically or anaerobically by microbial action". FAO

Aerobic composting is a dynamic process and is influenced by microbial populations. There are several main factors that favor composting processes: the presence of oxygen, moisture, temperature, pH and C/N ratios. These factors are key to building sustainable organic waste management practices Maheshwari et al. (2014).

The aerobic composting method is an effective system in which the temperatures in the compost reach 60°C, it has been shown that when composted for a period of six weeks and when a high temperature is reached, it is sufficient to kill the main phytopathogens and to inhibit their spread in mature compost Muccignatto (2007).

The use of well-prepared compost in both protected cultivation and outdoor cultivation systems can increase the number and variety of beneficial soil microorganisms that can help suppress fungal diseases Frost (2003).

It is a sustainable and environmentally friendly way to manage organic waste and reduce landfill waste. Here are the basic steps involved in composting:

Select a Composting Method

There are several composting methods to choose from, including traditional composting piles, compost bins, or compost tumblers. Select a method that suits your space, available materials, and composting goals.

Gather Organic Materials

Collect a mix of "green" and "brown" organic materials. Green materials include vegetable scraps, fruit peels, coffee grounds, tea leaves, fresh grass clippings, and plant trimmings. Brown materials include dry leaves, straw, shredded paper, cardboard, and wood chips. Aim for a balance of nitrogen-rich (green) and carbon-rich (brown) materials in your compost pile.

Chop and Shred

To speed up the decomposition process, chop or shred larger organic materials into smaller pieces. This increases the surface area and helps the materials break down more easily.

Layer the Materials

Start with a layer of brown materials as the base, followed by a layer of green materials. Continue layering the materials, alternating between brown and green, to create a balanced compost pile. Ideally, aim for a ratio of approximately three parts brown to one part green.

Moisture Management

Keep the compost pile moist but not overly wet. It should resemble a damp sponge. If the pile is too dry, sprinkle water to moisten it. If it's too wet, add dry brown materials to absorb excess moisture.

Turn and Mix

Regularly turn and mix the compost pile to provide aeration and facilitate decomposition. This can be done using a pitchfork or shovel. Turning the pile every few weeks helps distribute oxygen and promotes the breakdown of materials.

Monitor and Adjust

Monitor the compost pile regularly to ensure it remains properly balanced and to identify any issues. Adjust the moisture levels, add browner or green materials if needed, and mix thoroughly to maintain optimal conditions for decomposition.

Wait and Harvest

Composting is a natural process that takes time. Depending on the materials used and the composting method, it can take several months to a year for the compost to fully mature. When the compost has a dark, crumbly texture and an earthy smell, it is ready to be harvested and used in your garden.

Remember to avoid adding meat, dairy products, oily substances, or pet waste to your compost pile, as they can attract pests or introduce pathogens. With proper management and patience, composting can be a rewarding way to reduce waste, improve soil health, and support sustainable gardening practices

2.7.3 Green manuring

Vera Petrova, Roxana Ciceoi,
Okray Orel, Eszter Takacs

Green manuring, also known as cover cropping or green manure cropping, is a practice in which specific plants or cover crops are grown and incorporated into the soil to improve soil fertility, structure, and overall health.

Green fertilizers are plants that are grown to improve the structure, organic matter content of nutrients in the soil. The main characteristic of the species used for green manure is that they form a large leaf mass and are plowed into the soil while they are young, before flowering or fruiting. They are grown for their green leafy material, which is high in nutrients and provides soil cover. They can be grown alone or mixed with other crops (Peter & Rayns, 2008).

Some authors described green manures as a cover crop that is chopped up and turned into the soil. The surface area of the integrated biomass is increased when the cover crop is chopped into small pieces, which leads to a faster rate of breakdown by soil microbes (Martin, 2012).

Green manures planted between crops, such as winter coverings or annual coverings, can be used to fix soil N (build

fertility), retain soil N (hold and move) and reduce leaching (minimize losses).

When these green manures are subsequently introduced, their decomposition stimulates microbial activity and the release of soil nitrogen, which is available for the next crop (Briggs et al. 2005). Green manure, through allelopathy, can suppress the development of weeds. It has been found that some *Brassicas* species could suppress It has been found that some cabbage species can suppress the development of weeds after plowing into the soil as green manure crops (Boydston & Hang, 1995; Al-Khatib et al. 1997; Krishnan et al. 1998).

Efforts should be made to avoid damage and stress to plants, and also over fertilization, thereby avoiding making the crop particularly attractive and susceptible to pests.

Manure can be an integral part of IPM programs by promoting healthy ecosystems, encouraging natural pest control mechanisms, and reducing reliance on chemical interventions.

2.7.4 Liming

Vera Petrova,
Florin Stănică

Liming is the practice of applying calcium (Ca) and magnesium (Mg) - rich materials in different forms, such as marl, chalk, limestone, burnt lime, or hydrated lime, to soil (Pang, Z, 2019).

Liming is a soil management practice that involves the application of lime (calcium carbonate or calcium-magnesium carbonate) to soils. These materials act as a base and neutralize soil acidity, particularly in acid soils. The neutralization of soil acidity through liming often leads to improved plant growth and increased activity of soil bacteria. However, excessive application of lime can be detrimental to plant life. The practice of liming evolved from an earlier method called marling, which involved spreading raw chalk and lime debris on soil to adjust pH levels or aggregate size.

https://www.agriland.ie/farming-news/in-the-limelight-ground-conditions-ideal-for-liming/

Efforts should be made to avoid damage and stress to plants, and also over fertilization, thereby avoiding making the crop particularly attractive and susceptible to pests. The history of these practices can be traced back to the 1200s, with the earliest examples found in the modern British Isles (Mathew, 1993). It is commonly used to adjust soil pH levels and improve soil fertility.

Here are some key points about liming:

Soil pH Adjustment

Liming is primarily carried out to raise the pH of acidic soils. Acidic soils, with a pH below the optimal range for most plants (around pH 6 to 7), can limit nutrient availability and hinder plant growth. Lime neutralizes soil acidity by increasing the pH, creating a more favorable environment for plant roots and beneficial soil organisms.

Nutrient Availability

Soil pH plays a crucial role in nutrient availability. Acidic soils often have reduced availability of essential nutrients such as phosphorus, potassium, and calcium. Liming helps to release these nutrients from the soil, making them more accessible to plants. It also promotes the breakdown of organic matter, releasing additional nutrients.

Microbial Activity

Soil microorganisms play a vital role in nutrient cycling and organic matter decomposition. Liming can enhance microbial activity and promote a more balanced soil ecosystem. Certain beneficial microorganisms, like nitrogen-fixing bacteria, thrive in neutral or slightly alkaline pH conditions, which can be achieved through liming.

Aluminum and Manganese Toxicity

Acidic soils can contain high levels of aluminum and manganese, which can be toxic to plants. Lime application can reduce the toxicity of these elements by raising the soil pH and rendering them less available for uptake by plant roots.

Soil Structure and Water Infiltration

Liming improves soil structure by flocculating clay particles, which reduces soil compaction and enhances water infiltration. This allows for better root penetration and nutrient uptake by plants.

Crop-Specific Requirements

Different crops have varying preferences for soil pH. Liming helps to create the optimal pH range for specific crops, promoting healthier growth and higher yields.

It is important to note that the amount of lime needed and the frequency of application depend on the initial soil pH, the desired pH level, and the soil type. Soil testing is crucial to determine the appropriate lime dosage and application timing.
Overall, liming is an important practice in agriculture and gardening to optimize soil conditions, enhance nutrient availability, and support healthy plant growth.

2.7.5 Irrigation

Vera Petrova, Ovidiu Jerca
Lavinia Iliescu, Beatrice Iacomi

Irrigation is the artificial application of water to plants or agricultural fields to supplement natural rainfall and provide adequate moisture for plant growth. It is an essential practice in areas with limited rainfall or during periods of drought to ensure the proper development and productivity of crops.

Irrigation plays a vital role in modern agriculture by providing water to crops when natural rainfall is insufficient or irregular. It is a fundamental practice that helps enhance agricultural productivity, ensure crop growth, and maximize yields. Various irrigation techniques have been developed and employed worldwide to efficiently deliver water to crops and optimize its utilization. These techniques aim to meet the water requirements of plants while minimizing water wastage and maximizing water use efficiency.

Here are some commonly used irrigation techniques:

Surface Irrigation

This is one of the oldest and simplest forms of irrigation, involving the application of water over the soil surface. It can be further categorized into furrow irrigation, border irrigation, and basin irrigation. Surface irrigation is suitable for a wide range of crops and can be implemented in both small-scale and large-scale farming systems.

Sprinkler Irrigation

Sprinkler irrigation involves the use of sprinkler heads or nozzles that distribute water in the form of small droplets over the crop area. The sprinklers are strategically placed to ensure uniform water distribution. Sprinkler irrigation is versatile and can be adapted to various field conditions, soil types, and crop requirements. It is commonly used for field crops, orchards, and vegetable production.

Drip Irrigation

Drip irrigation, also known as micro-irrigation, is a highly efficient technique that delivers water directly to the plant roots through a network of pipes, tubing, and emitters. Water is applied in small quantities at a slow and constant rate, minimizing water loss through evaporation and runoff. Drip irrigation is particularly advantageous in areas with limited water availability and for crops that require precise water management, such as fruits, vegetables, and horticultural crops.

Drip Irrigation

Subsurface irrigation involves the application of water directly to the root zone of plants below the soil surface. Water is delivered through buried pipes or porous tubes, allowing for targeted watering and reduced water loss due to evaporation. Subsurface irrigation is beneficial in arid and semi-arid regions, as it helps conserve water and prevents surface soil evaporation.

Centre Pivot Irrigation

Centre pivot irrigation systems consist of a large, rotating arm with sprinklers that pivot around a central point, resembling the shape of a circle. This technique is commonly used for large-scale agriculture, especially in areas with flat topography. Centre pivot irrigation enables efficient water application over a large area, reducing labour and water requirements.

Lateral Move Irrigation

Lateral move irrigation systems, also known as linear irrigation, involve long lateral pipes equipped with sprinklers that move across the field in a straight line. This technique allows for uniform water distribution and is suitable for rectangular or square-shaped fields. Lateral move irrigation is commonly used for row crops and forage production.

Flooding irrigation

is a traditional and widely used method of irrigation where water is applied to the fields by allowing it to flow over the surface. It involves the controlled release of water onto the field, creating a temporary flooded condition. This technique is particularly suitable for crops that tolerate or benefit from standing water, such as rice.

Each irrigation technique has its advantages and considerations, depending on factors such as soil type, crop type, climate, and water availability. Choosing the appropriate irrigation technique and implementing efficient water management practices are crucial for sustainable agriculture, ensuring optimal crop growth, and maximizing water use efficiency while minimizing environmental impact.

Irrigation can have a major influence on the spread of some pathogens and on disease development. Irrigation applied during dry seasons means the propagules of pathogens are not exposed to desiccation during periods of drought. Consequently, the level of inoculum increases. The seriousness of this situation was compounded in areas where, because of irrigation, it is possible to grow two susceptible crops in the same field in one year. In addition, irrigation water may contain propagules of pathogens, which it carries from one place to another unless carefully treated before use.

By lengthening the duration, a layer of free moisture persists on leaf surfaces (the leaf wetness period), overhead irrigation may encourage disease. The possibility that enough time will be available for fungal spores to develop, form infection structures, and penetrate the plant surface to the relatively stable and hospitable environment within the leaf increases as leaf wetness periods lengthen. In a dry climate, irrigated crops may stand out as a green island and draw virus-carrying insects. In such cases, it is often better to delay sowing an irrigated crop for some time after other vegetation has dried up and the vector population has been reduced by desiccation. On the other hand, irrigation can be a technique for lowering inoculum levels and delaying the onset of disease. Alternately, drying and rewetting soil encourages the activity of microorganisms that destroy sclerotia. Overhead irrigation can reduce or inactivate airborne inoculum by washing it out of the atmosphere.

Short daily watering encourage the germination of powdery mildew spores but the plants do not stay wet enough for long enough for the fungus to penetrate. Overhead sprinkling of dormant fruit trees reduces the incidence of apple scab because the short-lived ascospores are released in response to temperature changes whilst the tree is dormant and cannot survive until leaves are present. Flood, furrow and overhead (spray, sprinkler) irrigation can facilitate the spread of pathogens.

Flood irrigation can spread soil-borne inoculum all over an area while furrow irrigation disperses inoculum along rows. The action of overhead irrigation systems washes inoculum out of the air and facilitates the spread of pathogens that rely on water splash for dispersal. Many important foliage and fruit pathogens such as *Phytophthora infestans* and *Alternaria solani* form their spores at night and release them during the day. These spores are removed from the air and dispersed by early morning overhead irrigation. *Phytophthora infestans* spores dry out on the plant and are unable to infect it if overhead irrigation is postponed until the evening or early night. However, *A. solani* spores can live until a dew forms at night and are resistant to drying out, so the time of overhead watering has minimal impact on the emergence of a disease. Overhead irrigation plays a role in the distribution of inoculum within a crop as it washes inoculum from higher to lower parts of the plant. Water is directly applied to the root zones of individual plants using trickle or drip irrigation, which was developed in response to the need to conserve water and is too slow to spread infections. Additionally, drip irrigation creates a mosaic of soil moisture conditions as opposed to uniformly wet conditions, which likely prevents the development of root infections (Ogle, 1997).

Phytophthora infestans
Source here

Alternaria solani
Source here

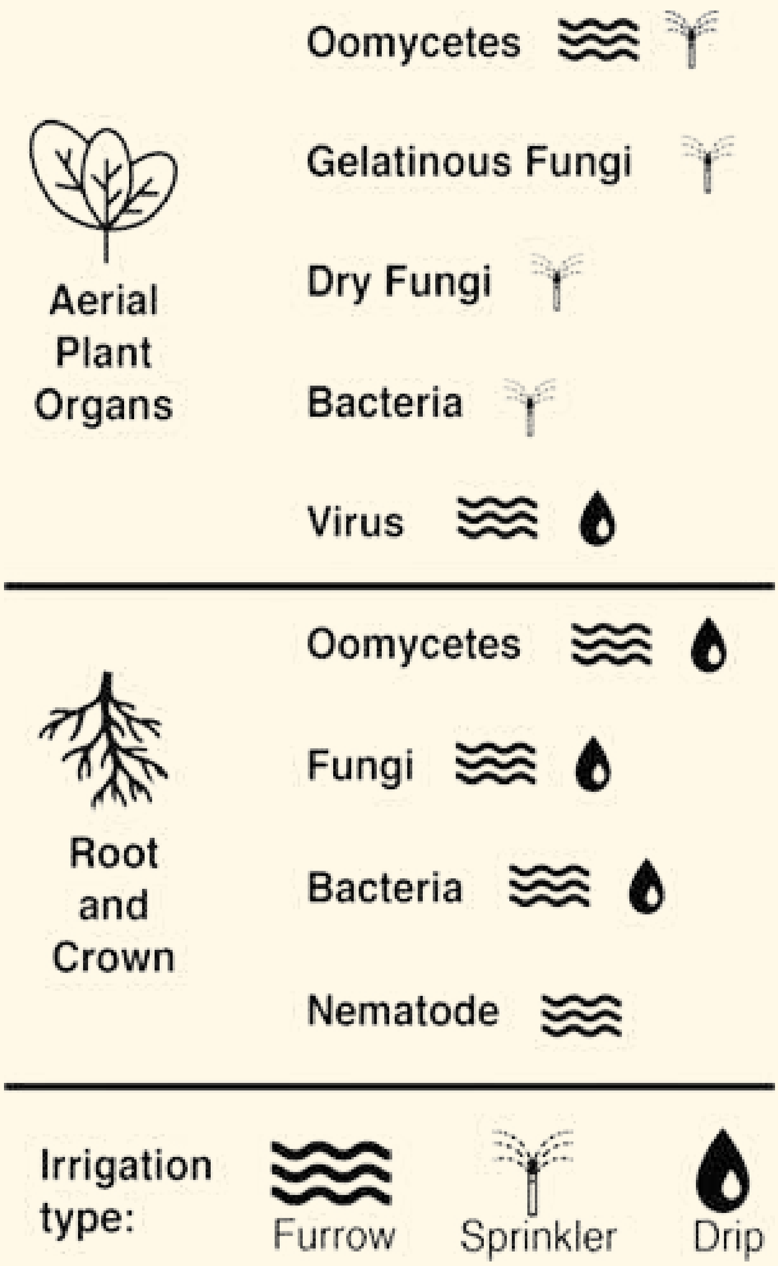
Based on research made by Café-Filho (2018) the technology of water application and method of irrigation have been profusely studied as to their direct relation to plant diseases. Many plant pathosystems, from leaf blights to vascular wilts, are affected by irrigation management in terms of disease severity and epidemic spread rates. The irrigation technique also has an impact on vector population levels and distribution for plant viruses. The author made reviews experimental data on the effect of different irrigation configurations and management systems on some representative plant diseases.

There are a number of management options, such as furrow irrigation, overhead sprinklers, micro sprinklers, and drip irrigation that may have a significant impact on the propagule dispersion, induction of germination, biofilm formation, penetration, and survival of each distinct group of pathogens. Drip irrigation may be the best option for the oomycetes and bacteria linked to the organs of aerial plants because of their great reliance on unrestricted water sources and high humidity levels. Among the true fungi, the effects of the irrigation system and management differ, and species of dry and wet spores respond distinctly to each individual method. In some groups, such as the Erysiphales, free water may hamper disease progress. To actively spread throughout the crop, nematodes and oomycetes require free water in the soil. By disrupting the insect's contact with the plant, sprinkle irrigation water can reduce viruses that accompany their vectors. When choosing the kind, frequency, and water amount to be administered to manage a specific plant disease and is crucial to achieving good yields and high product quality, understanding of the causal agent and of the disease epidemiological components is crucial.

The paddy system of growing rice is perhaps the oldest example of using flooding for plant disease management. The primary purpose of flooding is to control weeds. However, it also reduces the number of fungal propagules, insects and nematodes in the soil probably by subjecting them to attack by soil-borne bacteria.

By reducing the number of weeds, which may harbor rice pathogens and insects, it also indirectly affects disease development. Flooding can also speed the destruction of agricultural waste harboring inoculum. Rice blast (*Pyricularia oryzae*) is less severe on flooded paddy rice than on upland or non-irrigated rice because fewer hours of dew occur in paddy than in upland rice and because populations of fungi, bacteria, nematodes and actinomycetes are, lower in flooded soils. On the other hand, flooding can predispose some plants to disease, floodwaters can carry propagules of pathogens such as *Phytophthora* and algae growing in floodwaters produce oxygen, which encourages the growth of some fungi. Similar to tillage techniques, floods may have an impact on both the initial inoculum level and the rate of disease propagation. Flooding diseased cotton 'trash' for up to six weeks reduced the incidence of bacterial leaf blight (*Xanthomonas campestris pv. malvacearum*). In contrast, flooding seems to have little effect on *Verticillium wilt* fungi. Banana wilt (*Fusarium oxysporum f. sp. cubense*) can be partially controlled by flooding infected soils for up to six months. Such practices are expensive, require large amounts of water and keep land out of production for considerable periods. However, these disadvantages may be overcome if wetland rice can be incorporated into a rotation. This strategy occurs in areas of south East Asia where satisfactory results have been obtained in the control of *Phytophthora parasitica* (black shank of tobacco) and *Sclerotinia spp.* attacking vegetable crops.

Flooding has also been used to control nematodes. Hydrogen sulphide produced by anaerobic organisms under flooded conditions kills nematodes but the cost of such treatment is prohibitive. Some soil-borne pathogens may be controlled by manipulating soil water potentials in relation to their growth requirements because they vary considerably in the minimum water potentials required for spore germination and for hyphal growth.



https://www.intechopen.com/chapters/61837

However, if a soil is drained or irrigated to limit the activities of a pathogen the imposed conditions may favor the development of other pathogens and stress plants sufficiently to cause production losses (Ogle, 1997).

Here are some key points about irrigation:

Water Sources

Irrigation can utilize various water sources, including rivers, lakes, reservoirs, wells, and groundwater. The availability and quality of water sources are important factors to consider when planning irrigation systems.

Types of Irrigation Systems

There are different types of irrigation systems, including:

Sprinkler Irrigation

Water is distributed through sprinklers or sprayers, simulating rainfall. This method is suitable for a wide range of crops and can be used in both large-scale and small-scale farming.

Drip Irrigation

Water is delivered directly to the plant's root zone through a network of tubes or pipes with emitters. Drip irrigation is efficient and minimizes water loss through evaporation or runoff.

Surface Irrigation

Water is applied to the soil surface and allowed to infiltrate and move through the field by gravity. This method includes furrow irrigation, border irrigation, and basin irrigation.

Subsurface Irrigation

Water is applied below the soil surface through buried pipes or drip lines. It is particularly useful for water-sensitive crops or areas with high evaporation rates.

Irrigation Scheduling

Proper timing and frequency of irrigation are crucial for optimizing water use efficiency and plant health. Factors such as crop type, growth stage, soil type, weather conditions, and evapotranspiration rates need to be considered when determining the irrigation schedule.

Water Management

Efficient water management is essential to minimize water waste and environmental impact. This includes techniques such as proper system design, regular maintenance, monitoring soil moisture levels, using water-saving technologies (e.g., moisture sensors), and implementing irrigation scheduling based on crop water requirements.

Water Conservation

Conserving water in irrigation is crucial for sustainable agriculture. Techniques such as mulching, which reduces evaporation, and using precision irrigation methods, like drip irrigation, help minimize water loss. Additionally, adopting practices such as crop rotation, soil conservation measures, and optimizing irrigation application rates can contribute to water conservation.

Environmental Considerations

Proper irrigation management is important to avoid issues such as waterlogging, soil salinity, and nutrient leaching. It is essential to monitor soil moisture levels, ensure proper drainage, and implement appropriate fertilization practices to maintain soil health and prevent environmental degradation.

Technological Advances

Advancements in irrigation technology have led to the development of automated systems, remote sensing, and precision irrigation techniques. These innovations enable farmers to monitor and control irrigation systems more accurately, improving water-use efficiency and reducing costs.

Irrigation plays a vital role in agriculture by providing water to crops, increasing productivity, and ensuring food security. However, it is essential to balance water requirements, sustainable practices, and environmental considerations to optimize irrigation efficiency and minimize the impact on water resources.

2.7.6 Drainage

Vera Petrova

Irrigation is the artificial application of water to plants or agricultural fields to supplement natural rainfall and provide adequate moisture for plant growth. It is an essential practice in areas with limited rainfall or during periods of drought to ensure the proper development and productivity of crops.

The ability of soil to drain effectively can influence the suitability of plant growth in a particular region. In many agricultural settings, optimal drainage is crucial for enhancing or maintaining productivity and efficiently managing water resources (Haroun, 2004). It is possible to identify areas with inadequate drainage, leading to waterlogged conditions, by observing soil color. In regions characterized by prolonged saturation periods and consequent restricted conditions, localized mottles of varying colors can be observed within the soil matrix.

Drainage plays a vital role in soil health and overall plant well-being. Here's some information about the relationship between drainage and soil health:

Excess Water Removal

Proper drainage helps to remove excess water from the soil, preventing waterlogging. Waterlogged conditions can be detrimental to soil health as they restrict oxygen availability to plant roots, leading to root suffocation and reduced plant growth. Effective drainage ensures that water flows away from the root zone, maintaining a balance between air and water in the soil.

Nutrient Availability

Good drainage facilitates the movement of nutrients through the soil profile. It prevents nutrient leaching, where essential nutrients are washed away with excessive water, ensuring that nutrients remain available for plant uptake. Adequate drainage helps maintain a healthy nutrient balance in the soil, supporting optimal plant nutrition and growth.

Soil Aeration

Proper drainage enhances soil aeration by facilitating the exchange of gases between the soil and the atmosphere. It allows oxygen to enter the soil, which is crucial for the respiration of plant roots and beneficial soil organisms. Adequate oxygen levels in the soil promote the growth of beneficial aerobic microorganisms and contribute to a healthy soil ecosystem.

Soil Structure

Drainage plays a role in maintaining good soil structure. Excessive water in poorly drained soils can lead to compaction and soil erosion. Compacted soils have reduced pore space, limiting water infiltration, root penetration, and nutrient movement. Proper drainage helps to alleviate compaction and maintain a favorable soil structure, enabling healthy root development and improving overall soil health.

Disease Prevention

Well-drained soil can help reduce the incidence of soil-borne diseases. Many pathogens thrive in moist conditions, and waterlogged soils create a favorable environment for their growth and spread. By promoting effective drainage, the risk of soil-borne diseases can be minimized, contributing to improved soil health.

Proper drainage can have both direct and indirect effects on pests in agricultural fields. Here are some ways in which drainage can impact pests. Effective drainage systems help remove excess water from the soil, preventing the formation of stagnant pools or areas with prolonged waterlogging. Standing water creates favorable conditions for the breeding and development of certain pests, such as mosquitoes and aquatic insects. By reducing or eliminating standing water, drainage can minimize the habitat and breeding sites for these pests.

Some pests have specific life cycles that are influenced by moisture levels. Excessive soil moisture can promote the survival and reproduction of certain pests, while inadequate moisture can disrupt their life cycles. Proper drainage can help maintain optimal moisture levels in the soil, making it less favorable for pests that thrive in excessively wet or dry conditions.

Excessive moisture in the soil can provide hiding places and shelter for certain pests, such as slugs, snails, and some soil-dwelling insects. Adequate drainage reduces these moist microenvironments, making it less hospitable for pests to seek shelter and survive.

Proper drainage improves soil structure and aeration, promoting beneficial soil organisms that contribute to natural pest control. Healthy soil ecosystems with a diverse community of beneficial organisms, including predatory insects, nematodes, and microbes, can help suppress pest populations by preying on or competing with them.

Excess moisture in poorly drained soils can lead to the development and spread of root diseases, such as root rot or damping-off. These diseases weaken plants and make them more susceptible to pest infestations. Adequate drainage helps maintain a healthy root environment, reducing the risk of root diseases and indirectly minimizing pest pressures.

It's important to note that while proper drainage can have positive effects on pest management, it is not a standalone solution for pest control. Integrated Pest Management (IPM) practices, which include a combination of cultural, biological, and chemical control methods, are typically necessary for comprehensive pest management strategies. These may include crop rotation, resistant cultivars, beneficial insect releases, and judicious use of pesticides when needed.

Overall, effective drainage contributes to creating less favorable conditions for pests, disrupts their life cycles, and promotes a healthier plant environment, all of which can help in minimizing pest populations and their impact on agricultural crops.

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[1] Chapter 5, Prevention and Cultural Methods for Pest Management - Home and Garden Pest Management Guide – 2019 Edition, 13pp.

Baldfaced hornet (*Dolichovespula maculata*)

Source here

Eastern yellowjacket (*Vespula maculifrons*)

Source here

Source here

European hornet (*Vespa crabro*)

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Black and yellow mud dauber (*Sceliphron caementarium*)

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Unit 2.8 Mulching

Milena Yordanova,
Lavinia Iliescu

A growing emphasis is being placed on environmentally responsible and sustainable pest management techniques in contemporary agriculture and gardening operations. IPM, or integrated pest management, is a strategy that seeks to balance ecological harmony and pest control. Mulching is a key element of this all-encompassing approach.

A tried-and-true agricultural practice known as mulching includes covering the soil's surface with a barrier made of organic or inorganic materials. One of the many functions of this layer is insect control. Farmers and gardeners can drastically reduce their dependency on chemical pesticides while fostering natural methods for pest control by implementing mulching as part of an IPM approach.

We shall discuss the scientist's knowledge of both organic and inorganic mulches as an IPM technique. We want to encourage farmers, gardeners, and environmentalists to use mulching as a key component of a larger plan for a future that is greener and more ecologically balanced.

Mulching as IPM tool

Mulching, the application of a covering layer of material to the soil surface, is a commonly used cultural practice, especially in horticulture. Various materials can be used as mulch, which is spread on the ground to protect the roots of the plants from heat, cold, or drought or to keep the soil free of weeds. Mulching prevents weeds from sprouting and growing by preventing light from reaching the soil surface. They are widely used in horticulture and are especially effective in perennial crops such as strawberries, where they can be used to control weeds, (Frost, 2003; Mc Craw, 2003). Mulches help create healthy soil and plants that are less susceptible to insect pests and diseases. Mulch also keeps the soil cooler in the summer and warmer in the winter. Covering the soil with mulch will reduce compaction, erosion, and soil splash during the rainy season (Government of British Columbia, 2019).

Mulches can be classified as inorganic or organic.

Living mulch (cover crops).
Source:
https://extension.wsu.edu/snohomish/clover-under-corn/

2.8.1 Inorganic mulches

Inorganic mulches include plastics, stones, and other materials.

In a comprehensive review, which was made by Greer and Dole (2003), of inorganic mulches and their possibilities to be used against viral diseases of vegetables, is summarized that using reflective mulches is a novel way to stop the spread of non-persistent viruses. The UV rays from the sun are reflected by the mulches, confounding the insect vector. Different writers have shown how reflecting mulches can deter aphids and thrips.

They also synthesize that early in the season, plants planted on colored mulch may have less insect pests. Later, crop leaves will cover the mulches, decreasing their ability to inhibit pests. But with crops that have been substantially trimmed, like tomatoes, the mulch keeps working all season. The impact of colorful plastic mulches on populations of insect pests that spread viruses, particularly aphids, thrips, and whiteflies, was thoroughly examined by Greer and Dole in 2003. Pests can be controlled by colored mulches (black plastic, white and white-on-black mulch, blue mulch, yellow mulch, red mulch. clear mulch, orange mulch, and pink mulch), however, brightness or contrast with bare soil may be more essential than color.(Greer and Dole 2003).

Vincent et. al, (2003) summarized that It is possible to create artificial mulches that are pest-repellent. For instance, the hue of plastic materials can be changed to alter the spectrum of incident light, which modifies the behavior of a particular insect. While thrips are drawn to blue, black, and white, aphids are attracted to yellow and blue. While some bug species may be attracted to aluminum-coated items, others may be repelled. The wavelengths of UV light that are reflected have been connected to the capacity to repel.

2.8.2 Organic mulches

Organic mulches such as compost, manure or lawn clippings improve soil properties, e.g. structure and aeration, provide nutrients for the plants and feed the beneficial microbes in the soil. If lawn clippings are used as mulch, they need to be dried and applied in a 5 – 10 cm layer. For better weed control when covered with organic mulch, the layer needs to be between 5 and 10 cm, and a number of studies have found that a thicker layer of 10 cm has better protection against weeds. (Jodaugienė, et al. 2012)

Organic mulches that have not been composted such as raw bark and wood chips are not as effective as composted organic mulches because they compete with the plants and microbes for nitrogen and tend to acidify the soil. Thick mulches can also slow soil warming and plant growth in the spring (Government of British Columbia, 2019).

Annual crops are planted during these mulches. For perennials such as top and soft fruits, mulching can be combined with mowing (Frost, 2003; McCraw, 2003).

Fruit tree pests can be managed with the use of crop residue mulches, but the trees will require additional defense against rodents, which also tend to multiply in number.



According to Zehnder, et al. (2007), organic mulches are frequently employed in organic farming to improve soil's ability to store moisture, add organic matter, and lower soil temperature. Studies have shown that application of straw mulch can suppress some insect pests such as the Colorado potato beetle, probably through a combination of effects involving reduced host-finding ability and increased predation from natural enemies. Additionally, there is a lot of research on straw mulch's ability to lower viral and aphid infection rates in various crops. However, the application of organic mulch favors the development of several pests, such as the squash bug *Anasa tristis* and the American palm cixiid *Myndus crudus*. Mulches or other barriers placed around the onion plant can also block the egg-laying fly of Delia antiqua it walks down the stem to lay its eggs in the soil at the base of the plant.

Cereal straw and stalks, crop residue, sawdust, leaves, grass, manure, weeds and numerous aquatic plants are examples of natural materials used as mulch. In reality, just about any readily available, ideally affordable, organic ingredient is used. Many pathogens have a food source, a location to live, and a way to multiply when agricultural residues are used as mulch, which can have an impact on the prevalence of the disease. By modifying the physical environment of the host and the pathogen, crop residues may potentially have an impact on the occurrence of illness. Organic mulches improve the soil by adding nutrients and organic matter, lower soil temperature (by up to 5°C), smothering weeds, increasing infiltration and absorption of water, reducing water loss from the soil, increasing infiltration and absorption of water, and protecting seedlings from the effects of rain, hail, and wind (important in the tropics where rain is heavy). All of these elements might affect how a disease develops. Mulch on the soil surface prevents leaves, flowers, and fruits from coming into direct contact with the soil or disease propagules there, which slows the spread of bacterial and fungal propagules brought on by water splashes. Crop leftovers typically increase soil microorganism competition for nitrogen, carbon, or both, which reduces issues with soil-borne diseases. (Ogle, 1997). Vincent et. al, (2003) summarized that straw mulch indirectly affects beetle populations and significantly reduces damage by promoting a variety of Colorado potato beetle egg and larval predator species, such as *Coleomegilla maculata*, *Hippodamia convergens*, *Chrysopa carnea*, and *Perillus bioculatus*. (Vincent et. al, 2003)

Examining different types of mulches, Mochiah and Baidoo, (2012) found that all soil covers tested suppressed pest numbers in pepper, with living mulch showing slightly better results than straw. On the other hand, straw mulch attracts more natural enemies, providing them with better shelter.

Coleomegilla maculata
Source here

Hippodamia convergens
Source here

Chrysopa carnea
Source here

Perillus bioculatus
Source here

However, in rare instances, mulching has led to an increase in disease incidence and severity, possibly as a result of systemic microclimate changes that favor the pathogen. By boosting the activity of organisms that hinder infections' growth or survival, organic soil additions can suppress pathogens. In some instances, disease incidence and severity have increased.

The issue can be resolved by amending the soil near plant bases with a lot of chicken manure. Similarly, to this, adding chitin from fish, crab, or other animal wastes to soil encourages nematode egg parasitism by fungi and lowers inoculum levels. Sadly, adding additives to the soil does not always have the desired result. The pathogen thrives on modification, which may lead to an increase in disease incidence or severity. Additionally, as some organic soil additives break down, phytotoxic compounds are created (Ogle, 1997).

Source here

Crop mulching can help to lessen weed development and warm up the soil and vegetation, which will promote and enhance plant growth and make them more resistant to pests and diseases. The use of fleece, however, can sometimes have a negative effect because it may foster the growth of new diseases because of the microclimate that is formed at the soil level under the fence. (Farmers' Toolbox for Integrated Pest Management)

Type of mulch material	Advantages in:			Disadvantages
	Weed control	Pest control	Disease control	
Inorganic mulche				
Clear plastic	-	-	-	Perfect conditions for weeds growing
Black plastic	+	-	-	
Red plastic	+	-	-	
Reflective		Repellence of aphids and trip	confusing insect vectors	the leaves of the plants later cover the mulches and reduce their effectiveness
Silver plastic		deterred thrips	Stop spread of TSWV	
Newspaper	2-4 layers	-	-	
Pine needles	-	-	-	
Sawdust	5 cm			

Type of mulch material	Advantages in:			Disadvantages
	Weed control	Pest control	Disease control	
Organic mulches				
Bark and wood chips	5-8 cm			
Compost	5-8 cm			Could contain weed seeds if is not composted properly
Grass clipping	5-6 cm withered or dry layer			Could contain weed seeds
Hay or straw	8-10 cm (some recommendations are for 15-20 cm)	Suppress Colorado potato beetle– 10 cm layer; Cucumber striped beetle; *Delia antiqua*, (onion fly)		Could contain weed seeds or other seeds
Hulls and ground corncobs	5-10 cm			
Leaves	5-8 cm			
Peat moss	5-8 cm			
Pine needles	-	-	-	

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Unit 2.9 Pest exclusion by screens and barriers

Rumen Tomov, Roxana Ciceoi,
Okray Orel

Pest exclusion by screens and barriers involves the use of physical barriers, such as trunk barriers, screens, nets, fences, tranches etc, to prevent pests from entering an area where they are not wanted. They are produced by different materials and have pest specific size and construction.

In addition of coomon used materials, a pioneering investigations have been carried out to create tailored agricultural plastics, which involve: agents to alter spectral properties (Ashkenazi 1996); additives to augment diffusion and the penetration of light deeper into the plant canopy (Pollet et al. 2000); additives that reduce energy losses by blocking infrared radiation (Edser 2002); and additives to modify the transmitted light spectrum (Edser 2002).

Hort4EUGreen

2.9.1 Trunk barrier

Fruit tree trunks are a route for various pests crawling up and underneath fruit trees for eating vulnerable new growth, laying eggs, mate etc. Crawling insects reduce production, and making plants susceptible to other pests for example ants which promote the spread of aphids and can carry bacterial and fungal diseases to healthy plants.

Source: https://www.thedailygarden.us/garden-word-of-the-day/sticky-barriers

Crawling insects belong to different taxonomic groups. Some species from *Geometridae* family as Mottled umber moth (*Erannis defoliaria*), winter moth (*Operophtera brumata*) and March moth (*Alsophila aescularia*) have wingless females which, after emerging from the pupal or chrysalis stage in the soil, must climb the tree to mate and lay their eggs. Other crawling species are Cutworms (*Agrotis spp.*), *Hyphantria cunea*, some Weevils etc.

Erannis defoliaria
Source here

Operophtera brumata
Source here

Alsophila aescularia
Source here

Prevention of this movement can be achieved by banding the trees with various commercially available and homemade products - glue bands with non-drying adhesive wrapped around tree trunks as a barrier to block insect’s movement.

They are available on the market under different names – glue bands, barrier tape, Sticky barrier etc. They are produced by different materials – plastic band/tape, fluffy cotton band etc. Some producers offer products suitable for Smooth-barked trees or trees with fissured bark. These bands have different size, color, glue and other characters. Sticky barriers can be home made (petroleum jelly, axle grease) as well. The installation of glue bands, depends on biology of the target pest.

The prevention from crawling insects could be achieved by applying glue or horticultural grease around the trunk as well. Since the sticky material can damage bark tree trunks should first be wrapped with tape.

Products:

- Insect barrier glue - https://www.allotment-garden.org/store/equipment/insect-barrier-glue-200g
- Liquid Tree Glue "M" - https://progarein.com/en/category-product/insect-control/crawling-insects-trunk
- Pasty Tree Glue Glu Gom® - https://progarein.com/en/category-product/insect-control/crawling-insects-trunk
- Tree Glue in Gel - https://progarein.com/en/category-product/insect-control/crawling-insects-trunk
- Tree Glue Marbella® - https://progarein.com/en/category-product/insect-control/crawling-insects-trunk
- Solabiol Boltac Greasebands, Growing Success Glue Band Traps, Vitax Tree Bands, Neudorff Greaseband or Agralan Glue Bands, Vitax Fruit Tree Grease or Agralan Insect Barrier Glue - https://www.rhs.org.uk/prevention-protection/grease-bands-and-tree-barrier-glues

Additional information:
https://www.e-econex.net/en/insect-traps/econex-barrera-para-troncos-7.html
https://www.andermatt.com/hag/caterpillar-glue-band/
https://www.allotment-garden.org/store/equipment/tree-bands
https://deepgreenpermaculture.com/2019/02/27/horticultural-glues-and-tree-banding-trees-to-controls-ants-and-other-pests/
https://polymertape.com/products/insect-barrier-tape
https://progarein.com/en/category-product/insect-control/crawling-insects-trunk
https://www.thedailygarden.us/garden-word-of-the-day/sticky-barriers
https://www.rhs.org.uk/prevention-protection/grease-bands-and-tree-barrier-glues
https://deepgreenpermaculture.com/2019/02/27/horticultural-glues-and-tree-banding-trees-to-controls-ants-and-other-pests/

2.9.2 Pest control nets

Pest control nets are mesh covers with different hole sizes that are stretched above the single plant or entire crop plantation. **The use of nets** is a physical measure for protection of high value crops, mainly fruit and vegetables from different pests - **Aphids, leafhoppers, leafminers, moths, thrips, whiteflies, vertebrates**

According to Weintraub, 2009 the advantage of mesh screening, as opposed to solid plastic sheets, is that it permits movement of air and help reduce humidity, which enhances plant pathogen development. Nevertheless new diseases under the net can appear and such nets can't be used in windy areas. (EU Toolbox for IPM, 2023)

Special nets with different hole sizes for protection of different plantings (gardens and vegetable gardens, greenhouses, farmland, seedbeds, orchards) and crops (Strawberry, Blueberry, Grape, Cherry, Citrus, Aple etc.) are available on the market: (1) **Fruit Tree Netts.** They are large enough to be placed over the plant in its entirety; (2) **Fruit protection bags** – for protection of single fruit/ bagging the fruit; **Insect Nett** – fine or ultrafine mesh etc.

Some potential advantages and disadvantages of pest protection nets that have been discussed in the literature.

Advantages

Reduce insect pest populations: Pest protection nets can act as a physical barrier to exclude pests, which can reduce the populations of immigrant pests and invasive species (Athanassiou et al., 2015).

Increased crop yields: The use of insect pest nets can also increase crop yields by protecting the crops from insect pests and other factors that can reduce yield (Cuthbertson et al., 2012).

Reduced use of pesticides: The use of pest protection nets can lead to a reduced need for chemical pesticides, which can be costly and harmful to the environment (Athanassiou et al., 2015).

Reduce insect pest populations: Pest protection nets can act as a physical barrier to exclude pests, which can reduce the populations of immigrant pests and invasive species (Athanassiou et al., 2015).

Disadvantages

- Cost: Pest protection nets can be expensive, especially for larger fields or farms, which can make it difficult for small-scale farmers to use them (Athanassiou et al., 2015).

- Limited air and light circulation: The use of pest protection nets can reduce air and light circulation, which can negatively impact crop growth and development (Cuthbertson et al., 2012).

- Maintenance: Pest protection nets require regular maintenance to ensure they remain effective, which can be time-consuming and costly (Athanassiou et al., 2015).

- Risk of heat stress: Pest protection nets can lead to increased temperatures, which can cause heat stress for crops and reduce yields (Cuthbertson et al., 2012).

Here are some examples of pest control nets:

Pest protection mesh for perenials

The use of pest protection mesh nets is suitable for perennials - mainly in orchards and somewhat in vineyards Chouinard et al. (2016).

An effect of various types of nets on the microclimate, tree growth and management, fruit quality, diseases, disorders, economical insect pests and beneficial insects is analyzed by Aoun (2018).

Insect screens for greenhouses

To reduce the potential for insect pest problems to develop, preventing them from entering and establishing **in the greenhouse is essential**. (https://www.producegrower.com/article/hydroponic-production-pointers-insect-screens-control-pests/). The use of physical barriers such as insect screens on ventilation inlets and doors, are increasingly becoming a major component of IPP systems for greenhouses. The use of screens to exclude insects from greenhouses may lead to reduced pesticide use but the materials used for the screen may turn out to be non-biodegradable. Ajwang et al., 2002. Some 93% of the crops covered with IES were grown in the coastal, Mediterranean climatic zones, which do not require heating in the winter. Almost 50% of the major vegetable crops: cucumber, eggplant, tomato, pepper and strawberry, were grown under IES (50,400 uncovered versus 48,700 covered hectares) (Weintraub, 2009)

A literature review of the developments in the theory of physical and technical aspects of insect screens, is presented by Ajwang et al., 2002. According to (NGMA 2001) four different insect screen materials are in use in the USA: (1) **stainless steel and brass**, (2) **Polyethylene** - monofilament, woven with solid strands or film that is punched full of “micro-holes” and used as a crude; (3) polyethylene/acrylic and (4) nylon. According to construction insect screens are: (1) weaving, (2) knitting, and (3) punching. The various forms of Insect exclusion screens have been reviewed extensively by

Weintraub and Berlinger (2004) and Weintraub (2009) as well. Screen mesh sizes needed to exclude major greenhouse pest species is presented by Bethke (1994).

Ultraviolet-absorbing screens

It has long been known that some species of insects use ultraviolet light for orientation (Kring 1972) and all insect species examined to date have UV receptors (Briscoe and Chittka 2001).

Antignus et al. 1998 reported **ultraviolet-absorbing screens (bionets)** which serve as optical barriers to protect tomatoes from certain virus and insect pests.

The effects of UV-absorbing nets on reducing the populations of different species of insect pests (aphids, leafhoppers, thrips, and whiteflies) have been well documented (Antignus et al. 1996; Costa and Robb 1999; Costa et al. 2002; Chyzik et al. 2003; Kumar and Poehling 2006; Doukas and Payne 2007; Weintraub et al. 2008). The UV-absorbing materials have proven to be very effective in reducing the spread of insect-transmitted plant viruses (Antignus et al. 1996; Diaz et al. 2006).

Climate screens

Xsect Balance ensures effective aphid and whitefly exclusion with maximum airflow, providing the ultimate balance between exclusion and porosity potential, creating an all-around better

growing climate. Xsect insect control screens are uniquely engineered to keep harmful insects out while allowing for maximum airflow, creating a cooler, less humid greenhouse climate that is healthier and more productive for people and plants alike.
Source: https://www.ludvigsvensson.com/en/climate-screens/climate-screens-products/all-climate-screen-products/xsect-balance)

Colored Shade Netting
Recently entomologists have started looking at the effects of the **colored shade nets** on insect pest populations (Weintraub, 2009). Ben-Yakir et al. (2008) tested the landing of thrips and whiteflies on black, red, yellow and blue nets covering chives or cotton plants. They found that covering plants with yellow netting protected plants from whitefly infestation; the pest landed on the net but did not penetrate the nets to reach the plants. Similarly, thrips demonstrated an arrest response on the yellow and blue nets and were less likely to penetrate the netting.

Overview of insect screens and nettings for all types of pests from birds to thrips for greenhouse crops could be found at https://www.usgr.com/insect-screen/insect-screen/

Some **supliers** of nets are:
https://www.wnplastic.com/insect-control-net.html
https://www.usgr.com/insect-screen/

Additional information
https://eyouagro.com/blog/7-secrets-of-fruit-tree-netting/
https://www.gardening-naturally.com/netting-frost-protection/garden-netting/bird-netting?gclid=CjwKCAjwyqWkBhBMEiwAp2yUFjvWowcrGMnh7lxDiXK2BbxErlVDarlqYqv2Mi2tQ8Ts0T7l9EMzaxoCGbkQAvD_BwE
https://www.wmjames.co.uk/fruit-tree-netting.html
https://www.farmtek.com/cat/ft-fruit-tree-nets.html
https://www.huck-net.co.uk/nets-ropes-and-cordage/fruit-tree-netting_19810/
https://www.usgr.com/insect-screen/bird_netting/
https://www.geziproofing.com/contact.html
https://extension.umn.edu/commericial-fruit-growing-guides/hail-netting-apple-orchards

2.9.3 Row covers

A row cover is a lightweight fabric that is used to cover rows of plants in order to protect them from insect pests, birds, and other pests. It is one of the simplest and most effective methods of pest management.

Row covers can be either transparent or semi-transparent and can be made from a variety of materials, such as insect netting, agricultural fleece, or paper. By covering the rows of plants with row covers, pests such as aphids, beetles, and caterpillars cannot access the crops, reducing the damage caused by these insects.

Useful information about Advantages, Limitations, Types and How To Use Row covers could be found in Rennie Orchards 2023
Source: https://rennieorchards.com/row-covers/

There are many types of row covers but two of them are used for pest control- (1) **Floating Row Covers** and (2) **Netting Row Covers**.

Floating Row Covers

A floating row cover is a lightweight protective covering used in gardening and agriculture to provide a physical barrier that protects plants from pests, weather, and other environmental factors. The cover consists of a thin, semi-transparent, fabric-like material made of spun polypropylene or polyester. The material is draped over the plants and secured in place using stakes or soil. The cover 'floats' over the plants, allowing them to grow while providing protection. The cover is permeable to light, air, and water, allowing the plants to receive the necessary nutrients for growth.

Floating row covers are often used to extend the growing season by creating a microclimate that traps heat and moisture around plants or crops. The covers are also effective in preventing insect and bird damage, protecting plants from frost damage, and reducing the impact of hailstorms. Floating row covers are available in various sizes and thicknesses, with lighter fabrics being ideal for insect protection and warmer climates, and heavier fabrics for frost protection and colder climates. The covers are reusable and can last for several growing seasons if properly cared for.

Floating Row Covers

Various forms of floating row covers or fleeces were tested in the 1980s (Harrewijn et al. 1991). Studies on the protection afforded to field crops against pathogen-bearing insects causing direct damage have been conducted in: carrots (Rekika et al. 2008), peppers (Avilla et al. 1997, Goldwater, et al. 2018), squash (Webb and Linda 1992; Qureshi et al. 2007) and other crops.

They are especially important for controlling plant pathogen vectors as aphids, leafhoppers, but according to https://hort.extension.wisc.edu/articles/floating-row-cover/ Covering crops can eliminate many pests on a variety of plants, including:

- caterpillars (imported cabbageworm, cabbage looper and diamondback moth) on cabbage, broccoli, and cauliflower;
- fleabeetles on cabbage, potato, eggplant or salad greens;
- onion maggot on onion;
- seedcorn maggot on beans, corn and other crops (*Delia platura*);
- thrips on a variety of plants;

Floating row covers are made of woven plastic, polyester, or polypropylene and are cloth-like in appearance.. (Olle and Bender, 2010, Rennie Orchards 2023). There are several weights of covers for different uses. (https://hort.extension.wisc.edu/articles/floating-row-cover/)

They are loosely applied after seeding or transplanting to ensure there will be sufficient material volume to float up as plants grow and they are removed just prior to harvesting (Weintraub, 2009).

Netting Row Covers

Netting row covers are a type of protective covering that shields plants from insects, birds, animals, and weather damage such as wind or hail. These covers are constructed from a lightweight yet durable mesh netting material, typically made from polyester or nylon, that is able to withstand harsh environmental conditions. Similar to floating row covers, netting row covers are positioned over the plants or crops and secured in place using stakes or weights. However, because of the porous nature of the mesh material, netting row covers are better at allowing for airflow and can be left over plants for extended periods. It is advisable to place netting row covers over crops early in the season to prevent pests from laying eggs on the leaves.

Netting row covers are made of woven fabrics or mesh, which improves ventilation under the cover. Their main benefit is preventing pests from getting to the plants. Useful advises how to use row covers with tomato, pepper, eggplant, Squash, cucumber, pumpkin, watermelon, muskmelon/cantaloupe, lettuce, spinach, arugula, radish, carrot, Asian greens, radish, broccoli, cabbage, cauliflower, mustard, kale, collard, Swiss chard, beet, potato, green beans, and strawberry could be found at https://extension.umd.edu/resource/row-covers

Additional information

https://gardenerspath.com/how-to/greenhouses-and-coldframes/floating-row-covers/
https://www.epicgardening.com/floating-row-covers/
https://www.gardeners.com/how-to/row-covers/5111.html
https://extension.umd.edu/resource/row-covers
https://rennieorchards.com/row-covers/
https://www.uvm.edu/sites/default/files/media/Using%20Row%20Covers%20in%20Vegetable%20Production.pdf).
https://extension.umn.edu/pest-management/using-row-covers-manage-insects#netting-row-covers-815148).
https://extension.unh.edu/resource/benefits-row-covers).

2.9.4 Trenches

Trenches are one of the methods used in pest management to control soil-dwelling pests like cutworms and wireworms. A trench is a narrow furrow or a ditch dug around the perimeter of an area or a crop that is being protected. The trench is a barrier that prevents pests from crossing into the protected area.

The width and depth of the trench depend on the size and type of pest that is being targeted. For example, for cutworms, trenches need to be dug 7 to 10 centimeters deep and 12 to 15 inches wide. If slugs are the target pest, trenches should be dug deeper and wider. Trenches can be filled with different materials such as sand, crushed eggshells, or wood ash that act as abrasive elements to damage the pests' bodies and prevent them from crossing the trench. Digging of 30 to 60 cm deep trenches or erecting 30 cm high tin sheet barriers around field is useful for protecting them from moving bands of locusts. Trenches can be effective for several weeks, depending on the type of pest and the weather conditions.

2.9.5 Fences

Fencing is a crop protection method that involves the installation of physical barriers, around crops to prevent damage caused by pests and other animals. Fences can vary in height and composition to prevent access by different types of animals.

Fencing can be particularly effective for large mammals, that can cause significant damage to crops. By preventing access to the crop, farmers can reduce the risk of damage and loss of yield.

Fencing is particularly relevant to exclude low-flying insects (e.g., anthomyiids) from annual crops (e.g., onion and cole crops) as well (Boiteau &Vernon 2001). Fences 1 m high exclude 80% of flying female cabbage flies, *Delia radicum*. Height of the fences is critical and is limited by cost and resistance to wind. Although cabbage maggot flies can be captured up to 180 cm above ground level, Vernon & Mackenzie (1998) adopted fences 90 cm high as an optimal fencing method.

Overhangs (25 cm) decreased cabbage maggot fly, *Delia radicum*, trap catches inside the fenced plots and reduced damage to the crop (Bomford et al. 2000).

Segregating vegetable crops using fences and rotating them can enhance the efficiency of exclusion fences, primarily because of the natural predators of anthomyiid adults that the fence attracts over time. However, there are a few cons associated with fencing like exclusion of good flyers that can damage a crop next to the protected ones and those trespassers who overcome the barrier and enter the enclosed area can still cause harm to the protected crop.

Collars made of cardboard, tin cans, or aluminium foil and inserted halfway into the soil are effective barriers to cutworms. They prevent cutworms from being able to feed on seedling stems.

Mounding soil around grapevines can prevent the emergence of grape root borer moths.

Plastic Trellis Netts cold be used for protection of vegetable plants and fruit trees from birds, deer, squirrels and other animals.

Rabbit proof netting are fencing made of plastic or mesh that is used to keep rabbits out of gardens.

Copper Slug Tapes, rings and Bands could be used for protection of crops from slugs and snails. Slugs and snails hate copper because of a reaction between their mucus and the copper, so use self-adhesive Copper Tapes to protect pots and containers from slugs and snails. Use our best selling Copper Slug Tape to protect pots and containers from slugs, but if it is snails, or a combination of the two, then use Flexible Slug and Snail Tape or our Serrated Copper Snail Tape.

Additional information

https://www.greengardener.co.uk/shop/pest-control-outdoors/slug-control/copper-slug-and-snail-tapes/

https://www.greengardener.co.uk/product/copper-slug-tape/

https://freshpatio.com/vegetable-garden-fence-ideas/

https://www.wirefence.co.uk/install-a-rabbit-proof-fence/

2.9.6 Packaging/Bagging fruits

Rumen Tomov, Andreea Barbu

Field bagging of fruits and grapes is a pest control measure in which individual fruit or grape clusters are covered with protective bags made of paper, cloth, or synthetic materials.

The bags prevent pests, such as insects and birds, from accessing and damaging the fruit or grapes. This technique is commonly used in certain crops such as apples, peaches, and grapes. It is mostly used in small-scale or organic farming systems, where chemical pesticides are minimized or not used at all Sampson, et al. (2003).

Tonina et al. (2013) found that bagging apples significantly reduced the damage caused by codling moth and oriental fruit moth, thus increasing fruit yield and quality.

Cid et al. (2016) found that field bagging of grapes with insect-proof nets significantly reduced the populations of grapevine moth and other pests, while also improving grape quality in terms of sugar and acidity content.

2.9.7 Optical and sound generating devices

Optical barriers can be used to prevent the entry of pests into a crop field or a protected area.

Tattersall et al. (2011) evaluated the effectiveness of an infrared optical barrier that was used to prevent the entry of rabbits into a crop field. The barrier consisted of a series of infrared beams that emitted an alarm signal when interrupted by a rabbit, thereby deterring its entry into the field. The study found that the optical barrier significantly reduced rabbit damage to the crops.

Another way to deter vertebrate pests is by placing models of predators and raptors, in areas that are highly visible. Here are some examples of the use of model figures of predators and raptors for pest management in Europe.

Owl models for bird control

Owl models are commonly used to scare birds away from crops and other areas. Barba-Espín et al. (2013) evaluated the effectiveness of owl models in protecting grapevines from bird damage and found that the use of owl models significantly reduced bird damage to grapes.

Snake models for rodent control

Snake models are used to deter rodents by simulating the presence of a predator. Rosell & Bredbacka (2007) evaluated the

Rosell & Bredbacka (2007) evaluated the effectiveness of snake models in reducing rodent activity in a chicken farm and found that the use of snake models significantly reduced rodent activity in the farm.

Raptor models for pigeon control

Raptor models, such as falcons and hawks, are used to scare pigeons away from buildings and other areas. Krijger et al. (2014) evaluated the efficacy of raptor models for the control of pigeons on buildings and found that the use of raptor models significantly reduced the number of pigeons on buildings.

Acoustic devices use high-frequency sound waves to repel pests such as rodents, birds, and insects.

A case study was conducted in Spain to evaluate the effectiveness of the Pest Reject Ultrasonic Pest Repeller device in controlling the population of rodents. The device emitted sound waves at a frequency of 20-50 kHz that were intended to repel rodents. The study showed a significant reduction in the population of rodents in the treated area (González-Megías & Menéndez-Guerrero, 2019)

Noise-making devices can be used to create a loud and disruptive sound that can frighten birds and deter them from an area. This method is effective because birds are highly sensitive to sound and can be easily startled by loud, unfamiliar noises. Newberry & Eason, (1996) evaluated the effectiveness of bird banger guns in scaring away Canada geese from a water treatment plant and showed that the use of bird banger guns was effective in reducing the presence of Canada geese in the treated area. Visser (2001) evaluated the effectiveness of an electronic bird scarer in reducing the damage caused by crows in agricultural fields and showed that the use of electronic bird scarers significantly reduced crow damage to crops when used in combination with other control methods.

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Unit 2.10 Pest trapping

Rumen Tomov,
Roxana Ciceoi

Insect traps are devices with a special construction that prevents the insects that get into it from leaving it. These structures are varied and are tailored to the specific characteristics of the different groups of insects for which they are intended.

In order to fall into the traps, the insects must be attracted by lure. This lure can be of a different nature - pheromones, parapheromones, food-based attractants, volatiles, light, colors.

Traps use different approaches retain attracted insects, based on which the main categories of traps are dry, wet, dry or wet.

Different traps and lures have been developed and used over decades in IPM for: (1) monitoring surveys (to verify the status of pest population and detetct flight activity), (2) detection surveys (to determine the pest presence in the area), (3) pest control (mass trapping - trap and kill) or (4) male annihilation in specific area.

The successful pest management depends on properly chosen combination of trap type, lure and killing method.

2.10.1 Lures

A lure is an chemical food or colour that attracts insects for the purpose of monitoring or control (Coombs and Hall 1998). In general, 'lure' is defined as a thing that attracts or lures an animal to do something (Oxford 2008), or anything that serves as an enticement (Webster 2008).

A **lure** is a substance or object used to attract animals or insects towards a specific area or trap. The purpose of a lure is to increase the effectiveness of the trap or method of control by using an attractive scent or object to entice the target animal or insect to come closer. In some cases the Lure is a Bait is often used to attract animals towards a trap.

A **bait** is a pesticide formulation that combines an edible and/or attractive substance with a pesticide, e.g. grasshopper bait (Pedigo 2002, Gordh and Headrick 2001). For tsetse fly baits, refer to Van den Bossche and De Deken (2004); for fruit fly baits, refer to Nigg et al. (2004). A lure intended to attract specific organisms (Gordh and Headrick 2001).

The main difference between a lure and bait is the way they are used. A lure is typically used to attract animals or insects towards a specific area, while bait is used as a type of food or substance that can be consumed by the target animal, often as a part of a trap or other method of control.

The main difference between a lure and bait is the way they are used. A lure is typically used to attract animals or insects towards a specific area, while bait is used as a type of food or substance that can be consumed by the target animal, often as a part of a trap or other method of control. A lure is more of an attractant that entices animals towards the trap or control method, while bait is something that the animal consumes that contains a substance or mechanism that causes harm or traps the animal.

Different types of lures

Light

The use of light is already widespread in integrated pest management (Garstang, 2004). Traps using light as a lure are called Light traps. Insect activity is generally classified into groups of nocturnal, diurnal (active daytime) and crepuscular (active at dusk or morning before sunrise/sunset). This activity is influenced by biotic factors (competition, predators, etc.) (Gottliebb et al., 2005). According to Fournet et al., (2004), Barbosa and Castellanos (2005), insects regulate their activity patterns to be safe and avoid predators, so that their activities do not coincide with the time of predator activity. Ting et al. (2016) states that the most catches of insects is in the evening (sunset), followed in the early morning, namely in the crepuscular group.

The vision of insect pests ranges from a wavelength of 350 nm (ultraviolet) to 700 nm (Land 1997). Insects can be attracted (positive phototaxis) or repelled (negative phototaxis) to special light sources (Park and Lee 2017).

Many species, representative of most orders, have been shown to be very sensitive to ultraviolet light and some very significant phototaxes (behavioral responses to light) are initiated by it. In light traps, incandescent or mercury vapor light bulbs are widely used, but LEDs (light emitting diodes) have been used increasingly in recent times (Oh 2011, Mangan and Chapa 2013). The advantages of LEDs are numerous and include small size, low weight, low electricity consumption, long lifetime, low temperature, high luminous efficiency, selectivity of specific wavelength, and light intensity (Cohnstaedt et al. 2008, Yeh and Chung 2009).

Based on the phototactic behaviors of the agricultural insects, green or blue LEDs are most attractive for *Bemisia tabaci*, *Trialeurodes vaporariorum*, *Myzus persicae*, *Liriomyza trifolii*, *Spodoptera exigua*, and *Spodoptera litura*. Green LED attracts *Plutella xylostella* and *Frankliniella occidentalis*. Similarly, green or blue LEDs are more attractive to agricultural insects, such as Liriomyza sativae etc., than other wavelength LEDs. Applying LED technology for greenhouses along with conventional traps reduces crop loss due to moths, beetles, aphids, and weevils. LEDs have potential value in integrated pest management. (Park and Lee, 2017). It has long been known that some species of insects use ultraviolet light for orientation (Kring, 1972) and all insect species examined to date have UV receptors (Briscoe and Chittka, 2001).

Colour

The use of color is already widespread in integrated pest management. Traps using chromatic attraction as a lure are called Color traps. the color also enhances the attractive effect of the other baits in all the traps used. The color vision of insects requires that they have the ability to discriminate between wavelengths to which it is sensitive. Field observations and behavioral experiments have demonstrated that representatives of many insect orders are able to distinguish between colors. (Gillott, 2005). The fact that insects are attracted to different colors has been used to develop different traps. Traps and monitoring devices are produced in a specific colour wavelength and trap pattern to ensure maximum attraction to the target pest. Moericke (1952) was first to demonstrate that aphid alight on plants in response to color (phototaxis). Aphids respond strongly to yellow and alight on this color; they respond less so to green and orange, and few respond to white, red, blue, black or violet (Moericke 1955).

Hort4EUGreen

Thrips, another important plant disease vectoring insect, did not respond to the same colors as aphids, except for blue, which was attractive (Wilde 1962).

Insect color preferences (based on commercially available traps)

Colour	Pest
Yellow	Winged aphids (*Aphidoidea*) Whiteflies or greenhouse white flies (Trialeurodes vaporariorum) Fungus gnats (*Sciaridae*) Thrips (*Thysanoptera*), especially grape thrips Fruit flies (*Drosophila suzukii*) Leaf-miner flies (*Agromyzidae)* Green leafhoppers (*Empoasca vitis*) Yellow Impact boards are attractive to a wide range of insect pests including aphids, whitefly, thrips, fungus gnats, fruit flies and leaf miner flies.
Blue	Thrips, western flower thrips, Apple Blossom Beetle Tropinota Hirta (*Epicometis Hirta*)
Light blue	Some thrips species, bugs (*Heteroptera*), thrips, sawflies, flea beetles
White	Thrips, California flower thrips (*Frankliniella occidentalis)*, apple sawfly (*Hoplocampa testudinea*), plum sawflies (*Hoplocampa minuta* or *Hoplocampa flava*), raspberry beetle (*Byturus tomentosus*), *Aonidiella aurantii*
Red	*Xyleborus dispar*, *Drosophila suzukii*, leaf hopper species (e.g. *Empoasca spp*.) and gall midges (e.g. *Dasineura oxicoccana*).
Orange	*Chamaepsila rosae*, *Ceratitis capitate*, *Bactrocera oleae*
Green	Certain leafhoppers and plant bugs are attracted to the color green
Black	*Tuta absoluta*
Transparent	*Halyomorpha halys*

In certain situations, when there are a large number of biocontrol agents in use, there might be an unintended high capture of predatory insects. A study conducted by Clare et al. in 2000 found that red traps had lower catches of beneficial insects compared to yellow and white traps. The study also revealed that green traps caught fewer non-target Hymenoptera, but the green color was not as visible to the target species. On the other hand, black traps were effective in enhancing visual contrast but reduced the attraction of beneficial insects like pollinators.

Colour

Pheromones produced by individuals of a species that modify the behaviour of other individuals of the same species (i.e. an intraspecific effect). There are several definitions of Pheromones:

Chemical signal or message (or a synthetic analogue of that substance) (an exocrine chemical messenger secretion) released by an individual that induces either a behavioural reaction or a developmental process in other individuals of the same species (Resh and Cardé 2003, FAO/IAEA/USDA 2003, Coombs and Hall 1998, Leak 1999, Coppel and Mertins 1977).

An agent of intraspecific chemical communication, e.g. sex pheromone, alarm pheromone, aggregation pheromone, trail pheromone
(Gordh and Headrick 2001, Pedigo 2002).

A volatile compound dispersed to the air or laid down on substrate that is used for intraspecific communication (Grimaldi and Engel 2005). See 'allomone', 'kairomone', 'synomone', 'semiochemical', 'parapheromone', 'sex pheromone', 'pheromone trap'.
IAEA

Para-pheromones

Specific chemical compounds produced by plants and which mimic the effect of insect pheromones. Para-pheromones may be synthesized and used to detect, monitor, mass-trap or disrupt the mating of target insect species (Gordh and Headrick 2001, IAEA 2003). Para-pheromones are generally highly volatile, and can be used with panels, delta-traps and bucket-type traps Some of them have controlled release formulations providing a longer lasting attractant for field use.

List of pheromones available on the market in Europe for attracting horticulture insect pests

Pest name	Supplier	Pest name	Supplier
Acleris rhombana	Pherobank,Trifolio_M GmbH,Pherobees, International pheromone Systems	*Anarsia lineatella*	International pheromone Systems, Probodelt, Pherobank, Russell IPM Ltd, SEDQ Healthy Crops, S.L, Novagrica, Andermatt, Trifolio_M GmbH, Pherobees
Acrobasis nuxvorella	Pherobees	*Anthonomus rubi*	International pheromone Systems,Russell IPM Ltd
Acrobasis vaccinii	Pherobees,Pherobank	*Aonidiella aurantii*	International pheromone Systems, Pherobank, Russell IPM Ltd, Novagrica, Pherobees
Acrolepiopsis assectella	International pheromone Systems, Pherobank, Trifolio_M GmbH, Pherobees	*Archips podana*	International pheromone Systems, Novagrica, Biobest,Pherobank,Trifolio_M GmbH, Pherobees
Adoxophyes orana	International pheromone Systems,Biobest, Pherobank, Novagrica, Andermatt,Trifolio_M GmbH, Pherobees	*Archips rosana*	International pheromone Systems, Novagrica, Biobest,Pherobank,Trifolio_M GmbH, Pherobees
Agriotes lineatus	International pheromoneSystems Biobest, PherobankNovagrica,Andermatt,Trifolio_MGmbH, Pherobees	*Archips xylosteana*	Pherobees, Novagrica,Pherobank, Trifolio_M GmbH, International pheromone Systems
Agriotes obscurus	International pheromone Systems, Pherobank, Pherobees	*Argyresthia conjugella*	Pherobees, Pherobank, Trifolio_M GmbH
Agriotes spp	Pherobees, Pherobank	*Argyresthia goedartella*	Pherobank
Agriotes sputator	International pheromone Systems, Pherobank, Pherobees	*Argyresthia pruniella*	Pherobees, Pherobank,Trifolio_M GmbH
Agrotis exclamationis	International pheromone Systems, Pherobank, Novagrica, Trifolio_M GmbH, Pherobees	*Argyrotaenia citrana*	International pheromone Systems, Pherobank, Pherobees
Agrotis segetum	International pheromone Systems, Pherobank, Novagrica, Andermatt, Trifolio_M GmbH, Pherobees	*Argyrotaenia pulchellana*	International pheromone Systems, Pherobank, Pherobees
Amphipyra pyramidea	International pheromone Systems	*Argyrotaenia velutinana*	Pherobank,Pherobank, International pheromone Systems

Pest name	Supplier	Pest name	Supplier
Autographa gamma	International pheromone Systems,Probodelt,Pherobank, Novagrica, Trifolio_M GmbH,Pherobees	*Choristoneura rosaceana*	International pheromone Systems, Pherobees
Bactrocera cucurbitae	International pheromone,Systems, Russell IPM Ltd, Pherobank, Pherobank, Pherobees	*Chrysodeixis chalcites*	Pherobank, Russell IPM Ltd., Novagrica, Trifolio_M GmbH,Biohelp, International pheromone Systems, Pherobees
Bactrocera dorsalis	Russell IPM Ltd,Pherobank, Pherobees, International pheromone Systems, Pherobees	*Clepsis spectrana*	International pheromone Systems, Pherobank
Bactrocera oleae	Probodelt, Russell IPM,Ltd, SEDQ Healthy Crops,S.L,Novagrica, Pherobank, Pherobees	*Cnephasia asseclana*	International pheromone Systems
Bactrocera spp.	Novagrica	*Cnephasia longana*	Pherobees, International pheromone Systems
Bactrocera zonata	Russell IPM Ltd,Pherobees, Pherobank, International pheromone Systems	*Contarinia nasturtii*	Pherobees, Pherobank, Andermatt, Andermatt
Byturus tomentosus	Andermatt	*Cossus cossus*	Pherobees, Biobest, Pherobank, Novagrica, Andermatt, Trifolio_M GmbH
Cacoecimorpha pronubana	Pherobees, Pherobank,International pheromone Systems	*Cryptoblabes gnidiella*	Pherobees, Pherobank, Trifolio_M GmbH, International pheromone Systems
Carposina niponensis	Pherobees	*Cryptophlebia batrachopa*	International pheromone Systems
Carposina sasakii	International pheromone Systems, Pherobank	*Cydia pomonella*	International pheromone Systems, Biobest, Trifolio_M GmbH,Probodelt, Russell IPM Ltd, SEDQ Healthy Crops, S.L, Novagrica, Andermatt, Pherobees, Pherobank
Carrot fly	Koppert	*Cydia pyrivora*	Pherobees, Pherobank, Novagrica, International pheromone Systems
Ceratitis capitata	International pheromone Systems,Russell IPM Ltd, SEDQ Healthy Crops,S.L, Novagrica, Agrobio,Andermatt, Pherobank, Pherobees, Pherobank, Pherobees	*Dacus oleae*	Pherobees, Agrobio
Ceratitis cosyra	Pherobees, Pherobank.Novagrica, International pheromone Systems	*Dasineura mali*	Pherobees, Russell IPM Ltd

Pest name	Supplier	Pest name	Supplier
Dasineura oxycoccana	Russell IPM Ltd	*Euzophera bigella*	International pheromone Systems,Pherobank, Pherobees
Dasineura plicatrix	Russell IPM Ltd	*Euzophera pinguis*	Pherobees, Probodelt, Pherobank, Russell IPM Ltd, Agrobio
Dispidiotus perniciosus	International pheromone Systems	*Euzophera punicaella*	Pherobees, Pherobank
Drosophila suzukii	International pheromone Systems, Novagrica, Russell IPM Ltd,Pherobees	*Euzophera semifuneralis*	Pherobees, Pherobank
Duponchelia fovealis	International pheromone Systems, Pherobank, Russell IPM Ltd, Pherobees	*Evergestis forficalis*	Pherobees, Pherobank, International pheromone Systems
Earias vittella	Pherobees, Pherobank, International pheromone Systems	*Exomala orientalis*	Pherobees
Ectomyelois ceratoniae	Pherobees, Novagrica, International pheromone Systems	*Frankliniella occidentalis*	Pherobees, International pheromone Systems, Russell IPM Ltd
Enarmonia formosana	Pherobees, Pherobank, Andermatt, Trifolio_M GmbH	*Gortyna xanthenes*	Pherobees, Pherobank, International pheromone Systems
Epichoristodes acerbella	Pherobees, Pherobank, International pheromone Systems	*Grapholita funebrana*	Trifolio_M GmbH, Novagrica, Pherobees, Probodelt, Andermatt
Epiphyas postvittana	Pherobees, Pherobank, Russell IPM Ltd, International pheromone,Systems Pherobank	*Grapholita lobarzewskii*	Pherobank, Pherobank, Novagrica, Andermatt, Trifolio_M GmbH, Pherobees
Eulia ministrana	International pheromone Systems	*Grapholita molesta*	Novagrica, Andermatt, Trifolio_M GmbH, Pherobees, Pherobank
Eupoecilia ambiguella	Pherobees, Trifolio_M GmbH, Pherobank, Andermatt	*Halymorpha halys*	Pherobank, Novagrica, Andermatt, Trifolio_M GmbH, Pherobees
Euproctis chrysorrhoea	Pherobank	*Hedya nubiferana*	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank, Novagrica

Pest name	Supplier	Pest name	Supplier
Helicoverpa armigera	Pherobees, Pherobank, Novagrica, Andermatt, Trifolio_M GmbH	*Lyonetia clerkella*	Pherobees, Trifolio_M GmbH
Heliothis peltigera	Trifolio_M GmbH	*Malacosoma neustria*	Pherobank
Hellula undalis	Pherobees, Trifolio_M GmbH	*Mamestra brassicae*	Pherobank, Novagrica, Andermatt, Trifolio_M GmbH, Pherobees
Hippotion celerio	Andermatt	*Mamestra oleracea*	Pherobank, Pherobees
Hylemya antiqua	Trifolio_M GmbH	*Melolontha melolontha*	Novagrica
Hyphantria cunea	Trifolio_M GmbH	*Operophtera brumata*	Pherobees
Lacanobia oleracea	Trifolio_M GmbH, Andermatt	*Operophthera brumata*	Pherobank
Leucoptera malifoliella	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank	*Orgyia antiqua*	Trifolio_M GmbH, Novagrica, Andermatt
Lithocolletis blancardella	Novagrica	*Orthosia gracilis*	Pherobees, Andermatt, Trifolio_M GmbH
Lithophane unimoda	Andermatt	*Ostrinia nubilalis*	Novagrica, Andermatt, Trifolio_M GmbH, Pherobees, Pherobank
Lobesia botrana	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank, Novagrica	*Otiorhynchus sulcatus*	Andermatt
Lygocoris pabulinus	Pherobees	*Pammene rhediella*	Novagrica, Andermatt, Trifolio_M GmbH, Pherobees
Lymantria dispar	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank, Novagrica	*Pandemis heparana*	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank, Novagrica

Pest name	Supplier	Pest name	Supplier
Pennisetia hylaeiformis	Pherobank, Trifolio_M GmbH, Pherobees	*Recurvaria nanella*	Trifolio_M GmbH
Peridroma saucia	Pherobank, Andermatt, Trifolio_M GmbH, Pherobees	*Resseliella theobaldi*	Pherobees
Phyllocnistis citrella	Pherobees, Andermatt, Trifolio_M GmbH	*Rhagoletis cerasi*	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank,Novagrica
Phyllonorycter blancardella	Pherobees, Pherobank, Novagrica, Andermatt, Trifolio_M GmbH	*Rhagoletis cingulata*	Andermatt
Phyllonorycter corylifoliella	Novagrica, Pherobank	*Rhagoletis completa*	Pherobank, Trifolio_M GmbH, Pherobees
Phyllotreta spp.	Pherobank	*Scolytus amygdali*	Pherobees, Trifolio_M GmbH
Planococcus citri	Novagrica, Andermatt,Trifolio_M GmbH, Pherobees, Pherobank	*Sparganothis pilleriana*	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank, Novagrica
Planococcus ficus	Pherobank, Andermatt, Trifolio_M GmbH, Pherobees	*Spilonota ocellana*	Pherobank, Novagrica, Andermatt, Trifolio_M GmbH, Pherobees
Plutella xylostella	Pherobank,Novagrica, Andermatt, Trifolio_M GmbH, Pherobees, Pherobees	*Spodoptera eridania*	Pherobank, Trifolio_M GmbH, Pherobees
Popillia japonica	Pherobank, Pherobees	*Spodoptera exigua*	Trifolio_M GmbH, Pherobees, Pherobank, Novagrica, Andermatt
Prays citri	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank,Novagrica	*Spodoptera frugiperda*	Pherobees, Pherobank, Novagrica, Andermatt, Trifolio_M GmbH
Prays oleae	Pherobees, Pherobank, Novagrica, Andermatt, Trifolio_M GmbH	*Synanthedon myopeaformis*	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank, Novagrica
Quadraspidiotus perniciosus	Andermatt, Pherobees, Pherobank, Novagrica	*Synanthedon pictipes*	Pherobank, Trifolio_M GmbH, Pherobees

Pest name	Supplier
Synanthedon tipuliformis	Trifolio_M GmbH, Pherobees, Pherobank, Novagrica, Andermatt
Synanthedon vespiformis	Trifolio_M GmbH, Pherobees, Pherobank, Novagrica, Andermatt
Thrips species	Pherobees, Trifolio_M GmbH, Pherobank
Trichoplusia ni	Pherobank, Novagrica, Andermatt, Trifolio_M GmbH, Pherobees
Tropinota hirta	Pherobank
Tuta absoluta	Trifolio_M GmbH, Pherobees, Pherobank, Novagrica, Andermatt
Yponomeuta malinellus	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank, Novagrica
Yponomeuta padella	Trifolio_M GmbH, Pherobees, Pherobank
Zeuzera pyrina	Trifolio_M GmbH, Pherobees, Pherobank, Novagrica, Andermatt
Popillia japonica	Pherobank, Pherobees
Prays citri	Andermatt, Trifolio_M GmbH, Pherobees, Pherobank,Novagrica
Prays oleae	Pherobees, Pherobank, Novagrica, Andermatt, Trifolio_M GmbH
Quadraspidiotus perniciosus	Andermatt, Pherobees, Pherobank, Novagrica

Links to major producers:

PHEROBEES (https://pherobees.com/)
Trifolio_M GmbH (https://www.trifolio-m.de/en/produkt/tripheron-pheromones/)
Pherobank (https://www.pherobank.com/)
Novagrica (https://www.novagrica.com/shop/attractants/)
Andermatt (https://www.andermatt.com/crop-production/?_solution=monitoring-systems-mass-trapping%2Cmonitoring-mass-trapping)
International pheromone Systems (https://www.internationalpheromones.com/)
Russell IPM Ltd (https://russellipm.com/agricultural/pheromones/)
Probodelt (https://probodelt.com/fr/produits/surveillance/)
SEDQ Healthy Crops, S.L (https://sedq.es/en/categoria/forestry-and-gardening/)
Biobest (https://www.biobestgroup.com/products/pheromone-caps)

Para-pheromones may also be mixed with a sticky material and applied to the surface of the panels. Detailed information about Para-pheromones could be found in ISPM 26, IAEA 2003, Coombs and Hall 1998, Gordh and Headrick 2001, (NAL 2008).

Food-based attractants

Liquid protein attractants capture both females and males. These liquid attractants are generally less sensitive than the para-pheromones. In addition, liquid attractants capture high numbers of non-target insects and require more frequent servicing. New synthetic food attractant technologies are available for use, including the long-lasting three-component and two-component mixtures contained in the same patch, as well as the three components incorporated in a single cone-shaped plug (ISPM 26). Detailed information about lures and traps for fruit flies could be found in ISPM 26 and IAEA 2003

Yeast pellets made of inactivated torula yeast, is an excellent food attractant for many fruit flies, particularly the olive fly (*Bactrocera oleae*) and the Mediterranean fruit fly (*Ceratitis capitata*). Yeast pellets are intended to be used in insect traps such as Smart Trap, McPhail or similar type traps.

https://www.greatlakesipm.com/monitoring/lures/fruit-fly/glsc370500-scentry-torula-yeast-pellets-100cs

Yeast-based baits, like commercial slug baits, can also be effective. One commonly used bait for slugs is beer, as slugs are attracted to fermented substances. Other options include sugar water, molasses, and ripe fruits like strawberries or tomatoes. Ammonium platelet - Food attractant for females and males.

Odour attractants

Some insects, such as bees and butterflies, are attracted to the scent of flowers. Floral scents can be used in traps to attract these insects. The product 'Thripnok' contains a combination of two natural and safe floral scents, that attract a range of flower inhabiting thrips species, such as western flower thrips, *Frankliniella occidentals*, and onion thrips, *Thrip tabaci*. Adding 'Thripnok' to sticky traps increased trap catch of thrips by 3x in glasshouse and polytunnel strawberry trials.

https://images.app.goo.gl/EecknEf2Bc99fDbWA

Kairomones

Methyl eugenol is a kairomone attractant used in traps for monitoring and control of fruit flies, (Shelly et al. 2004). The product 'Lurem' contains a kairomone that is slowly released when the dispenser is opened. In this way, it makes the adult thrips more active. They emerge from their hiding places and are drawn more into sticky traps.

https://images.app.goo.gl/fvAg7BGa6EYyidAG7

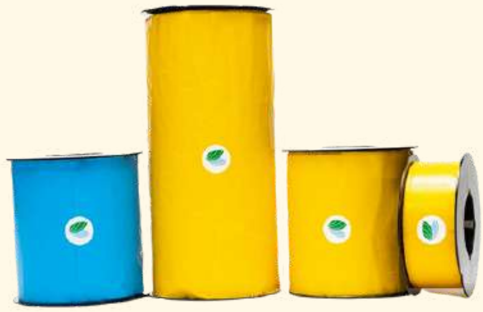
2.10.2 Kill methods

Traps retain attracted insects through the use of killing and preserving agents. Killing agents in wet and dry traps have physical or chemical mode of action. Captured insects die in the following ways:

Adhesion

The insects get stuck to surface coated with glue. This surface could be paper or plastic board, roll of polyethylene sheet etc. Adhesion is the killing agent in traps called – Sticky Traps, Adhesive traps, Roller traps. Generally, sticky traps are only used for monitoring pest infestations and not directly as a control method but recently developed roller traps a effective enough for mass trapping.

https://images.app.goo.gl/mK8fCghATzu6xh8A9



https://images.app.goo.gl/NWdKd1dbYft5J3pMA

Drowning

The insect captured drowns in the attractant solution or in water with surfactant preventing their escape. The liquid is the killing agent in traps called - wet traps/water traps.

Oily liquids or propylene glycol (antifreeze) are recommended to reduce evaporation. Addition of a small amount of detergent (e.g. liquid soap) can remove the surface tension of water to prevent escapes and vegetable oil can be added to reduce evaporation of water from the surface. When bucket-type traps are used with liquid proteins, the liquid bait solution functions as the retention system. In this case the liquid protein baits have to be mixed with 1.5 to 2 g of borax to slow down the decomposition of the captured insects. ISPM 26.

Chemical agent (Insecticides)

The use of insecticides in traps is subject to the registration and approval of the product in the respective national legislation. Some bucket-type traps could be used as dry traps and insecticides are used to prevent their escaping. ISPM 26 Killing agents used in panels, delta-traps and in bucket traps when used dry are usually a form of a volatile toxicant such as DDVP (2,2-Dichlorovinyl dimethyl phosphate) naled, and malathion, although some of these are repellent at higher doses. In attract-and-kill sprayables, a toxicant is included in the formulation, as few plant volatiles are toxic enough to kill target insects. Toxicants for sprayables may have contact activity, stomach activity, or both.

Physical destruction

Trunk Cardboard banding can provide some supplemental control of some pests, during the growing season (e.g. Codling moth). Band with trapped insects are removed and destroyed.

Natural death

Design of funnel traps facilitates the entry of insects while preventing them from escaping. Trapped insects die naturally by dehydration, starvation, or suffocation, depending on the conditions inside the trap.

2.10.3 Traps

The shortest definition of trap is - A baited device used for catching (Trapping guidelines for area-wide fruit fly programmes/IAEA 2003).

There are many types of traps shortly described below. Insect traps may be used for monitoring or surveying insect populations, or reducing damage to crops or structures. There are many types of traps for other animals as well, from cage traps that allow for live capture and release of animals, to lethal traps that kill animals quickly and humanely. Vertebrate traps may be used for monitoring or research purposes, while others may be used for pest control or for managing populations of certain species.

Insect traps

Based on the killing agent, there are three types of insect traps commonly used:

Dry traps

The fly is caught on a sticky material board or killed by a chemical agent. Some of the most widely used dry traps are Cook and Cunningham (C&C), ChamP, Jackson/Delta, Lynfield, open bottom dry trap (OBDT) or Phase IV, red sphere, Steiner and yellow panel/Rebell traps.

Wet traps

The fly is captured and drowns in the attractant solution or in water with surfactant. One of the most widely used wet traps is the McPhail trap. The Harris trap is also a wet trap with a more limited use.

Dry or wet traps

The fly is captured and drowns in the attractant solution or in water with surfactant. One of the most widely used wet traps is the McPhail trap. The Harris trap is also a wet trap with a more limited use.

Based on the construction and pest targeted there are the following traps commonly used:

Delta traps

These traps are a type of sticky trap used to capture flying insects, such as moths and flies. Delta trap is a triangular insect trap [delta-shaped from the fourth letter of the Greek alphabet 'Δ'] containing a lure, e.g. a sex pheromone, and coated with a sticky substance on the inside to hold the insect after it enters the trap (Cooper & Mill 2008). Their distinctive triangular shape is designed to enhance their attractiveness to insects. The traps are usually hung from a supporting structure, such as a tree branch or pole, and can be rotated to face different directions to capture insects from all sides. One advantage of delta traps is that they are relatively inexpensive and easy to use, requiring only the sticky board and a supporting structure.

https://images.app.goo.gl/tP2iyMRqZQ6gJZjb9

However, they do have some limitations, such as their inability to capture all flying insects, and the potential for non-target organisms to become trapped on the sticky surface. A delta-shaped trap **Jackson trap** is usually used with a parapheromone lure to attract and capture male fruit flies (IAEA 2003).

Color traps

A typical color trap consists of a sticky card or panel that is coated with a colored substance, such as fluorescent paint, that will attract the targeted insect species. The trap is often hung or placed in an area where there is a high concentration of the targeted insects, such as near standing water for mosquitoes or fruit trees for fruit flies. Insects are attracted to the trap colors because they resemble the colors of flowers, fruit, or other potential food sources. When insects fly toward the trap, they become stuck on the sticky surface of the card or panel, and are unable to escape. The trapped insects can be counted and identified to monitor population levels and assess the effectiveness of control measures.

Yellow panel trap/Rebell trap

The Yellow panel trap consists of a yellow rectangular cardboard plate (23 cm × 14 cm) coated with plastic. The rectangle is covered on both sides with a thin layer of sticky material. The **Rebell trap** is a three-dimensional YPtype trap with two crossed yellow rectangular plates (15 cm × 20 cm) made of plastic (polypropylene) making them extremely durable (Figure 20). The trap is also coated with a thin layer of sticky material on both sides of both plates. A wire hanger, placed on top of the trap body, is used to hang it from tree branches.

These traps can be used as visual traps alone and baited with TML, spiroketal or ammonium salts (ammonium acetate). (ISPM 26)

https://images.app.goo.gl/ji3wnoxuxR6Bn3BT8

Light traps

These traps can be used as visual traps alone and baited with TML, spiroketal or ammonium salts (ammonium acetate). (ISPM 26)

Funnel traps

These traps involve a funnel-shaped opening that leads into a container with a killing agent at the bottom. Insects are attracted to the lure at the top of the funnel and then fall into the container and are killed.

Pitfall traps (Bucket-type traps)

These traps involve a container that is buried in the ground with a lip or funnel leading into it. When insects crawl or fall into the container, they are trapped and unable to escape. Pitfall traps, are commonly used to capture ground-dwelling insects, such as ants, beetles, and ground-dwelling spiders.

https://images.app.goo.gl/g7MuTk9rVdJqBL6G6

Here are some construction categories for Pitfall traps:

Simple pitfall trap

This is the most basic type of pitfall trap, consisting of a small container or cup (such as a plastic cup) buried in the ground so that the rim is flush with the soil surface. When insects walk across the soil surface, they fall into the trap and cannot climb out.

Funnel pitfall trap

This type of trap consists of a container or cup buried in the ground with a funnel-shaped lid that guides insects into the trap. The funnel is positioned so that insects walking on the soil surface fall into the trap and cannot get out.

Multiple cup pitfall trap

This type of trap consists of several cups or containers buried in the ground in a line or pattern. Insects walking across the soil surface fall into one of the cups and cannot get out.

Barrier pitfall trap

This type of trap is designed to capture insects that travel along a certain path, such as an ant trail or beetle runway. A barrier is constructed around the path, and pitfall traps are placed in the barrier so that insects fall into the traps as they travel along the path.

Barrier pitfall trap

There are many variations of the basic pitfall trap design, including adding a killing agent or bait to attract specific types of insects, using different types of containers or materials, or modifying the trap to increase its effectiveness.

Malaise traps

These trapsare large tent-like structure made of insect-proof fabric or netting that is set up in the field. The trap is designed to intercept and capture flying insects as they fly into the fabric. One side of the trap is sloped or angled to create a barrier that insects fly into and then get funneled into a collector bottle or container.

Source here

Inside the trap, there is often a collection chamber or container filled with a preservative fluid, such as ethanol, to preserve the captured insects. This container is then checked and emptied periodically over days or weeks. The design of the Malaise trap is important to maximize its effectiveness. The fabric used should be lightweight, but durable enough to withstand wind and weather. The fabric is usually a mesh that is fine enough to capture small insects while allowing larger ones to fly over the trap. The collector bottle is often filled with a preservative fluid to prevent captured insects from decomposing. For detailed accounts of methodology, see (Malaise, 1937), van Achterberg (2009) and Montgomery et al. (2021).

Cone traps

Cone traps are small, plastic or wooden cones that are used to capture bark beetles. The traps are typically baited with pheromones or other attractants that are specific to the targeted beetle species. The cone trap consists of a truncated cone shape that is open at the top and closed at the bottom. The top of the cone is usually covered with a

mesh to prevent larger insects from getting inside. The bottom of the cone contains a collection cup with a preservative fluid, such as ethanol, to preserve the captured beetles. In use, the cone trap is often placed on or near a tree that is infested with bark beetles. The trap is intended to simulate the bark of the tree, attracting beetles to land on the surface of the cone and become trapped in the collection cup.

Source here

Vane Traps

Source here

Vane traps are a type of insect trap that uses a combination of visual cues and airflow to attract and capture flying insects. It consists of a central tower, which is usually made from a hollow plastic or metal filament, and a set of vanes or arms that extend outwards from the top of the tower. The vanes are typically made of thin, lightweight materials such as plastic or fabric and are designed to flap in the wind, creating a shimmering or waving motion that attracts insects' attention. The airflow generated by the flapping vanes also helps to draw insects towards the central tower, where they become trapped in a sticky or adhesive material applied to the surface or in collection jar. Vane traps can be used to capture a range of flying insects

Suction traps

These traps work by drawing in insects with a strong suction fan mounted on top of a collection container. The trap is typically powered by a battery or a main power supply, and consists of a tower or pole with a large funnel-shaped opening on top. The opening leads to a collection container where the trapped insects are stored for analysis. The suction fan creates a strong air flow that draws insects into the collection container. The fan is usually powered by a rechargeable battery or mains power supply, and can operate continuously for several weeks or months.

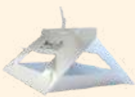
https://images.app.goo.gl/8Eb8rYLtnY3Ayxum9

Net traps

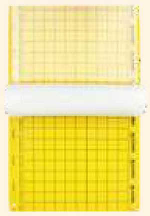
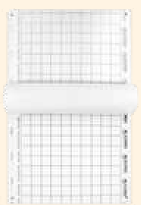
These traps use fine mesh nets that are used to catch flying insects like butterflies or dragonflies. The net can either be operated manually or with a motorized mechanism.

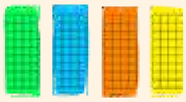
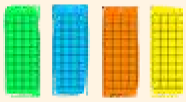
The specific construction of the trap depends on the target insect species and the goals of the trapping study. Detailed information about trapping of fruit flies using Cook and Cunningham trap, ChamP trap, Easy trap, Jackson trap, Lynfield trap, McPhail trap type, Multilure trap, Red sphere trap, Tephri trap etc. could be found in (ISPM 26)

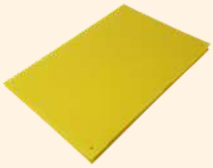
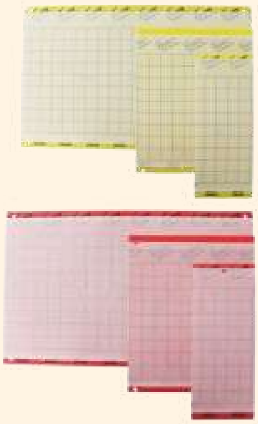
Commercially available traps

Trap type	Description	Product/manufacturer name
Optiroll Super White Plus 	*Attracted pest*: blueberry gall midge, Dasineura oxycoccana, and thrips species - important pests in blueberry crops. *Lure:* encapsulated formulation of the female sex pheromone of blueberry gall midge *Killing agent*: adhesion	Russell IPM Ldt
 Delta Traps	*Attracted pest:* Small to medium size Lepidoptera *Lure*: species-specific pheromone *Kill method*: Captured insects are stuck in the glue	Novagrica
 Delta trap transparent	*Attracted pest*: Small to medium size Lepidoptera *Lure*: Species-specific pheromone *Kill method*: Captured insects are stuck in the glue	Novagrica

Trap type	Description	Product/manufacturer name
 Red Delta trap	*Attracted pest*: Lepidoptera pests in both indoor and outdoor growing areas *Lure:* Species-specific pheromone *Killing agent*: Captured insects are stuck in the glue	Russell IPM Ldt
 ECONEX DISPOSABLE WHITE TRIANGULAR	*Attracted pest:* Numerous insect species *Lure*: Species-specific pheromone *Kill method*: Captured insects are stuck in the glue	Econex
 ECONEX DISPOSABLE RED TRIANGULAR	*Attracted pest: Drosophila suzukii* (Spotted wing drosophila) *Lure*: Pheromone *Kill method*: Captured insects are stuck in the glue	Econex
 Econex folding white	*Attracted pest:* Numerous insect species *Lure*: Species-specific pheromone *Kill method*: Captured insects are stuck in the glue	Econex
 Delta trap	*Attracted pest: Tuta absoluta* (Tomato Moth), *Zeuzera pyrina* (Leopard moth) *Lure*: Pheromone *Kill method*: Captured insects are stuck in the glue	Pherobees
  Jackson trap	*Attracted pest:* Fruit flies *Lure: Species specific attractant* *Kill method:* Captured insects are stuck in the glue	Biosani Econex
 Individualized Delta Trap	*Attracted pest:* Small to medium size Lepidoptera *Lure:* Sexual or other specific pheromones *Kill method:* Captured insects are stuck in the glue	Biosani

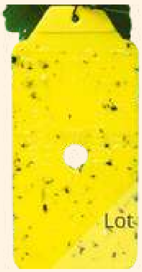
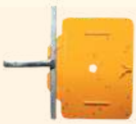
Trap type	Description	Product/manufacturer name
 ECONEX WHITE TRIANGULAR without sheets	*Attracted pest*: Diptera *Lure:* Species-specific pheromone, chromatic attraction *Killing agent*: Captured insects are stuck in the glue	Econex
 PLUM MOTH TRAP REFILL	*Attracted pest: Grapholita funebrana* (Plum moth), *Cydia pomonella* (Codling moth) *Lure*: Species-specific pheromone attraction *Kill method*: Captured insects are stuck in the glue	Andermatt
Colour traps/Sticky traps		
 Yellow sticky traps	*Attracted pest:* Aphidoidea (Winged aphids), *Trialeurodes vaporariorum* (Greenhouse white fly), Sciaridae (Fungus gnats), Thysanoptera (Thrips), Fruit flies (*Drosophila*), Agromyzidae (Leaf miner flies), *Empoasca vitis* (Green leafhopper) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Plantura, Novagrica, International pheromone Systems, Koppert, Econex, Andermatt Harmony Ecotech Pvt. LTD
 Blue sticky traps	*Attracted pest:* Thysanoptera (Thrips) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Econex
 White sticky traps	*Attracted pest:* Numerous insect species *Lure*: Colour /with a pheromone diffuser *Kill method*: Captured insects are stuck in the glue	Pherobees

Trap type	Description	Product/manufacturer name
White sticky traps	*Attracted pest*: *Frankliniella occidentalis (Western flower thrips),* Hoplocampa testudinea (European apple sawfly), *Hoplocampa flava* (plum sawfly),*Hoplocampa minuta* (plum sawfly), *Byturus tomentosus* (Raspberry beetle) *Lure:* Colour *Killing agent*: Captured insects are stuck in the glue	Plantura
 Red sticky traps	*Attracted pest: Xyleborus dispar* (Pear blight beetle) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Plantura
 Red sticky traps	*Attracted pest:* Drosophila suzukii (Spotted wing drosophila) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Econex
 Orange sticky traps	*Attracted pest: Psila rosae* (Carrot fly) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Plantura, International pheromone Systems
 Green sticky traps	*Attracted pest: Aphidoidea* (Winged aphids), *Thysanoptera* (Thrips), *Cicadellidae* (Leafhoppers) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	International pheromone Systems
 Black sticky traps	*Attracted pest: Tuta absoluta (Tomato Moth)* *Lure: Colour* *Kill method: Captured insects are stuck in the glue*	Koppert, Econex

Trap type	Description	Product/manufacturer name
 Rigid yellow chromatic plate	*Attracted pest*: *Bactrocera oleae* (Olive fly), *Ceratitis capitata* (Medfly), *Rhagoletis cerasi* (Cherry fruit fly), *Empoasca* spp., *Trialeurodes vaporariorum* (Greenhouse white fly), *Aphidoidea* (Winged aphids) *Lure:* Colour *Killing agent*: Captured insects are stuck in the glue	Probodelt
 Rigid/flexible blue chromatic plate	*Attracted pest: Thysanoptera* (Thrips) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Probodelt
 California Red Scale Sticky Trap	*Attracted pest: Aonidiella aurantii* (California red scale) *Lure*: Colour / pheromone attractant *Kill method*: Captured insects are stuck in the glue	Russell IPM Ltd
 Impact board traps	*Attracted pest: Thysanoptera* (Thrips) - Light Blue impact boards, *Frankliniella occidentalis* (Western flower thrips) - Blue Impact boards; Heteroptera (Bugs), Thysanoptera (Thrips), Hymenoptera (Sawflies), Coleoptera (Flea beetles) - White Impact boards; *Drosophila suzukii* (Spotted wing drosophila), leaf hopper species (e.g. Empoasca spp.), gall midges (e.g. *Dasineura oxycoccana* (Blueberry gall midge) - Red Impact Boards; Aphids, whitefly, Thysanoptera (Thrips), Fungus gnats, Fruit flies, Agromyzidae (Leaf miner flies) - Yellow Impact boards *Tuta absoluta* (Tomato Moth) - Black Impact Boards *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Russell IPM Ltd
 Stanes GOAL	*Attracted pest: Whiteflies* *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	T-Stanes

Trap type	Description	Product/manufacturer name
Roller sticki Traps		
 Roller Traps	*Attracted pest*: Numerous insect species *Lure:* Colour *Killing agent*: Captured insects are stuck in the glue	International pheromone Systems
 Roller Traps	*Attracted pest:* Thysanoptera (Thrips) - white chromatic, blue/ Whiteflies, Aphids - yellow / *Tuta absoluta* (Tomato Moth) - black *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Econex Biosani
 Optiroll Super White Plus	*Attracted pest: Dasineura oxycoccana* (Blueberry gall midge), Thysanoptera (Thrips) *Lure*: Encapsulated formulation of the female sex pheromone of blueberry gall midge *Kill method*: Captured insects are stuck in the glue	Russell IPM Ltd
 Optiroll Red	*Attracted pest: Drosophila suzukii* (Spotted wing drosophila), Leaf hoppers and Gall midges, such as *Dasineura oxycoccana* (Blueberry gall midge) *Lure*: Colour, spotted wing drosophila dry lure or gall midge pheromones. *Kill method*: Captured insects are stuck in the glue	Russell IPM Ltd
 Optiroll Tuta+ Yellow	*Attracted pest: Tuta absoluta* (Tomato Moth) and other glasshouse pests *Lure*: Colour and Tuta absoluta pheromone incorporated directly into the adhesive layer *Kill method*: Captured insects are stuck in the glue	Russell IPM Ltd

Trap type	Description	Product/manufacturer name
 Optiroll Black Tuta+	*Attracted pest*: *Tuta absoluta* (Tomato Moth) *Lure*: Colour black Colour, slow release formulation of Tuta absoluta pheromone, incorporated directly into the adhesive layer *Killing agent*: Captured insects are stuck in the glue	Russell IPM Ltd
 Optiroll Blue Range	*Attracted pest:* Thysanoptera (Thrips) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Russell IPM Ltd
 Optiroll Yellow Range	*Attracted pest:* Whiteflies whitefly and Aphidoidea (Winged aphids) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Russell IPM Ltd
 Econex black roll	*Attracted pest:* Tuta absoluta (Tomato Moth) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Econex
 Rollertrap	*Attracted pest:* Whiteflies, Thysanoptera *(Thrips)*, *Agromyzidae* (Leaf miner flies), Fungus gnats. *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Koppert
Yellow panel trap/Rebell trap		
 Rebell trap	*Attracted pest: Fruit fly species such as Rhagoletis cerasi (Cherry fruit fly), Rhagoletis completa (walnut fruit fly), Ceratitis capitata (Medfly)* *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Novagrica

Trap type	Description	Product/manufacturer name
 Rebell® Rosso	*Attracted pest*: *Xyleborus dispar* (Pear blight beetle) in orchards (pome and prunoids) and vines. *Lure:* Colour *Killing agent*: Captured insects are stuck in the glue	Biosani
 Rebell® Giallo	*Attracted pest:* Whiteflies (*Trialeurodes vaporariorum* and *Bemísia tabaci*), Agromyzidae (Leaf miner flies) and Fungus gnat or scarid fly (*Bradysia* spp. and *Lycoriella* spp.) in protected crops, as well as for leafhoppers or cicadelas (*Jacobiasca lybica* (Green leafhopper), *Scaphoideus titanus* (American grapevine leafhopper), *Empoasca* spp. and for Thysanoptera (Thrips) (*Frankliniella occidentalis* and others) in vineyards *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Biosani
 Rebell® Bianco	*Attracted pest: Hoplocampa brevis* (pear sawfly), *Hoplocampa flava* (plum sawfly), *Hoplocampa minuta* (plum sawfly), *Hoplocampa testudinea* (European apple sawfly), as well as for monitoring and controlling raspberry beetles (*Byturus rubi*, *Byturus tomentosus* and *Byturus uniColour*) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Biosani Andermatt
 Rebell® Orange	*Attracted pest: Psila rosae* (Carrot fly) *Lure*: Colour *Kill method*: Captured insects are stuck in the glue	Biosani Andermatt
 Rebell® Amarillo	*Attracted pest: Rhagoletis cerasi* (Cherry fruit fly), *Ceratitis capitata* (Medfly), *Bactrocera oleae* (Olive fly), *Ceutorrhynchus napi* (Rape stem weevil),*Ceutorrhynchus quadridens* (Cabbage stem weevil) *Lure*: Colour in combination with ammonium platelets *Kill method*: Captured insects are stuck in the glue	Biosani

Trap type	Description	Product/manufacturer name
 Rebell® Blu	*Attracted pest*: *Frankliniella occidentalis* (Western flower thrips) and *Thrips tabaci* (Tobacco thrips or onion thrips) and other thrips species. *Lure*: Diffuser of a multi-specific semiochemical *Kill method*: Captured insects are stuck in the glue	Biosani
 Carroy fly trap	*Attracted pest: Psila rosae* (Carrot fly) *Lure:* Colour *Kill method:* Captured insects are stuck in the glue get caught in the glue.	Koppert
 Tutaroll	*Attracted pest: Tuta absoluta* (Tomato Moth) *Lure*: Slow release *Tuta absoluta* pheromone formulation re stuck in the glue *Kill method*: Captured insects are stuck in the glue get caught in the glue.	Russell IPM Ltd
Light traps		
 solar light trap	*Attracted pest*: Flying nocturnal insects *Lure*: Ultra violet light *Kill method*: Captured insects drown in the liquid	Harmony Ecotech Pvt. Ltd.
 Ferolite	*Attracted pest: Tuta absoluta* (Tomato Moth) *Lure:* Specific wavelength of light in combination with sex pheromones *Kill method:* Captured insects drown in the liquid	Russell IPM
 PheroGlo trap	*Attracted pest: Tuta absoluta* (Tomato Moth), *Plutella xylostella* (Diamond Back Moth) *Lure:* Light in combination with sex pheromones *Kill method:* Captured insects drown in the liquid	Harmony Ecotech Pvt. Ltd.

Trap type	Description	Product/manufacturer name
Funnel traps		
 Moth Trap	*Attracted pest*: Flying moths *Lure*: Pheromone *Kill method*: Captured insects drown in the liquid or or are killed by insecticide	Harmony Ecotech Pvt. Ltd.
 Funnel trap	*Attracted pest:* Medium sized and large Lepidoptera *Lure:* Species-specific pheromone *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Novagrica
 Funnel Trap Mod for Drosophila	*Attracted pest: Drosophila suzukii* (Spotted wing drosophila) *Lure:* Species-specific lures *Kill method: Captured insects drown in the liquid*	Novagrica
 MothCatcher trap (universally known as bucket traps)	*Attracted pest:* Moth and flying insects, such as *Spodoptera frugiperda* (Fall armyworm), *Cydia pomonella* (Codling moth) and *Ceratitis capitata* (Medfly) Yellow and Green – attract the most moths and flying insect pests in open field environments. All Green – attract fewer non-target insects and are useful where bumblebee pollination and natural enemies are being used. *Lure:* Species-specific pheromone lures *Kill method: Captured insects drown in the liquid*	Russell IPM Ltd
 Mini MothCatcher trap / Mini Unitrap	*Attracted pest:* micro Lepidoptera such as *Tuta absoluta* (Tomato Moth) *Lure:* Species-specific pheromone lures or attractants to target specific species *Kill method:* Once in the trap they cannot escape	Russell IPM Ltd International pheromone Systems Koppert

Trap type	Description	Product/manufacturer name
	*Attracted pest:* Fruit flies *Lure:* Pheromone/para-pheromone lure in a lure cage and a liquid or dry attractant in the bucket *Kill method:* Captured insects drown in the liquid	Russell IPM Ltd International pheromone Systems Novagrica Koppert
 McPhail trap	*Attracted pest:* Fruit flies & other flying insects *Lure:* Pheromone/para-pheromone lure *Kill method:* Captured insects drown in the liquid	Harmony Ecotech
 Multifunnel Trap	*Attracted pest:* Bark beetles *Lure:* Shape of trap *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Biosani,
 Multifunnel trap	*Attracted pest:* Bark beetles *Lure:* Shape of trap *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Novagrica
 ECONEX POLILLERO trap	*Attracted pest:* Large moth species, Diptera and beetles *Lure:* Visual attractant and pheromone, *Kill method:* Captured insects drown in the liquid	Econex
 ECONEX GREEN POLILLERO	*Attracted pest:* Large moth species *Lure:* Colour of the base is a visual attractant *Kill method:* Captured insects drown in the liquid	Econex

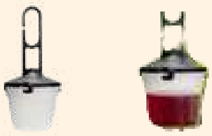
Trap type	Description	Product/manufacturer name
 Green and opaque funnel trap	*Attracted pest:* Lepidoptera (Large butterflies) *Lure:* Colour of the base is a visual attractant *Kill method:* Captured insects drown in the liquid	Biosani
 Green and transparent funnel trap	*Attracted pest:* Lepidoptera (Large butterflies) *Lure:* Species-specific pheromone *Kill method:* Captured insects drown in the liquid or are kept in the bucket and die due to dehydration, lack of food and exhaustion	Biosani Koppert
 EOSTRAP®	*Attracted pest:* All types of insect, particularly Diptera (such as *Ceratitis capitata* and *Bactrocera oleae*), Coleoptera and Lepidoptera, particularly the larger moths. *Lure:* The pheromone diffuser laid in the upper plastic support or food attractant in the trap base *Kill method:* Captured insects drown in the liquid	Econex
 INVAGINATED EOSTRAP®	*Attracted pest:* Diptera pests, especially *Ceratitis capitata* (Medfly) and *Bactrocera oleae* (Olive fly). *Lure:* specfic attractant in the trap base *Kill method:* Captured insects drown in the liquid	Econex
 Unitrap – Pole Version	*Attracted pest:* Large moth species *Lure:* Pheromone *Kill method:* Captured insects drown in the liquid or are kept in the bucket and die due to dehydration, lack of food and exhaustion.	International pheromone Systems
 ECONEX MOSQUERO	*Attracted pest:* Diptera pests, especially *Ceratitis capitata* (Medfly) and *Bactrocera oleae* (Olive fly). *Lure:* Colour of the base is a visual attractant *Kill method:* Captured insects drown in the liquid	Econex

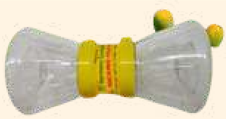
Trap type	Description	Product/manufacturer name
 Maxitrap XL fly trap	*Attracted pest:* Diptera pests, especially *Ceratitis capitata* (Medfly) and *Bactrocera oleae* (Olive fly). *Lure:* Liquid Bactrotrap 16% attractant *Kill method:* Captured insects drown in the liquid or are kept in the bucket and die due to dehydration, lack of food and exhaustion, or are killed by insecticide	Probodelt
 Tephritidae Trap	*Attracted pest:* Fruit flies *Lure:* Food attractant, species-specific lure. *Kill method:* Captured insects drown in the liquid or are kept in the bucket and die due to dehydration, lack of food and exhaustion, or are killed by insecticide	Russell IPM Ltd
 Mosquito cup (Tephri-type trap)	*Attracted pest: Bactrocera dorsalis* (Oriental fruit fly), *Bactrocera oleae* (Olive fly), *Ceratitis capitata* (Medfly), *Rhagoletis cerasi* (Cherry fruit fly), *Rhagoletis completa* (walnut fruit fly) *Lure:* Food attractant, species-specific lure. *Kill method:* Captured insects drown in the liquid or are kept in the bucket and die due to dehydration, lack of food and exhaustion, or or are killed by insecticide	Biosani Koppert
 Moth Funnel Tree	*Attracted pest: Euzophera pinguis* (Olive Pyralid Moth), *Prays citri* (Citrus Flower Moth), *Prays oleae* (Olive Moth), *Palpita unionalis* (Olive-green pirate), *Lobesia botrana* (European grapevine moth), *Cydia pomonella* (Codling moth), *Anarsia lineatella* (Peach twig borer), *Grapholita molesta* (Oriental fruit moth) *Lure:* Pheromone *Kill method:* Captured insects drown in the liquid or are kept in the bucket and die due to dehydration, lack of food and exhaustion, or are killed by insecticide	Probodelt

Trap type	Description	Product/manufacturer name
 Castellation Trap	*Attracted pest:* Small moths species *Lure:* Species-specific sex pheromone *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Koperts
 Green, yellow and transparent mini funnel trap	*Attracted pest:* Numerous insect species *Lure:* Species-specific pheromone *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Biosani
 New Suzukii trap	*Attracted pest: Drosophila suzukii* (Spotted wing drosophila) and similar fruit fly *Lure:* Russell IPM's long-lasting dry lure, or with MaxDro wet lure *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Russell IPM Ltd
 Drososan trap	*Attracted pest: Drosophila suzukii* (Spotted wing drosophila) and similar fruit fly *Lure:* Fruit Fly Attractant *Kill method:* Captured insects drown in the attractant	Koppert
 Pea and Bean Weevil Trap	*Attracted pest: Sitona lineatus (Pea and bean weevil)* *Lure:* Species-specific pheromone *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Koppert

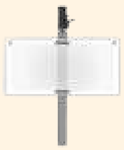
Trap type	Description	Product/manufacturer name
 Bruchid Beetle Trap	*Attracted pest: Bruchus rufimanus* (Broad-bean weevil) *Lure:* Species-specific lure *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Koperts
 Halyscan	*Attracted pest: Halyomorpha halys* (Brown marmorated stink bug) *Lure:* Species-specific aggregation pheromone. *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Koperts
Pitfall traps (Bucket-type traps)		
 Pitfall trap	*Attracted pest*: Soil dwelling Coleoptera *Lure*: position of the trap *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Novagrica Biosani Econex
 Armadilha mini-piramidal	*Attracted pest*: *Halyomorpha halys* (Brown marmorated stink bug) *Lure*: Pheromone *Kill method*: Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Biosani
Vane Traps		
 Apple Blossom Beetle trap	*Attracted pest: Epicometis hirta* (Blossom feeder) *Lure:* Pheromone *Kill method:* Captured insects drown in the liquid	Pherobees

Trap type	Description	Product/manufacturer name
 Green Vane Trap	*Attracted pest: Anthonumus rubi* (Strawberry blossom weevil) *Lygus rugulipenis* (Tarnished plant bug) *Lure:* Pheromone *Kill method:* Captured insects drown in the liquid	Russell IPM Ltd
 Raspberry Beetle Trap	*Attracted pest: Byturus tomentosus* (Raspberry beetle) *Lure:* Raspberry beetle attractant, white colour of the cross vanes which resemble raspberry flowers in combination with species-specific lure. *Kill method:* Captured insects drown in the liquid or are kept in the bucket and die due to dehydration, lack of food and exhaustion.	Russell IPM Ltd Andermatt Koppert
 Vane Trap/Small Vane Trap	*Attracted pest:* Flying beetle pests. *Lure:* Pheromone *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	International pheromone Systems
 Yellow Funnel trap with cross barrier	*Attracted pest: Zeuzera pyrina* (Leopard moth) and other large butterflies. *Lure:* Pheromone *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Biosani
 Green Funnel trap with cross barrier	*Attracted pest: Melolontha melolontha* (Common cockchafer), *Phyllopertha horticola* (Garden chafer) *Lure:* Specific attractant *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Biosani Andermatt
 Garden Chafer Trap	*Attracted pest: Phyllopertha horticola* (Garden chafer) *Lure:* Species-specific lure *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Koppert

Trap type	Description	Product/manufacturer name
 ESCOLITRAP®	*Attracted pest: Xylophagous insects* *Lure:* Colour and shape *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Econex
 Traps for Zeuzera pyrina	*Attracted pest: Zeuzera pyrina* (Leopard moth) *Lure:* Pheromones *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	Biosani
 Drosal Trap Pro	*Attracted pest: Drosophila suzukii* (Spotted wing drosophila) *Lure:* Liquid spotted wing drosophila attractant *Kill method:* Captured insects drown in the liquid	Biosani Andermatt
 MOSKISAN® 3.0 KIT	*Attracted pest: Ceratitis capitata* (Medfly) *Lure:* Colour and specific attractant inside the trap, *Kill method:* Captured insectsare killed by Killdisc ® containing the insecticide	Biosani
Other traps		
 Smart Trap	*Attracted pest: Ceratitis capitata* (Medfly), *Bactrocera oleae* (Olive fly) and other fruit flies *Lure:* Food attractant (yellow yeast pellets) *Kill method:* Captured insects drown in the liquid	Novagrica
 ECONEX BOTTLE TRAP	*Attracted pest: Ceratitis capitata* (Medfly), *Bactrocera oleae* (Olive fly), *Rhagoletis cerasi* (Cherry fruit fly), and other Diptera *Lure:* Food attractant chromotropic attraction *Kill method:* Captured insects drown in the liquid	Econex

Trap type	Description	Product/manufacturer name
 ECONEX BOTTLE TRAP DS	*Attracted pest: Drosophila suzukii* (Spotted wing drosophila) *Lure:* ECONEX *Drosophila suzukii* liquid attractant *Kill method:* Captured insects drown in the liquid	Econex
 Liquibaitor Trap	*Attracted pest:* Fruit fly pests including the *Ceratitis capitata* (Medfly), *Bactrocera cucurbitae* (Melon Fly), *Lure:* Pheromone/para-pheromone lure *Kill method:* Captured insects drown in the liquid	International pheromone Systems
 ENTRAP	*Attracted pest:* Fruit flies *Lure:* Active ingredient *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion.	T-Stanes
 Fruit Fly trap	*Attracted pest:* Fruit flies *Lure:* Attractant *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion.	Harmony Ecotech Pvt. LTD
 Venchuree fruit fly trap	*Attracted pest: Ceratitis capitata* (Medfly), *Bactrocera oleae* (Olive fly) and other fruit flies *Lure:* Food attractant (yellow yeast pellets) *Kill method:* Captured insects drown in the liquid	Harmony Ecotech Pvt. LTD
 Conetrap Trap	*Attracted pest: Ceratitis capitata* (Medfly), *Bactrocera oleae* (Olive fly) *Lure:* orange base (chromatic attraction) *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion.	Probodelt
 Heliothis trap	*Attracted pest: Heliothis sp.* *Lure:* Pheromone *Kill method:* Captured insects are kept in the trap top and regularly removed	Pherobank

Trap type	Description	Product/manufacturer name
Water traps		
 Tutasan trap	*Attracted pest: Tuta absoluta* (Tomato Moth) *Lure:* Pheromone in combination with Pherodis *Kill method:* Captured insects drown in the liquid	Koppert
 Water Trap	*Attracted pest:* Micromoth pests in glasshouses *Lure:* Pheromone *Kill method:* Captured insects drown in the liquid	International pheromone Systems
 Water trap	*Attracted pest:* Lepidoptera (Butterflies) *Lure:* Pheromone *Kill method:* Captured insects drown in the liquid	Agroline
 Tutatrap Trap	*Attracted pest: Tuta absoluta* (Tomato Moth) *Lure:* pheromone *Kill method: Captured insects drown in the liquid*	Probodelt
 ECONE[illegible](ECO)	*Attracted pest: Tuta absoluta* (Tomato Moth) *Lure:* Pheromone *Kill method:* Captured insects drown in the liquid	Econex
 Water Trap for Tuta Absolute	*Attracted pest: Tuta absoluta* (Tomato Moth) *Lure:* Pheromone *Kill method:* Captured insects drown in the liquid	Biosani
 Water trap	*Attracted pest:* All flying moths, *Tuta absoluta* (Tomato Moth) *Plutella xylostella* (Diamond Back Moth) *Lure:* Pheromone *Kill method:* Captured insects drown in the liquid	Harmony Ecotech

Trap type	Description	Product/manufacturer name
 ECO-TRAP	*Attracted pest: Bactrocera oleae* (Olive fly) *Lure:* ammonium bicarbonate (food attractant) and a pheromone dispenser *Kill method:* Captured insects are killed by deltamethrin (insecticide).	Vioryl
 Reusable Stink Bug Trap RESCUE	*Attracted pest: Halyomorpha halys* (Brown marmorated stink bug) *Lure:* Pheromone *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	pestcontroleverything
 Dead-Inn Pyramid Trap	*Attracted pest: Halyomorpha halys* (Brown marmorated stink bug) *Lure:* Pheromone *Kill method:* Captured insects are kept in the bucket and die due to dehydration, lack of food and exhaustion	AgBio Inc., Westminster, CO
 Transparent sticky board	*Attracted pest: Halyomorpha halys* (Brown marmorated stink bug) *Lure:* Pheromone *Kill method:* Captured insects are stuck in the glue	Trécé Inc.

Hort4EUGreen

Mole traps

Scissor Trap

This trap looks like a pair of scissors and is placed in an active mole run. When the mole moves through the run, the trap is triggered and closes on the mole, killing it instantly. The trap is designed to catch and kill moles. It consists of two metal arms that resemble a pair of scissors when closed. These arms are attached to a sturdy base or frame that holds them in place. The arms have sharp, pointed blades positioned inward. Scissor Traps are typically set in active mole runs. The trap is usually placed in an existing mole tunnel where the soil is slightly raised or soft. When a mole presses against the trigger plate while moving through the tunnel, it releases the catch, causing the arms to snap shut. Once triggered, the scissor-like arms of the trap close rapidly and the sharp blades come together, catching and crushing the mole. This results in an instantaneous kill, ensuring that the mole is eliminated quickly and humanely.

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Mole traps

Harpoon Trap

This trap is a type of mole trap that operates on the principle of impaling the mole with a sharp spear-like object, known as a harpoon. This type of trap is designed to catch burrowing pests like moles with a quick and humane kill. The trap consists of a cylinder-shaped body, which contains the harpoon and a spring mechanism. The trap is set by pressing the spring mechanism into the ground, which propels the harpoon upwards.

When a mole passes through the area where the trap is set, it triggers the mechanism, and the harpoon impales the mole on contact. This method is considered to be an effective, humane, and environmentally-friendly way to control mole infestations (Peacock, 2013).

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Choker Trap

A choker trap is a loop of wire that is set in the mole run. When the mole passes through the loop, it tightens around its neck, suffocating it. A Choker Trap is a type of trap used for capturing animals by constraining their neck or head.

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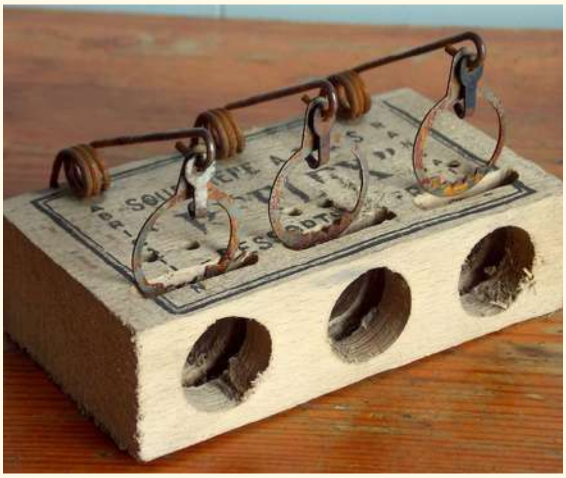
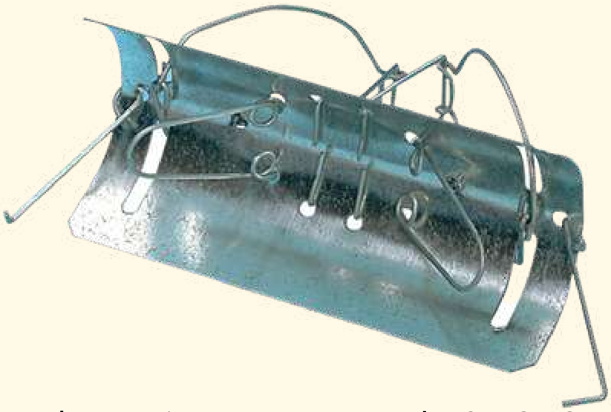


https://images.app.goo.gl/vLZmzafHicWwxMbP6

The trap consists of a loop, usually made of wire, cable, or nylon, that is placed around a tree or other object. The loop is then connected to a release mechanism, which allows the loop to be tightened around the animal's neck or head when triggered (Choker trap, 2022).

Duffus Mole Trap

This trap is used for catching moles in underground tunnels and burrows. The Duffus Mole Trap consists of a metal tube, which is placed vertically in the ground, with a mechanism at the base of the tube that is triggered by the mole's movement. When the mole passes through the tube, it triggers the mechanism, causing a plunger to be released from the top of the tube, striking the mole on the head and killing it instantly (Duffus Moe Trap, 2021).



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Bottle Trap

A Bottle Trap is a type of trap used for catching moles in underground tunnels and burrows. This trap is a glass bottle with a narrow neck placed over a mole run. When the mole passes through the neck of the bottle, it falls into the bottle and cannot escape. The Bottle Trap for moles is a humane method of trapping and removing moles from the garden. (Bottle trap for moles, 2021).

Snail and slug traps

Beer traps

This is a popular trap that involves burying a container, such as a jar or plastic cup, into the ground so that its rim is level with the soil. The container is filled with beer, and the scent of it lures the snails and slugs into the jar. They are unable to escape and drown in the beer.

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2.10.4 Monitoring and trapping methods

According to (IAEA, 2003), the three objectives of insect trapping survey are:

Detection survey

To determine if species are present in an area.

Delimiting survey

To determine the boundaries of an area considered to be infested or free from a pest.

Monitoring survey

Ongoing survey to verify the characteristics of a pest population including seasonal population fluctuation, relative abundance host sequence and others.

According to (IAEA, 2003), trapping surveys are applied in:

Infested area

to determine species presence and to monitor established fruit fly populations (it is assumed that no fruit fly control measures are used in the area).

Suppression

suppression is a process that is applied to reach a fruit fly low prevalence area. Trapping is applied to measure the efficacy of control measures such as bait sprays, Sterile Insect Technique (SIT), biological control and Male Annihilation Technique (MAT), used in an infested area to reduce the fruit fly population and thereby limit damage and spread.

Eradication

Eradication is a process applied to reach a fruit fly free area. Trapping is applied to measure the efficacy of control measures such as bait sprays, SIT, biological control, and MAT, used to eliminate a pest from an area.

Exclusion

Exclusion is a process applied to minimize the risk of introduction or re-introduction of a pest in a free area. Trapping is applied to determine the presence of species that are under exclusion measures and confirms or rejects the free area status.

The most used insect monitoring and trapping methods are the following:

Light Trapping

Light traps are one of the most common and efficient methods for surveying insect that fly at night. At their most basic, light traps simply consist of a light attractant and a viewing surface, often a bedsheet. More structured light traps commonly consist of a funnel, vanes (which deflect insects toward the funnel), and a collection container, which together are used in conjunction with the light source to form a structured trap. In either case, light-attracted insects fly toward the light source, hit a surface or vanes surrounding the light, and can then be observed and recorded or sampled and collected.

Common styles of vaned light traps include Robinson traps and Heath traps (Macgregor et al., 2017). Mercury vapor bulbs are the most commonly used attractant and have consistently caught a higher abundance and diversity of insects than other standard bulbs due to the powerful low-wavelength light emitted (Jonason et al., 2014; White et al., 2016). Other commonly used bulb types include UV, metal halide, and LED (Ferro and Summerlin, 2019). Although many commercial light traps are available and can be deployed in remote locations, light trapping can be as simple as documenting the moths that are attracted to your porch light (Montgomery et al. 2021). Cristiano et al. (2002) evaluated the efficacy of light traps in controlling the population of olive fruit fly and found that the light traps significantly reduced the population of the pest, and could be used as a part of integrated pest management strategies.

Robinson trap

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Heath traps

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Van Ieperen et al. (2006) used optical trapping (laser beams) to control the population of thrips in onion fields in the Netherlands. Eriksson et al. (2019) evaluated a device that uses infrared light optical trap to attract and trap the codling moth, a major apple pest. The device, called an "Optical Codling Moth Monitoring (OCMM) system," showed good efficacy in detecting and trapping codling moths in the treated apple orchard. [2]

Malaise trapping

is a popular method used by entomologists to capture flying insects over an extended period of time. It is a passive sampling technique that involves setting up a a "Malaise trap" to collect a wide variety of flying insects, such as bees, flies, beetles, and even some smaller butterflies. Malaise trapping is an efficient method for studying insect populations and biodiversity. By setting up multiple Malaise traps at different locations and time points, entomologists can collect large quantities of insects for species identification, population studies, and ecological research. Additionally, Malaise trapping allows entomologists to passively sample insects over extended periods, providing valuable data on seasonal and long-term trends in insect abundance and diversity.

Pan Trapping

Pan traps (Moericke, 1951) are trays filled with liquid set out to collect insects. Pan traps often rely on color as an attractant and are effective primarily because insects mistake them for food resources. An insect flies to a pan, attempts to land, then becomes trapped in the liquid solution—often soapy water, propylene glycol, or saline. Pan traps can be made from nearly any object that holds liquid—i.e., a disposable plate filled with water and a few drops of dish soap Montgomery et al. (2021).

Pan traps
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Pitfall Trapping

The method is applied for capturing ground-dwelling (epigeic) insects. In essence, an insect walks to the trap edge, loses balance, and falls in the container what is then checked, and reset. Pitfall traps produce taxonomically biased samples, but are inexpensive and popular for monitoring. Several recent reviews have discussed pitfall trapping, and standardized traps have been proposed by Brown and Matthews (2016). Like any insect sampling method, For detailed methodological accounts, see Southwood and Henderson (2000), Brown and Matthews (2016), and Hoekman et al. (2017). Montgomery et al. 2021.

Pitfall Trapping
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Attract-and-kill

The attract-and-kill is an approach for direct pest control using semiochemicals as attractant. There are several definitions of the technique “Attract-and-kill”.

According to Gregg et al. (2018) it is a combination of a semiochemical attractant and a killing agent, paired with a trapping device, a formulation for direct application (i.e., a sprayable), or a dispersed and discrete bait station. Other names for these techniques include mass trapping, lure-and-kill (Charmillot et al. 2000), and attracticide (Downham et al. 1995).

An advantage of attract-and-kill is the restriction or elimination of contact between a toxicant and the crop, beneficial organisms, or the environment.

According to El-Sayed et al. (2009) this technique, also known as “lure and kill”, “attract-and kill” or “attraction-annihilation” is the combination of an attractant, which can be odorants or visual cues or a combination of both, and a killing agent (pathogen or insecticide) and may lead to the annihilation of males, females, or both.

Method of pest control – selectively attracting a pest insect to a source using a chemical attractant, e.g. sex pheromone, and then killing the insect with an insecticide (IAEA 2003).

The current status and recent developments in attract-and-kill with compounds intended to attract females or both sexes with focus on agricultural and horticultural crops are reviewed by Gregg et al. (2018).

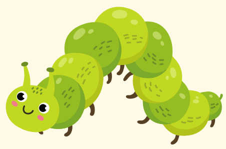
Several concepts are developed on the base of the technique “Attract-and-kill”:

Mass trapping

The technique of mass trapping involves the use of chemical lures that attract insects to traps where they are caught and eventually die. To effectively reduce economic damage by controlling the insect population, the traps need to be efficient and dense, while the lures should possess strong attractant power to catch sufficient numbers of insects. The use of traps, baited with pheromones or other attractants, to control insect pests. Chemical pesticides or biopesticides can be used in conjunction with the pheromones to kill target insects (Coombs and Hall 1998).

Male Annihilation Technique (MAT)

The male annihilation technique involves the use of a high density of bait stations consisting of a male lure combined with an insecticide. An insect pest control method that reduces pest populations by employing mass trapping to lure and kill male insects before they have a chance to mate. The method is often used to control fruit flies Horng and Plant (1993), SPC (2002).



Attract-and-kill is rarely used as a stand-alone tactic in pest management. Frequently it does not provide sufficient control, especially in horticultural crops where marketing standards require low levels of damage. In such cases, attract-and-kill can be used in conjunction with conventional cover sprays of insecticides (Hossain et al. 2013), such that the extent to which the latter can be reduced provides a measure of the former's efficacy, thereby reducing the selection pressure for resistance and assisting the conservation of natural enemies.

Useful tips for insect trapping

Despite the fact that the general characteristics and mode of action of main type of traps are same, different manufactures make some modifications of shape, use different color, materials etc. Because of that the general recommendation for use of pest traps in IPM programs is: follow the manufacturer's recommendation.

The following elements of trapping procedure should be taken into consideration according to manufacturer's recommendation.

Trap type and lures. Plenty of different traps and lures are available on the market. The most appropriate for particular crop, pest and environmental conditions should be chosen.

Trap density (number of traps per unit area what depends of size of trap and type of lure)

Trap deployment (determination of the specific location of the traps)

Trap array (The spatial pattern of trap placement within an area)

The height of the trap location. (According to the characteristics of the target. they may be stuck on sticks, attached to plant parts, or placed on the ground)

Position the crown of the plants according to light and air flow

Trap mapping

Trap servicing (maintaining and refreshing the traps). The frequency of trap servicing during the period of trapping depends on the longevity of baits (attractant persistency), retention capacity, rate of catch (ISPM26)

Trap inspection (checking the traps for insects)

Trap replacement

Timing of trapping (Usually Before the emergence of the first generation and until the end of the season).

2.10.5 Pest that can be managed by commercially available traps

Pest	Trap_Commercial name	Producer
Agromyzidae Leaf-miner flies	Rebell® Giallo	Biosani
	Impact, boards (yellow)	Russell IPM
	Insectonet	Andermatt
	Yellow sticky traps	Plantura,Novagrica, International pheromone Systems, Koppert,Econex, Andermatt,Harmony Ecotech Pvt. LTD
Anarsia lineatella Peach twig borer	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
	Moth funnel tree	Probodelt
Anastrepha sp.	Tephritidae trap	Russell IPM
Anthonumus rubi Strawberry blossom weevil	Cross vane funnel trap	Russell IPM
	Green vane trap	Russell IPM Ltd
Aonidiella aurantii *California red scale*	California Red Scale Sticky Trap (yellow)	Russell IPM
	Impact boards (white)	Russell IPM

Pest	Trap_Commercial name	Producer
Aphidoidea Winged aphids	Yellow sticky traps	Plantura, Novagrica,International pheromone Systems, Koppert, Econex, Andermatt, Harmony Ecotech Pvt. LTD
	Green sticky traps	International pheromone Systems
	Impact boards (yellow)	Russell IPM
	Roller Traps yellow	Econex
	Rigid yellow chromatic plate	Probodelt
	Insectonet	Andermatt
	Optiroll yellow range	Russell IPM Ltd
Bactrocera cucurbitae Melon Fly	Flycatcher	Russell IPM
	Tephritidae trap	Russell IPM
	Flycatcher (mcphail) trap	Russell IPM Ltd
	Flycatcher (mcphail) trap	International pheromone Systems
Bactrocera dorsalis Oriental fruit fly	Tephritidae trap	Russell IPM
	Mosquito cup (tephri-type trap)	Koppert
	Mosquito cup (tephri-type trap)	Biosani

Pest	Trap_Commercial name	Producer
Bactrocera oleae (Olive fly)	ECONEX MOSQUERO	Econex
	Rigid yellow chromatic plate	Probodelt
	Conetrap Trap	Probodelt
	Flycatcher	Russell IPM
	Tephritidae trap	Russell IPM
	Mosquito cup (tephri-type trap)	Koppert
	Maxitrap XL fly trap	Probodelt
	Rebell® Amarillo	Biosani
	Mosquito cup (Tephri-type trap)	Biosani
	EOSTRAP	Econex
	Invaginated eostrap®	Econex
	Econex bottle trap	Econex
Bactrocera zonata Peach fruit fly	Flycatcher	Russell IPM
	Tephritidae trap	Russell IPM
Bark beetles	Multifunnel trap	Novagrica

Pest	Trap_Commercial name	Producer
Bemísia tabaci Tobacco whitefly	Rebell® Giallo	Biosani
Bruchus rufimanus Broad-bean weevil	Bruchid beetle trap	Koppert
Byturus rubi Raspberry beetle	Rebell® white	Biosani
	Rebell® white	Andermatt
Byturus tomentosus Raspberry beetle	White sticky traps	Plantura
	Rebell® white	Biosani
	Raspberry beetle trap	Andermatt
	Rebell® white	Andermatt
	Raspberry beetle trap	Koppert
	Raspberry beetle trap	Russell IPM Ltd
Byturus unicolor Raspberry beetle	Rebell® white	Andermatt
	Rebell® white	Biosani
Ceratitis capitata Medfly	Econex bottle trap	Econex
	Rebell trap	Novagrica
	Rigid yellow chromatic plate	Probodelt

Pest	Trap_Commercial name	Producer
Ceratitis capitata Medfly	Conetrap Trap	Probodelt
	Maxitrap XL fly trap	Probodelt
	Mosquito cup (tephri-type trap)	Biosani
	Flycatcher	Russell IPM
	Tephritidae trap	Russell IPM
	Mosquito cup (tephri-type trap)	Koppert
	Rebell® Amarillo	Biosani
	Flycatcher (mcphail) trap	Russell IPM Ltd
	Flycatcher (mcphail) trap	International pheromone Systems
	Drosal trap pro	Biosani
	Rebell trap	Novagrica
	Mosquito cup (Tephri-type trap)	Biosani
	ECONEX MOSQUERO	Econex
	EOSTRAP	Econex
	Invaginated eostrap®	Econex
Ceutorrhynchus napi Rape stem weevil	Rebell® Amarillo	Biosani

Pest	Trap_Commercial name	Producer
Ceutorrhynchus quadridens Cabbage stem weevil	Rebell®Amarillo	Biosani
Chrysodeixis chalcites Golden twin-spot moth	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
Cicadellidae Leafhoppers	Rebell®Giallo	Biosani
Coleoptera	EOSTRAP	Econex
Cydia pomonella Codling moth	Moth Funnel Tree	Probodelt
	Plum moth trap refill	Andermatt
	Moth funnel tree	Probodelt
	Codling moth trap	Andermatt
	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
	Delta Trap Individualized	Biosani
Dacus sp.	Tephritidae trap	Russell IPM

Pest	Trap_Commercial name	Producer
Dasineura mali Apple leaf-curling midge	Delta traps	Russell IPM
	Optiroll Super Plus (white-midge)	Russell IPM
Dasineura oxycoccana Blueberry gall midge	Delta traps	Russell IPM
	Optiroll Super Plus (white-midge)	Russell IPM
	Optiroll super white plus	Russell IPM Ltd
	Impact boards (red)	Russell IPM
	Optiroll Red	Russell IPM
Dasineura plicatrix Blackberry leaf midge	Delta trap	Russell IPM
	Optiroll Super Plus (White-midge)	Russell IPM
Diaphorina citri Asian citrus psyllid	Impact boards (green)	Russell IPM
Diptera	Econex white triangular	Econex
Drosophila suzukii Spotted wing drosophila	Funnel trap mod for drosophila	Novagrica
	Impact boards (red)	Russell IPM
	Econex disposable red triangular	Econex
↓	Econex bottle trap ds	Econex

Pest	Trap_Commercial name	Producer
Drosophila suzukii Spotted wing drosophila	Magipal	Russell IPM
	MaxDro	Russell IPM
	Optiroll Red	Russell IPM
	Red Impact boards	Russell IPM
	Red suzukii trap	Russell IPM
	SWD blister pack	Russell IPM
	DROSAL® Pro cup traps	Biohelp
	Drosal Trap Pro	Biosani
	Drosalure packaging tap	Biosani
	Drosal®pro	Andermatt
	Drososantrap	Koppert
	New suzukii trap	Russell IPM Ltd
	Red sticky traps	Econex
	Drosal trap pro	Biosani,
	Drosal trap pro	Andermatt
	Drososan trap	Koppert

Pest	Trap_Commercial name	Producer
Duponchelia fovealis European pepper moth	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
Empoasca spp.	Rigid yellow chromatic plate	Probodelt
	Green sticky traps	International pheromone Systems
	Impact boards (red)	Russell IPM
	Rebell® Giallo	Biosani
Empoasca vitis Green leafhopper	Yellow sticky traps	Plantura, Novagrica,International pheromone Systems, Koppert, Econex, Andermatt,Harmony Ecotech Pvt. LTD
Epicometis hirta Blossom feeder	Apple Blossom Beetle trap	Pherobees
Epiphyas postvittana Apple leaf roller	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
Euzophera pinguis Olive Pyralid Moth	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM

Pest	Trap_Commercial name	Producer
Euzophera pinguis Olive Pyralid Moth	Mothcatcher	Russell IPM
	Moth Funnel Tree	Probodelt
	Moth funnel tree	Probodelt
Flea beetles	Impact boards (white)	Russell IPM
Flying beetle pests	Vane Trap/Small Vane Trap	International pheromone Systems
Flying moths	Moth trap	Harmony Ecotech Pvt. Ltd
Flying nocturnal insects	Solar light trap	Harmony Ecotech Private Limited
	Solar light trap	Harmony Ecotech Pvt. Ltd.
Frankliniella occidentalis Western flower thrips	White sticky traps	Plantura
	Ferolite trap	Russell IPM
	Impact boards (blue or yellow)	Russell IPM
	MagiPal	Russell IPM
	Optiroll Blue (Super, Plus)	Russell IPM
Fruit flies ↓	Jackson trap	Biosani
	Jackson trap	Econex

Pest	Trap_Commercial name	Producer
Fruit flies	Fruit fly trap	Harmony Ecotech Pvt. Ltd
	Venchuree fruit fly trap	Harmony Ecotech Pvt. Ltd
	Liquibaitor Trap	International pheromone Systems
	Smart Trap	Novagrica
	Impact boards (yellow)	Russell IPM
	Entrap	T-Stanes
	McPhail trap	Novagrica
	McPhail trap	Koppert
Fruit flies & other flying insects	Mcphail trap	Harmony Ecotech Pvt. Ltd
Fruit flies (*Drosophila)*	Yellow sticky traps	Plantura, Novagrica, International pheromone Systems, Koppert, Econex, Andermatt,Harmony Ecotech Pvt. LTD
Fruit flies and other Diptera,	Econex bottle trap	Econex
Fungus gnat or scarid fly (*Bradysia* spp. and *Lycoriella* spp.)	Rebell® Giallo	Biosani
Fungus gnats	Impact boards (yellow)	Russell IPM
Grapholita funebrana (Plum moth)	Plum moth trap refill	Andermatt

Pest	Trap_Commercial name	Producer
Grapholita molesta Oriental fruit moth	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
	Moth funnel tree	Probodelt
Halyomorpha halys Brown marmorated stink bug	Armadilha mini-piramidal	Biosani
	Halyosan	Koppert
	Cross vane funnel traps	Russell IPM
	Delta traps	Russell IPM
	transparent lid of McPhail-trap with pheromone	Trécé Inc.
	Dead-Inn Pyramid Trap	AgBio Inc., Westminster, CO
	transparent sticky board	Trécé Inc.
	Reusable Stink Bug Trap, Rescue	Pestcontroleverything
Helicoverpa armigera Cotton bollworm	Green, yellow and transparent mini funnel trap	Biosani
	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM

Pest	Trap_Commercial name	Producer
Heliothis sp.	Heliothis trap	Pherobank
Heteroptera (Bugs)	Impact boards (white)	Russell IPM
Hoplocampa brevis (pear sawfly)	Rebell® white	Biosani
	Rebell® white	Andermatt
Hoplocampa flava (plum sawfly)	White sticky traps	Plantura
	Rebell® white	Biosani
Hoplocampa minuta (plum sawfly)	White sticky traps	Plantura
	Rebell® white	Biosani
	Rebell® white	Andermatt
Hoplocampa sp.	Rebell® white	Biosani
	Rebell® white	Andermatt
Hoplocampa testudinea European apple sawfly	White sticky traps	Plantura
	Rebell® white	Biosani
	Rebell® white	Andermatt
Insect pests in glasshouses	Roller trap	International pheromone Systems
Jacobiasca lybica (Green leafhopper)	Rebell® Giallo	Biosani

Pest	Trap_Commercial name	Producer
Large beetles	Multifunnel Trap	Biosani
Large moth species	Unitrap– Pole Version	International pheromone Systems
	ECONEX POLILLERO trap	Econex
Lepidoptera	EOSTRAP	Econex
Lepidoptera (Butterflies)	Water Trap	Agroline
Lepidoptera (Large butterflies)	Green and opaque funnel trap	Biosani
	Green and transparent funnel trap	Biosani
	Green and transparent funnel trap	Koppert
Lepidoptera pests in both indoor and outdoor growing areas	Delta trap red	Russell IPM
Lobesia botrana European grapevine moth	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
	Moth funnel tree	Probodelt
Lobesia botrana Grape moth	Delta Trap Individualized	Biosani
Lygus rugulipenis Tarnished plant bug	Green vane trap	Russell IPM Ltd

Pest	Trap_Commercial name	Producer
Lymantria dispar Gypsy moth	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
Mealybugs	Rebell®white	Biosani
Medium sized and large Lepidoptera	Funnel trap	Novagrica
Melolontha melolontha Common cockchafer	Green funnel trap with cross barrier	Biosani
	Green funnel trap with cross barrier	Andermatt
Micromoth pests in glasshouses	Water Trap	International pheromone Systems
Numerous insect species	Econex folding white	Econex
	Econex disposable white triangular	Econex
	Green, yellow and transparent mini funnel trap	Biosani
Palpita unionalis Olive-green pirate	Delta Trap Individualized	Biosani
	Delta Trap Individualized	Biosani
	Moth Funnel Tree	Probodelt
	Moth funnel tree	Probodelt

Pest	Trap_Commercial name	Producer
Phyllopertha horticola (Garden chafer)	Green funnel trap with cross barrier	Biosani
	Green funnel trap with cross barrier	Andermatt
	Garden chafer trap	Koppert
Pieris brassicae (Cabbage white butterfly)	Insectonet	Andermatt
Planococcus citri (Citrus mealybug)	Delta traps	Russell IPM
Planococcus ficus (Vine mealybug)	Delta traps	Russell IPM
Plutella xylostella (Diamond Back Moth)	Water trap	Harmony Ecotech Pvt. Ltd
	Pheroglo trap	Harmony Ecotech Pvt. Ltd
Prays citri (Citrus Flower Moth)	Moth Funnel Tree	Probodelt
	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
Prays oleae (Olive Moth)	Moth Funnel Tree	Probodelt
	Delta Trap Individualized	Biosani
	Delta Trap Individualized	Biosani
	Moth funnel tree	Probodelt

Pest	Trap_Commercial name	Producer
Psila rosae (Carrot fly)	Insectonet	Andermatt
	Rebell® Orange	Biosani
	Carroy fly trap	Koppert
	Orange sticky traps	Plantura, International pheromone Systems
	Rebell® Orange	Andermatt
Rhagoletis cerasi (Cherry fruit fly)	Rebell trap	Novagrica
	Econex bottle trap	Econex
	Mosquito cup (Tephri-type trap)	Biosani
	Mosquito cup (tephri-type trap)	Biosani
	Mosquito cup (tephri-type trap)	Koppert
	jackson trap	Biosani
	Rigid yellow chromatic plate	Probodelt
	Rebell® Amarillo	Biosani
Rhagoletis completa (walnut fruit fly) ↓	Rebell trap	Novagrica
	Mosquito cup (tephri-type trap)	Biosani
	Rebell trap	Novagrica

Pest	Trap_Commercial name	Producer
Rhagoletis completa (walnut fruit fly)	Mosquito cup (tephri-type trap)	Koppert
Sawflies	Impact boards (white)	Russell IPM
Scaphoideus titanus (American grapevine leafhopper)	Rebell® Giallo	Biosani
Sciaridae (Fungus gnats)	Yellow sticky traps	Plantura, Novagrica, International pheromone Systems, Koppert, Econex, Andermatt, Harmony Ecotech Pvt. LTD
Scolitidae	"Slot" type trap	Biosani
Sitona lineatus (Pea and bean weevil)	Pea and bean weevil trap	Koppert
Small beetles	Cross Barrier Trap	Biosani
Small moths species	Castellation Trap	Koppert
	Castellation trap	Koppert
Soil dwelling Coleoptera	Pitfall trap	Novagrica
	Pitfall trap	Biosani
	Pitfall trap	Econex
Spodoptera frugiperda (Fall armyworm)	Delta traps	Russell IPM
	Mothcatcher	Russell IPM

Pest	Trap_Commercial name	Producer
Synanthedon myopaeformis (Apple clearwing moth)	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
Thaumatotibia leucotreta (False codling moth)	Delta traps	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
Thysanoptera (Thrips)	Optiroll super white plus	Russell IPM Ltd
	Blue sticky traps	Plantura, Novagrica, International pheromone Systems, Koppert, Econex, Harmony Ecotech Pvt. LTD
	Green sticky traps	International pheromone Systems
	Roller Traps white	Biosani
	Roller Traps white	Econex
	Roller Traps blue	Econex
	Roller Traps blue	Econex
	Flexible blue chromatic plate/ Rigid blue chromatic plate	Probodelt

Pest	Trap_Commercial name	Producer
Thysanoptera (Thrips)	Rebell® Blu	Biosani
	Impact boards (white)	Russell IPM
	Impact boards (yellow)	Russell IPM
	Yellow sticky traps	Plantura, Novagrica, International pheromone Systems, Koppert,Econex, Andermatt, Harmony Ecotech Pvt. LTD
Thysanoptera (Thrips) (*Frankliniella occidentalis* and others)	Rebell® Giallo	Biosani
Thysanoptera (Thrips) (Thrips tabaci and others)	Impact bloards (blue or yellow)	Russell IPM
	MagiPal	Russell IPM
	Optiroll (blue or yellow)	Russell IPM
Trialeurodes vaporariorum (Greenhouse white fly)	Yellow sticky traps	Plantura, Novagrica,International pheromone Systems, Koppert, Econex, Andermatt, Harmony Ecotech Pvt. LTD
	Rebell® Giallo	Biosani
Tuta absoluta (Tomato Moth)	Water trap	Harmony Ecotech Pvt. Ltd
	Delta Trap Individualized	Biosani
	Delta Trap Individualized	Biosani
	Water Trap for Tuta Absolute	Biosani
↓	Roller Traps black	Econex

Pest	Trap_Commercial name	Producer
Tuta absoluta (Tomato Moth)	Roller Traps black	Econex
	Black sticky trap	Horiver (Koppert), Econex
	Tutatrap Trap	Probodelt
	Delta traps	Russell IPM
	Ferolite	Russell IPM
	Impact boards (black)	Russell IPM
	Magipal	Russell IPM
	Mini Mothcatcher	Russell IPM
	Mothcatcher	Russell IPM
	OptirollTuta+ (Black or Yellow)	Russell IPM
	Tuta absoluta pheromone lure	Russell IPM
	TutaRoll	Russell IPM
	Black sticky traps	Koppert
	Black sticky traps	Econex
	Pheroglo trap	Harmony Ecotech Pvt. Ltd
↓	Tutasan trap	Koppert

Pest	Trap_Commercial name	Producer
Tuta absoluta (Tomato Moth)	ECONEX WATER TRAP (ECO)	Econex
Whiteflies	Stanes goal	T-Stanes
	Roller Traps yellow	Econex
	Optiroll yellow range	Russell IPM Ltd
	Rigid yellow chromatic plate	Probodelt
	Impact boards (yellow)	Russell IPM
Xyleborus dispar (Pear blight beetle)	Red sticky traps	Plantura
	Rebell® Rosso	Biosani
Xylophagous insects	Escolitrap®	Econex
Zeuzera pyrina (Leopard moth)	Funnel trap with cross barrier	Biosani
	Traps for zeuzera pyrina	Biosani
	Delta traps	Russell IPM
	Yellow funnel trap with cross barrier	Biosani

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Useful links

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Source here

Japanese cedar longhorn beetle (*Callidiellum rufipenne*)

Source here

Unit 2.11 Pest removal

Rumen Tomov

2.11.1 Handpicking

Handpicking is a traditional and effective method for managing or controlling various horticulture pests in Europe. It involves physically removing pests from plants by hand. While labor-intensive, handpicking can be highly targeted and selective, making it a suitable method for certain pests.

Here are some examples of pests in horticultural crops in Europe that can be controlled by handpicking:

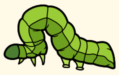
Insects: Several species of caterpillars can damage horticultural crops in Europe, such as cabbage loopers and diamondback moth larvae. Handpicking these larvae from the crop during the early morning or late afternoon is an effective and safe method to control their population.

Slugs and Snails

Handpicking slugs and snails from plants can be an effective method for managing their populations in smaller gardens or specific areas.

Weevils

Handpicking weevils from plants, especially during the early morning when they are sluggish, can help reduce their numbers.

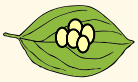


Cabbage Pests

Handpicking cabbage pests, such as cabbage worms and loopers, can be effective in small-scale gardens

Aphids and Other Soft-bodied Insects

Handpicking aphids and other soft-bodied insects or using a strong stream of water to dislodge them can help prevent their rapid reproduction and spread.



Egg Masses

Handpicking egg masses of certain pests, like those of gypsy moths, can prevent them from hatching and causing damage.

Weeds

Manual weeding is often used in conjunction with mechanical methods for weed control is specialty and high value crops such as vegetables. In orchards/vineyards etc., topper/mower for weed control are being used where there is usually a grassed area between each row of trees/vines etc. (Farmers' Toolbox for IPM)

Handpicking is often most practical for small-scale or home gardens where pest populations are relatively low. It is essential to perform handpicking regularly and consistently to prevent pest populations from rebounding. Additionally, when handpicking, it's crucial to properly dispose of the pests to prevent their return to the garden. Recently the modern idea, which uses a vacuum to remove pests was studied and implemented in practice (Weintraub and Horowitz 2001; Vincent 2002).

According to Vincent et al. 2009 the pneumatic control consists in using an airstream to dislodge insect pests. Insects that are removed by vacuum pressure are killed when they pass through the moving parts of the blower (mechanical shock). After being dislodged by a blowing device, individuals of some insect species are injured and die because they are unable to climb back onto the host plant. Other machines are equipped with a device for collecting the dislodged insects, which are subsequently killed.

In some European greenhouses, vacuum machines have been installed that run along tracks similar to those used for mobile watering systems. These automated systems move from one end of the greenhouse to the other effectively removing pests without applying chemicals. Weintraub PG, (2009) presents a comprehensive review of development of the idea for pneumatic removal of pests.

While handpicking can be an effective component of integrated pest management, it is generally not practical for large-scale commercial horticulture operations due to labor costs and time requirements. For larger-scale farms, handpicking may be used in combination with other control methods such as companion planting and cultural control as part of an IPM strategy.

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2.11.2 Mechanical weed control

Mechanical weed control refers to the use of physical tools and machinery to manage weeds in horticultural crops in Europe. Mechanical weed control is a versatile method used to manage a wide range of weeds in European horticulture.

Mechanical weed control methods can include hand-pulling, hoeing, mowing, and cultivation. The choice of method depends on the specific weed species, the growth stage of the weeds, and the horticultural crop being grown. For example, cultivation or hoeing can be effective for controlling annual weeds in row crops, while hand-pulling or spot treatment may be more appropriate for perennial weeds in small-scale or delicate plantings.

The effectiveness of mechanical weed control depends on the weed species, growth stage, and the specific mechanical tool or practice used.

It's important to note that mechanical weed control is generally more effective for annual weeds with shallow root systems and less effective for deep-rooted perennial weeds. As part of an integrated weed management strategy, mechanical weed control can be combined with other methods, such as mulching, cover cropping, and herbicide use, to achieve more sustainable and effective weed control in European horticulture.

Some common weeds in Europe that can be controlled or managed by mechanical weed control methods include:

Common Chickweed
(*Stellaria media*)

**can be controlled by regular hoeing and hand weeding can be effective in removing young plants before flowering.*

Source here

Shepherd's Purse
(*Capsella bursa-pastoris*)
Source here

Black-bindweed
(*Fallopia convolvulus*)
Source here

Common Purslane
(*Portulaca oleracea*)
*hand weeding and hoeing can be effective in removing young plants and preventing seed production.
Source here

Common Groundsel
(*Senecio vulgaris*)
*it can be controlled by hoeing or hand weeding before it sets seed.
Source here

Wild Mustard
(*Sinapis arvensis*)
Source here

Annual Meadowgrass
(*Poa annua*)

*It can be controlled by regular mowing or cultivation to prevent seed formation and spread. Hand weeding and hoeing can be effective in removing young seedlings and preventing seed production.

Source here

Italian Ryegrass
(*Lolium multiflorum*)
Source here

Wild Oat
(*Avena fatua*)
Source here

Dandelion

(*Taraxacum* spp.)

*Digging, hoeing, and pulling can be effective in removing the entire taproot, which is essential for plant regrowth.

Source here

Creeping Thistle

(*Cirsium arvense*)

Source here

Field Bindweed

(*Convolvulus arvensis*)

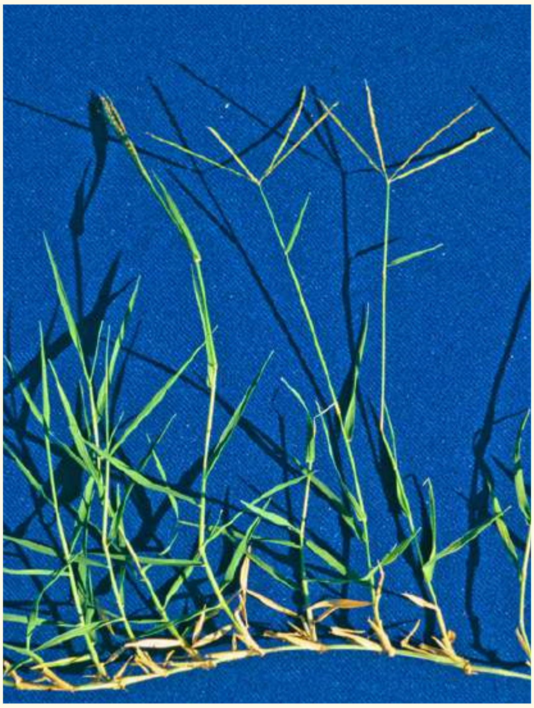
*Regular cultivation or digging to remove the roots and shoots can help manage its spread.

Source here

Common Nettle
(*Urtica dioica*)
Source here

Couch Grass
(*Elymus repens*)

Johnson Grass
(*Sorghum halepense*)
Source here



Bermuda Grass
(*Cynodon dactylon*)
Source here

Some examples of weed control are presented and discussed by Bozsa, et al. (2013), DiTommaso & Mohler (2007),Govaerts, et al. (2009), Grüber, et al. (2018), Guermandi, et al. (2019), Hamnér & Karlsson (2014), Sarúnaitė, et al. (2011), Scuderi, et al. (2018), Smith, et al. (2009), Topsakal, et al. (2011), Wolfe (2011).

While this method is primarily used for weed control, it can indirectly influence certain horticulture pest species by removing their habitat food sources or disrupting their life cycle.

Here are some examples of pests in horticultural crops in Europe that can be controlled by mechanical weed control:

Insects

Some insects use weeds as their habitat or food source. By mechanically removing weeds, their breeding and feeding grounds can be disrupted, potentially reducing insect pest populations. For example, certain weeds may serve as hosts for pests like aphids, thrips, or leafhoppers. Removing these weeds can limit pest access to crops. Mechanical weed control practices, such as hoeing or hand weeding, can help reduce weed hosts that provide shelter and food for thrips.

Removing weeds that attract whiteflies and serve as alternate hosts can help prevent their infestations and reduce populations.

Mechanical weed control practices, such as cultivation or mulching, can help disrupt aphid life cycles and reduce weed hosts that facilitate their movement and reproduction.

Mechanical weed control methods, like plowing or deeper soil cultivation, can help expose wireworms to predators and birds, reducing their populations.

Slugs and Snails

Weeds can provide shelter and moisture for slugs and snails, which are significant horticulture pests. Mechanical weed control practices, such as cultivation or hoeing, can disturb the weeds and reduce slug and snail habitats.

Diseases

Weeds can sometimes act as hosts for plant diseases, and by removing these weeds mechanically, the source of infection can be reduced.

Mechanical weed control is certainly a promising practice that can be used in many crops and in particular in permanent crops and annual crops which are seeded/planted in rows. Such techniques can achieve moderate levels of weed control in other crops. New technologies and robots are currently being developed for such mechanical weeding. Such new tools seem to be efficient and allow multiple passes in the same field (EU Toolbox for IPM, 2023).

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EU Toolbox for IPM (2023). Farmer's Toolbox for Integrated Pest Management, Final report. European Union, 2023, ISBN: 978-92-76-53692-5 DOI: 10.2762/457165

2.11.3 Stale seedbed

Stale seedbed is a horticultural practice that involves preparing the seedbed in advance and then allowing weed seeds to germinate before planting the crop.

The purpose of the stale seedbed technique is to control weed populations and reduce competition with the crop. Once the weeds have germinated, they can be destroyed through mechanical means, such as hoeing or shallow cultivation, before planting the crop.

This practice is named “sterile seed bed technique” and is described in EU Toolbox for IPM (2023) as technique that involves cultivating the soil, and then leaving it for a period until an initial flush of weeds has germinated. The grower will then lightly cultivate the soil to destroy the weed cover before the desired crop is planted/sown. Decompaction of the soil also contributes to reducing pest/disease pressure as soil structure also has an impact on biological activity and processes, root development and seed germination and emergence.

While it is primarily used for weed control, it can also influence certain horticulture pests by disrupting their habitat or life cycle.

The pests that can be influenced or controlled by the stale seedbed technique in European horticulture include:

Soil-borne Pests

The stale seedbed technique can also disrupt the life cycle of some soil-borne pests, such as certain nematodes and soil-dwelling insects. By allowing weed seeds to germinate and then destroying the weeds, the pests that rely on the weeds as hosts or habitats may be reduced. Stale seedbed technique can help reduce wireworm, cutworms (*Agrotis* spp.) and carrot fly populations by encouraging their emergence before planting and then removing them through mechanical means.

Slug and Snail Habitats

Stale seedbed can indirectly influence slug and snail populations by disrupting their preferred habitats. By cultivating the soil and exposing the weed seeds, the moist and sheltered environments that slugs and snails favor may be disturbed. In addition stale seedbed technique can help reduce their populations by creating a favorable environment for their eggs to hatch and then using different methods to remove them before planting.

Additional information is presented by English, & Mead (2015), Fitzpatrick & van den Bosch (2016), Green, et al. (2012), Maurer, & Fullerton (1994), Savage, & King (2014).

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Black carpenter ant (*Camponotus pennsylvanicus*)

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Source Eastern subterranean termite (*Reticulitermes flavipes*)

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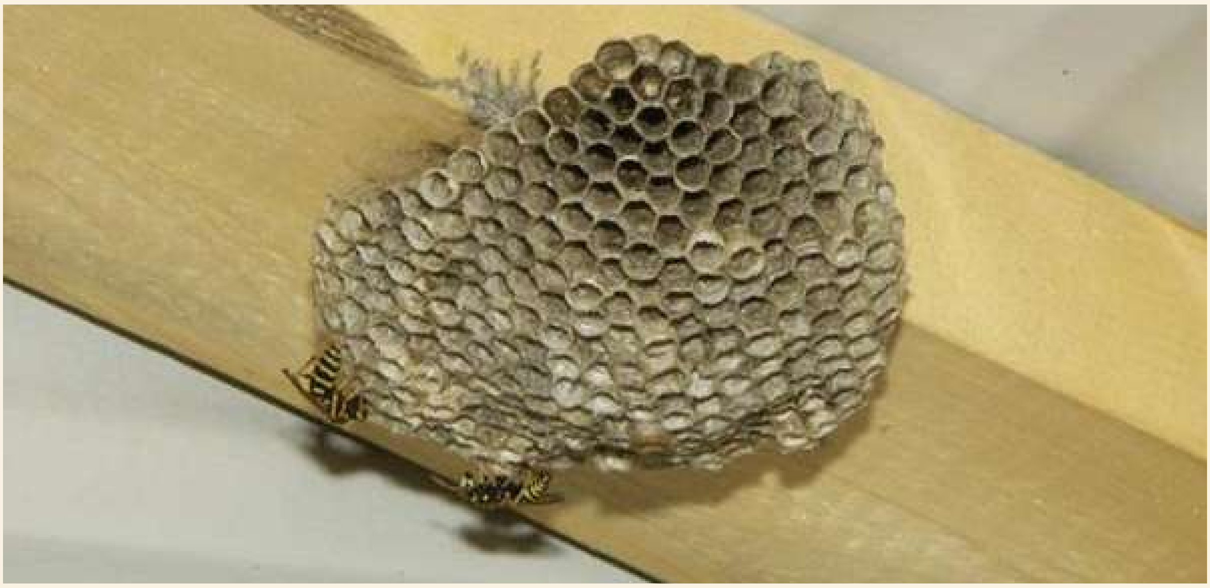
Paper wasp



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Japanese beetle damage to a blueberry leaf

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Japanese beetle (Popillia japonica)

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Spotted lanternfly (*Lycorma delicatula*)

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Unit 2.12 Preventing the spreading of harmful organisms

Vera Petrova, Rumen Tomov,
Lavinia Iliescu

2.12.1 Field sanitation

Field sanitation is a crucial aspect of integrated pest management (IPM) in European horticulture since many plant diseases and insect pests overwinter in plant debris, such as wrinkled fruits, fallen leaves, and others.

Diseases on these wrinkled fruits infect new leaves after spring (Hillock & Borthick, 2004). Field sanitation can help manage or control various horticulture pests in Europe by reducing their overwintering sites, breeding grounds, and food sources. Sanitation is widely applicable, but for it to be most effective, timing and an understanding of the characteristics of the pest species are essential (Hill, 1987). During the growth season, sick plants and contaminated leaves and fruits should be removed to prevent the spread of illness. Sanitation also prevents new pests from becoming established on the farm (Bajwa and Kogan 2004).

Field sanitation involves removing and destroying plant materials that can serve as breeding sites for pests and diseases.

Proper field sanitation practices may include the following:

- Prompt removal of crop residues after harvest.
- Destruction or proper disposal of infested plant material.
- Clearing debris and fallen fruits from the field.

According to some literature sources the field sanitation also involves eradicating harmful weed hosts or alternate hosts, cleaning field borders of alternate hosts as well (Hill, 1987), [1].

The most common means of field sanitation is destruction of crop residues by shredding and ploughing, separately or in combination. This process not only kills some pests directly but also speeds up natural rotting of the residues thus removing them as food or shelter source. (Bajwa & Kogan, 2004).

The pests and disease that can be controlled or managed by field sanitation in European horticulture include:

 **Insects**

Field sanitation can reduce the population of – (1) overwintering insects, such as certain beetles and caterpillars, by removing crop residues and plant debris where they may shelter or lay eggs, (2) Aphids by removing plant debris and other materials that provide shelter and food for aphids, (3) Thrips by removing plant debris where they can hide and reproduce (Shelton et al. 1997). (4)

Whiteflies by removing plant debris that provides shelter for whitefly adults and nymphs (Prabhaker & Castle, 2011), (5) Leafminers by removing plant debris where the pupae can overwinter. (6) Rotten onions have a great attraction for the onion maggot fly. To avoid adults laying eggs of Delia antiqua that will overwinter as pupae, fall clean-up of onion debris is essential; sanitation is equally important in the spring to avoid attracting newly emerged flies to onion fields Hillock & Borthick (2004). Collecting and using dropped fruit or else destroying them reduces the populations of the codling moth Cydia pomonella (Linnaeus) (Prokopy, 2001).

Diseases

Field sanitation helps limit the spread and survival of certain plant diseases by removing infected plant material and debris, which can serve as sources of inoculum for the next growing season. For example removing and raking up dead leaves on strawberry plants after harvest reducing botrytis grey mold on next year's fruit [1].

Slugs and Snails

Field sanitation can reduce slug and snail populations by removing hiding places and food sources, such as crop residues and fallen fruits.

Weeds

Proper field sanitation, such as removing weed seeds and plant debris, can prevent weed growth and reduce competition with crops.

Rodents

Field sanitation can make the field less attractive to rodents by removing crop residues and food sources.

Nematodes

Field sanitation can help manage nematode populations by removing crop residues and plant debris where nematodes may overwinter.

Additional information is presented by English & Mead, 2016; Scharbach & Zinkernagel, 2014; Shane & Richardson, 2003; Walling, 2000; van Es, & Hartman, 2019).

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2.12.2 Hygiene measures

Vera Petrova
Rumen Tomov

Hygiene measures in horticulture means regular cleaning of machinery and equipment for eliminating potential sources of infection. They play a critical role in preventing the introduction and spread of pests and diseases.

By maintaining proper hygiene practices, farmers can create a less favorable environment for pestsm reduce the risk of disease outbreaks and their impact on crops. Hygiene measures are often part of an integrated pest management (IPM) strategy, working in conjunction with other pest control methods to create a comprehensive approach to pest management (Shane & Richardson, 2003; Walling, 2000; van Es, & Hartman, 2019).

Proper hygiene measures practices may include the following:
Cleaning and sanitizing tools and equipment to prevent the spread of pests and diseases.

According to Farmers' Toolbox for Integrated Pest Management Machinery can often be responsible for the transport of pests or seed of weeds from field to field or farm to farm. Good growing and storage hygiene is important to minimise the spread of many pathogens injurious to many crops. Steam cleaning can eliminate the possibilities for disease transmitions. Similarly, cleaning and/or disinfecting growing trays, remains a useful way to reduce the initial source of inoculum. The same principle holds true for storage boxes and trays for all types of crops.

In addition farmers and other visitors to farm fields can all easily transfer the viruses that cause plant diseases and weeds. Although many diseases are found in the environment naturally, they can also spread through human contact (through feces, clothing, and equipment) and inputs (mostly irrigation water). The use of animal manure or sewage waste as organic fertilizer and the presence of animals in production areas are the main sources of contamination by diseases that can be dangerous to humans [1].

The pests and disease that can be controlled or managed by hygiene measures in European horticulture include:

Fungal pathogens

Practices such as cleaning tools can help prevent the spread and buildup of fungal pathogens that can infect plants and cause diseases like powdery mildew, gray mold, and root rot.

Bacterial pathogens

Hygiene measures can also prevent the spread of bacterial pathogens that cause diseases like bacterial wilt, bacterial canker, and fire blight. Cleaning tools, disinfecting surfaces, can help reduce the population of these pathogens.

Nematodes

Practices such as cleaning tools, can help reduce the population of nematodes in the soil. can help manage nematode populations by minimizing their survival and spread.

Additional Information about peventing the spread of harmful organisms through hygiene measures could be found at EU Toolbox for IPM 2023 and The ENDURE Information Centre (ENDURE IC)

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EU Toolbox for IPM 2023. Farmer's Toolbox for Integrated Pest Management, Final report European Union, 2023, ISBN: 978-92-76-53692-5 DOI: 10.2762/457165

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ENDURE IC http://www.endureinformationcentre.eu/?rvn=1

2.12.3 Management of alternate hosts

Vera Petrova
Rumen Tomov

The replacement of alternate hosts is a horticultural practice used to manage or control certain pests by removing or replacing plants that act as alternative hosts for these pests. By eliminating or reducing the availability of suitable hosts, the pest populations can be suppressed or prevented from building up.

Proper Replacement of alternate hosts may include the following:

- Regular weeding and removal of weed seeds.
- Replacing alternate hosts with non-susceptible plant species

Weeds or wild plants may act as alternative hosts for plant parasites to survive between growing seasons and provide a supply of inoculum for the following growing season.

Typically, weeds are mentioned as potential hosts. Therefore, it is typically preferable to remove brambles or other weeds from uncultivated land to help with bug management. To avoid destroying the plants that host the pest's natural enemies, caution must be exercised.

Regular weed removal lessens the need for nutrients and prevents pests from hibernating. A good example of preventive control is this.

dicotyledonous weeds contain *Meloidogyne* spp. and other nematodes, and certain leguminous green manure crops maintain the halo blight organism, *Pseudomonas syringe pv. phaseolicola*, according to Ogle & Dale (1997). The inoculum for the upcoming season is eliminated or decreased by removing the over-seasoned host. However, the relationships between weeds and crop parasites are often obscure and many weeds are symptomless carriers of various viruses.

The alternate hosts of numerous harmful rust fungi are additional significant inoculum sources. Some rusts are unable to finish their life cycles in the absence of alternative hosts, which gives the rust fungus the chance to engage in sexual recombination and perhaps create new races of the fungus. Initiatives to eradicate other hosts may or may not be successful, although the effect of an alternate host on a rust disease can vary substantially (Ogle & Dale, 1997).

Both pests and helpful insects can live in weeds and grasses. For instance, spider mite infestations are decreased when broadleaf weeds are removed from the vicinity of fruit trees. If the weeds are closely connected to the agricultural plants, they should be eliminated since they can harbor pest insects. Pests that typically live in weedy areas and can spread to nearby attractive plants include armyworms, crickets, cutworms, flea beetles, grasshoppers, lygus bugs, slugs, snails, stink bugs, and thrips.

Weeds must be removed before planting a crop in order to prevent insects from settling on the desired plants. Hillock & Borthick (2004), [1]

Destruction of alternative hosts may also require careful scrutiny as it may eliminate an important habitat for beneficial insects. (Capinera, 2001)

The pests that can be controlled by the replacement of alternate hosts in European horticulture include:

Diseases

By replacing alternate hosts with non-susceptible plant species, the disease pathogen's survival and spread can be limited. This practice is particularly relevant for diseases with broad host ranges, such as certain rusts and powdery mildews.

Insects

By replacing these alternate hosts with non-preferred or non-susceptible plant species, the insect's ability to complete its life cycle may be hindered. This practice can be effective for pests like aphids, whiteflies, and leafhoppers, which often have a range of host plants. Whiteflies use many broad-leaved weeds as alternative hosts when suitable crops are not present (Norris et al., 2003). Many vegetable pests, such as squash - and stinkbugs, overwinter in crop debris and plant cover at the edge of plantings. Elimination of these hibernating habitats can significantly reduce infestations in squash, beans, cabbage and other vegetables (Capinera, 2001).

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Nematodes

By replacing these host plants with nematode-resistant varieties or non-host species, the nematode population can be reduced.

Weeds

Some weed species act as alternate hosts for pests and diseases that attack cultivated crops. By managing and controlling weeds in and around horticultural fields, farmers can reduce the risk of pest and disease transfer from weeds to crops.

It's important to note that the effectiveness of replacing alternate hosts may vary depending on the specific pest and disease pressures, the availability of suitable replacement plants, and other factors. This method is often more practical in smaller-scale or localized horticultural systems, such as home gardens or specific crop plantations.

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2.12.4 Destruction of volunteer plants

Vera Petrova

The destruction of volunteer plants refers to the deliberate removal or eradication of unwanted plants that have self-sown or grown spontaneously in a particular area.

Volunteer plants are uncultivated self-sown plants which are not deliberately planted by gardener or farmer. Frequently, seeds that are dispersed by the wind, dropped by birds, or unintentionally incorporated into compost lead to the growth of volunteers. Unlike weeds, which are unwanted plants, volunteer plants could be self-set plants from the previous year's crop and sometimes people starts to care about them. But these plants could be hosts for pests. Many insects find volunteer plants to be particularly alluring, and them act as the focal point for subsequent infestations. Unless they are destroyed, they can help perpetuate a pest problem by furnishing a food source to long life-cycled pests of preceding crops.

Volunteer plants and crop plants remaining from previous seasons that establish in fallowed land or around cropping areas may provide sources of inoculum for succeeding crops. Such plants are the origin of subsequent infestations since they are incredibly alluring to numerous insects. They should be

Suppressing overwintering populations and reducing the growth rate of pest populations can be achieve by eliminating plants that serve as alternative hosts when the main crop is not present (Bajwa and Kogan 2004). These alternative host plants can exist within the crop field itself or in the surrounding areas. Whiteflies, for example, utilize various broad-leaved weeds as alternative hosts when their preferred crops are unavailable (Norris et al., 2003). Johnson grass is a particularly favorable host for sorghum midge (Pedigo, 2002). Effective pest control has been report through the destruction of these alternative host plants, often achieved by burning or other means. Many vegetable pests, including squash bugs and stinkbugs, overwinter in plant debris and cover at the edges of fields. Eliminating these hibernation habitats can significantly reduce infestations in crops such as squash, beans, and cabbage (Capinera, 2005). However, the destruction of alternative hosts should be approach with caution to avoid eliminating important habitats for beneficial insects. Volunteer plants from previous crop cycles can also serve as potential sources of pest carry-over. These plants may harbor a large number of insect pests during times when their presence would normally be unlikely. Removing volunteer plants becomes crucial, particularly when practicing crop rotation to control pests. For instance, removing volunteer maize in soybean fields prevents maize rootworm adults (*Diabrotica* spp.) from laying eggs and producing larvae that would infest maize in the following season (Goodwin, 1985).

The destruction of volunteer plants is also recommend to suppress other pests such as the Hessian fly, potato tuberworm, potato aphid, cutworms, and the wheat curl mite (Lidell and Schuster, 1990; Capinera, 2001; Buntin et al., 1999).

According to the Soil Wealth Nurturing Group, Potato tubers left in the soil after harvest can lead to a volunteer potato plant problem in the next cash crop.

Following a potato harvest, these volunteer potatoes (*Solanum tuberosum*) typically pose the biggest weed issue in the paddock. Through competition for resources and demand in vegetable farms, volunteer potatoes could result in losses in the following vegetable crops.

Volunteer potatoes can remain dormant for several months in the soil following harvest. They can germinate from a depth of 1 – 20 cm and can re-sprout after the foliage (stems) have been destroy. Therefore, volunteer potatoes can be costly and challenging to control. An integrate weed management strategy combining cultural measures, physical control where possible and chemical control is recommended.

Caldwell, et all (2013) recommended that volunteer onions, beans, potatoes, tomatoes etc. which are from previous crop growing have to be removed because they are hosts for pests.

Many authors point out that well-planned crop rotation is a precaution against the emergence of volunteer plants. Another method against their occurrence is mulching the soil surface - mulch prevents seeds from falling or the seeds of such plants from sprouting. Masilionyte et all (2017) found that cover crops can be used successfully against weeds and volunteer self-seeding plants.

2.12.5 Decontamination of seeds and bulbs

Rumen Tomov

Decontamination of seeds and bulbs refers to the process of removing or reducing the presence of harmful pathogens, contaminants, or pests from seeds and bulbs before they are used for planting or storage. Seeds and bulbs can carry a range of diseases, pests, or harmful microorganisms that can compromise plant growth and health, lower yield, or lead to crop losses. Decontamination ensures that these harmful elements are eliminated or reduced to acceptable levels, reducing the risk of infection and disease to plants. Decontamination of seeds and bulbs is important in modern horticulture because it helps prevent the spread of diseases and pests, improve the quality and quantity of crops, and ensure that traded seeds and bulbs meet international phytosanitary standards. Properly decontaminated seeds and bulbs are more likely to produce healthier and more productive plants, leading to higher crop yields and better environmental stewardship. The decontamination methods for seeds and bulbs vary in effectiveness and the level of resources required. The appropriate method for seed and bulb decontamination should be selected based on the type of pathogen, seed properties, and available resources.

Different methods can be used for the decontamination of seeds and bulbs, depending on the specific pathogen or contaminant and the type of seed or bulb being treated. In addition to chemical treatments these methods can include: (1) heat treatment, (2) cold treatment, (3) physical treatment, (4) biological treatment, (5) irradiation treatment etc.

Heat treatment

This method involves exposing the seeds and bulbs to high temperatures for a specific period. The heat can be applied using steam, hot water, or dry heat. The heat treatment method has been found to be effective in reducing fungal and bacterial pathogens.

Aerated Steam Treatment /Hot water steam

This method involves using hot steam to kill pathogens on the surface of seeds or bulbs. A conveyor belt system is used to pass the seeds or bulbs through a steam chamber under controlled temperature and duration. The process works by killing or sterilizing pests and diseases that may be present on the surface or within the seeds or bulbs. This method is efficient for large-scale decontamination.

Examples:

Fusarium spp.: Ibrahim et al. (2018) demonstrated that aerated steam treatment at 52-54°C for 30 minutes significantly reduced *Fusarium* spp. in tomato seeds.

Bacterial canker (Clavibacter michiganensis subsp. michiganensis): Moquet et al. (2015) showed that aerated steam treatment at 52-54°C for 20 minutes significantly reduced the bacterial load in tomato seeds.

Vapor Heat Treatment

This method combines heat and humidity to kill pathogens. Seeds or bulbs are placed in a chamber with controlled humidity, and steam is introduced. The combination of steam and heat effectively kills and removes contaminants without damaging the seeds or bulbs.

Examples:

Fusarium spp.: Kumar et al. (2019) showed that treatment with vapor heat at 50°C for 5 hours significantly reduced the incidence of *Fusarium* in onion bulbs.

Onion white rot (*Sclerotium cepivorum*): Stamps et al. (2005) showed that vapor heat treatment significantly reduced the incidence of white rot in onion bulbs.

Pea weevil (*Bruchus pisorum*): Balasubramanian et al. (2006) showed that vapor heat treatment significantly reduced the incidence of pea weevil damage in peas.

Hot Water Treatment/ Hot water immersion

This method involves immersing the seeds or bulbs in hot water at a specific temperature and holding them for a specific duration. Generally, the temperature of the water should be between 50-60 °C, which is high enough to kill most pests and disease-causing organisms but low enough that it of pest or disease being targeted.

does not damage the seeds or bulbs. The period of treatment is usually between 5 and 30 minutes, The temperature and duration vary depending on the type of seed or bulb being treated and the type of pest or disease being targeted.
Hot water treatment is a simple and effective way to control pests and diseases in seeds and bulbs. It destroys the microorganisms present on the seed surface without damaging the seeds or bulbs and increases the germination rate of the treated seeds.

For example, hot water treatment at 50 °C for 6 hours increased the germination rate of banana seed from 35% to 65% and eliminated fungi such as Fusarium oxysporum and Colletotrichum musae (Teixeira da Silva et al., 2014).
Hot water immersion can be used to control a wide range of pests and diseases in seeds and bulbs, including fungal and bacterial diseases, insect eggs and larvae, and weed seeds. It is a popular method because it is relatively simple, cost-effective, and environmentally friendly.
Examples:
Bacterial canker (*Clavibacter michiganensis* subsp. *michiganensis)*: Khatri-Chhetri et al. (2019) showed that hot water immersion at 50°C for 25 min reduced bacterial canker incidence by up to 69%.
Stem nematodes (*Ditylenchus dipsaci*): Nyczepir et al. (2018) showed that hot water immersion at 45°C for 16 min reduced stem nematode populations by up to 67% in onion bulbs.

Scab (*Streptomyces* spp.): Stopajnik et al. (2019) showed that hot water treatment at 55°C for 10 minutes reduced Apple scab incidence in apples.

Bacterial blight: Mahmood et al. (2018) found that a hot water treatment at 50°C for 10 minutes reduced the bacterial blight incidence in pepper seeds from 100% to 0% (doi: 10.24425/jppr.2018.123073).

Pathogens in garlic bulbs: (Cavallito et al., 1952) demonstrated reduction of patogens.

Flaming

This metod involves the application of heat to the plant or soil surface to kill pests and diseases. Flaming can be done manually or with the use of specialized equipment such as flamers or propane burners. Flaming is typically done using a propane-heated flame that is applied to the seed or bulb surface for a short period of time. The heat from the flame kills any disease-causing pathogens or insect eggs that may be present on the plant material, thereby preventing their transmission to the new crop. The effectiveness of flaming as a pest and disease control method depends on several factors, including the intensity and duration of the heat, the type of pest or pathogen being targeted, and the susceptibility of the plant material to heat damage.

Examles:

Fusarium fungi: Flaming can significantly reduce *Fusarium* inoculum on seeds and in soil (Rose, 2004).

Onion maggot (*Delia antiqua*): Onion maggot can be controlled by flaming onion sets before planting to prevent adult fly infestation. Flaming can reduce onion maggot density by up to 80% (Stenger et al., 2012).

Bean seed flies (*Delia platura* and *Delia floralis*): Flaming can also reduce the number of bean seed flies in the soil by up to 90%, making it a viable method for seed disinfection and soil decontamination (Stolz et al., 2018).

Wireworms (*Agriotes* spp.): Flaming not only kills the adult beetles but also sterilizes the soil to prevent the development of eggs and larvae (Mahlberg and Ebbesen, 2001).

Xanthomonas campestris pv. *Campestris* (black rot) - van der Wolf et al. (2016) showed that heat treatment with temperatures between 50-55°C significantly reduced the incidence of black rot in brassica seeds.

Bacterial spot (*Xanthomonas* spp.) - Timmer et al. (2002) showed that heat treatment with temperatures between 48-55°C reduced the incidence of bacterial spot in tomato seeds by 80%.

Verticillium sp.: *Verticillium wilt* - Righetti et al. (2019) showed that heat treatment with temperatures between 50-55°C reduced the incidence of *Verticillium wilt* in tomato seeds by 83%.

Seed-borne fungi: Ortíz-Ferrer et al. (2017) showed that heat treatment significantly reduced the incidence of seed-borne fungi as *Fusarium*, *Alternaria* and *Aspergillus* in tomato seeds.

Cold Treatment

This method involves exposing the seeds or bulbs to specific low temperatures for a specified period. This can be done by storing them in a refrigerator or using artificial cooling chambers.

Cold storage

This is a method of controlling pests and diseases in seeds and bulbs by storing them at low temperatures for a period of time. The process works by slowing down the metabolic processes of the pests and diseases, thereby reducing their ability to reproduce and spread.

Examples:

Seed-borne pathogens (e.g. *Fusarium* spp., *Aspergillus* spp.): Cold storage of seeds at temperatures between 0°C and 10°C can help to reduce the viability of these pathogens and prevent infections.

Thrips (*Thrips tabaci*): Amin et al. (2013) showed that cold storage of onion bulbs at 4°C for 21 days reduced thrips populations by 80% compared to untreated bulbs.

Gray mold (B*otrytis cinerea*): Stergios et al. (2015) showed that cold storage at 2°C effectively reduced the incidence of gray mold in strawberries stored for up to 10 days.

Rapid feezing

This is a method that involves exposing seeds, bulbs, or other plant materials to extremely low temperatures for a short period of time. This can be done using liquid nitrogen or other cryogenic techniques.

Rapid freezing is reported to be effective in controlling various seed-borne and soil-borne pathogens, such as fungi, bacteria, insects, and nematodes. Rapid freezing is a promising method of controlling pests and diseases in seeds and bulbs, and it has been used and studied in Europe. However, further research is needed to determine the optimal protocols for specific crops and pathogens and to evaluate the economic and environmental sustainability of the method. According to a review article Lobo & Campos. (2017) rapid freezing using liquid nitrogen has been used to control bacterial and fungal pathogens in seeds and plants in Europe. The article reports that the method has been used to treat a variety of seeds and bulbs, including wheat, barley, tomato, onion, garlic, and other vegetables and fruits.

Biological treatment

This method involves using benign microorganisms to fight against pathogens. These microorganisms include beneficial bacteria, fungi, and yeasts, which can colonize the seeds' surface and protect them from pathogens. The use of beneficial microbes such as Trichoderma and Bacillus has shown effective results in controlling soil-borne pathogens (Wang et al., 2019).

Examples:

Fusarium (Fusarium oxysporum.): F Wu et al., 2016) showed that the use of Trichoderma species can reduce the incidence of Fusarium oxysporum in tomato and pepper seeds

Pythium damping-off (*Pythium* spp.): Shrestha et al. (2019) showed that the application of *Bacillus* subtilis reduced *Pythium* damping-off incidence in tomato seedlings.

3. Root-knot nematodes (*Meloidogyne* spp.):

Nematodes (*Meloidogyne* spp.): Gómez-Lama Cabanás et al. (2018) showed that the application of Pseudomonas fluorescens reduced the population of root-knot nematodes in tomato crops.

Physical treatment

This method is a cost-effective and involves the use of physical means to remove pathogens and contaminants such as seed cleaning. For example, air separators, gravity tables, and metal detectors can be used to remove fungal contaminants from seeds (Nesterenko & Nikitina, 2019).

Examples:

Fusarium seed rot and damping-off: Kim et al. (2010) found that an electron treatment at 2 kGy significantly reduced the Fusarium seed rot incidence in tomato seeds from 45% to 12%, and the damping-off incidence from 83% to 20%

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2.12.6 Pruning

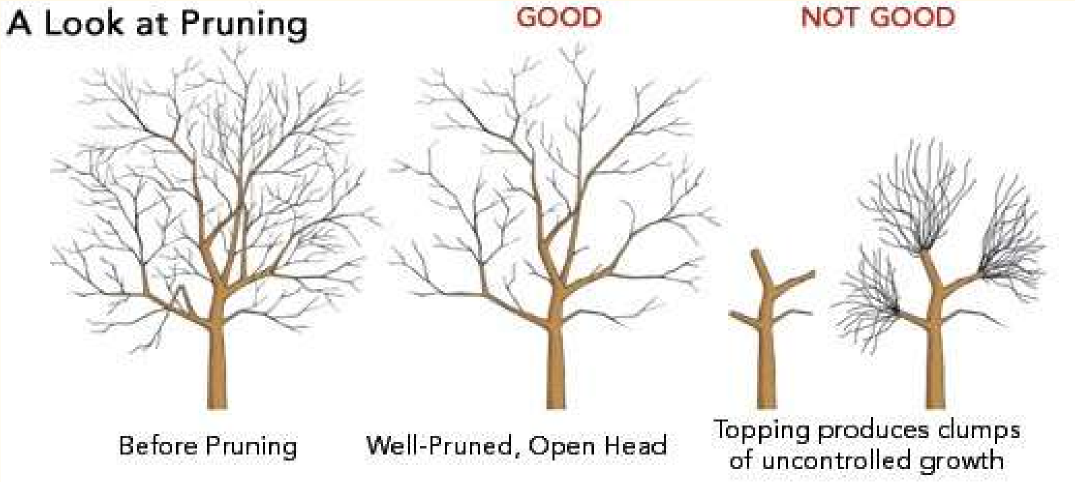
Vera Petrova, Lavinia Iliescu
Adrian Asanică

Pruning is a practice in horticulture, arboriculture, and silviculture that involves the selective removal of specific parts of a plant, which can include branches, buds, or roots.

To prevent future structural issues and minimize the need for major limb removal, it is recommended to prune trees when they are young. This helps avoid large wounds that can become entry points for decay and diseases. Remove branches that cross each other, have sharp angles of attachment to the trunk, or compete with the main leader of the tree. Diseased limbs should be pruned, and in some cases, pruning can help control pests limited to specific areas of the plant. Improved air circulation resulting from pruning can reduce the occurrence of certain diseases. However, it is important not to overprune, as it can cause unnecessary wounds or sunburn.

There are two main types of pruning cuts: heading and thinning. Heading cuts involve removing a branch to a stub, bud, or small branch, which stimulates new growth from buds just below the cut.

This type of pruning often leads to dense foliage and shoots. Thinning cuts, on the other hand, remove a branch at its point of attachment, promoting more balanced growth throughout the plant and maintaining its natural shape. It is crucial to avoid topping trees, which is the severe pruning of large branches in mature trees. Topping encourages the growth of weakly attached branches below the cut, making them prone to wind damage.



https://forestrypedia.com/tree-pruning-a-detailed-note/

Pruning is an essential practice for maintaining the size, shape, and healthy growth of most trees and shrubs. It is necessary to trim branches that have been affected by diseases, pest insects, or environmental stress. It is crucial to promptly remove dead, diseased, or insect-infested branches to prevent further harm and the spread of pests or diseases to nearby vegetation. Additionally, pruning can enhance light penetration and airflow, reducing moisture and humidity levels that contribute to various disease issues.

Nevertheless, improper pruning can lead to negative consequences for plant health, including bleeding, loss of flowers or fruit, winter dieback, and wood splitting due to frost damage. When dealing with pest or disease problems like fire blight, it is important to conduct pruning specifically for managing these issues, separate from routine pruning for size and vigor. Selective cutting is typically employed for pruning aimed at disease and pest control.It is worth noting that pruning differs from shearing, which is a non-selective technique primarily used for trimming hedges and plants with small branches that are difficult to prune selectively (Prevention 2019)

Pruning is the practice of selectively removing certain parts of a plant, such as branches, shoots, or buds. The primary purposes of pruning are to improve the overall health and appearance of the plant, control its size and shape, promote better fruit production, enhance airflow and light penetration, and remove diseased or damaged portions. Pruning cuts are typically made at specific points, such as just above a bud or at a branch collar, to encourage proper healing and minimize damage.

For example you should:

1. Trimming the lower branches of a tree to improve visibility and clearance for pedestrians or vehicles.
2. Removing dead or diseased branches from a fruit tree to promote healthy growth and prevent the spread of diseases.
3. Shaping a hedge by selectively trimming the branches to achieve a desired form or height.

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2.12.7 Defoliation

Vera Petrova, Lavinia Iliescu

Defoliation refers to the process of removing or losing leaves from a plant. It can occur naturally, such as during seasonal changes or in response to environmental stressors, or it can be a deliberate horticultural practice carried out by humans.

In horticulture and agriculture, defoliation can be intentionally performed as a management technique. It involves the removal of leaves from plants for various purposes, such as controlling pests, shaping or directing growth, improving air circulation and light penetration, or facilitating harvesting. Defoliation is commonly practiced in techniques like pruning, selective leaf removal, or leaf stripping.

In some cases, defoliation can also be used as a method for managing plant diseases or promoting specific plant responses. For example, in certain fruit trees, defoliation can be done to combat fungal infections or to stimulate new growth and fruit production.

It's important to note that while defoliation can be beneficial in specific situations, excessive or improper defoliation can have negative effects on plant health, growth, and productivity.

Therefore, it is essential to understand the specific requirements and tolerances of each plant species before implementing defoliation practices. Consulting with experts or referring to specific guidelines for each plant type is advisable to ensure proper defoliation techniques are applied.

Defoliation involves the deliberate removal of leaves from a plant. This technique is sometimes employed for specific reasons, such as to stimulate regrowth, manage certain pests or diseases, or promote better flowering or fruiting. Defoliation is often done selectively and with caution, as it can temporarily weaken the plant and impact its overall growth and vigor. Timing and extent of defoliation are crucial considerations to minimize stress on the plant.

To do:

- Removing leaves from a bonsai tree to stimulate back-budding and encourage the development of new branches.
- Defoliating tomato plants near the end of the growing season to direct energy towards ripening existing fruits.
- Removing foliage from grapevines in late summer to improve air circulation and reduce the risk of fungal diseases.

2.12.8 Thinning

Vera Petrova,
Lavinia Iliescu

Thinning is the process of selectively removing branches, shoots, or fruits from a plant to reduce crowding and enhance air circulation and light penetration.

Thinning helps to maintain a balanced structure, prevent diseases, and promote better quality and size of remaining fruits. It is commonly practiced in fruit trees, where excessive fruit load can lead to smaller and inferior fruits or branch breakage. Thinning can also be done to open up the canopy and reduce shading in ornamental plants.

To do:

- Thinning peach tree branches to ensure proper spacing between fruits, allowing them to grow to their full size and quality.
- Thinning the canopy of a dense evergreen shrub to increase light penetration and reduce the risk of fungal infections.
- Removing excess flower buds from a rose bush to promote larger, more vibrant blooms.

2.12.9 Topping

Vera Petrova,
Lavinia Iliescu

Topping, also known as heading or pollarding, involves the removal of the upper portion of a plant, usually the main stem or branches, to reduce its height or control growth

Topping is often done to manage the size of trees or shrubs that have outgrown their available space or to create a desired shape or form. However, it is important to note that topping can lead to weak regrowth, increased susceptibility to diseases and pests, and an unbalanced and unnatural appearance if not done correctly. It is generally recommended to explore other pruning methods before resorting to topping.

To do:

- Pruning the upper portion of a fast-growing tree to control its height and prevent interference with power lines.
- Topping a willow tree to encourage the growth of lateral branches and create a dense, rounded crown.
- Pollarding a tree, such as a plane tree, by regularly cutting back the main branches to a specific height, resulting in a distinct architectural form.

Aphids, scale, and fire blight-infected terminals are just a few examples of the overwintering stages of pest populations that can be significantly reduced by removing and destroying dead, diseased, or infested wood during the dormant phase. Pruning water sprouts, sucker growth, or foliage that aphids favor helps manage these pests in apple and other fruit trees. Excessive pruning, such as when it comes to fertilizing methods, might boost the number of pests like mites, aphids, and leafhoppers.

It's essential to consider proper techniques, timing, and the specific requirements of each plant species when performing any of these practices. Improper or excessive pruning, defoliation, thinning, or topping can harm the plant's health and aesthetics, so it's advisable to consult with a professional arborist or horticulturist if you have any doubts or concerns.

Remember that the suitability and specific techniques for each practice can vary depending on the plant species, desired outcomes, and local conditions. It's always recommended to consult with a professional or refer to reliable gardening resources for guidance specific to your situation.

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Wood spider carrying an egg sac

Source here

Wolf spider with spiderlings

Source here

Fish spider

Source here

Yellow garden spider

Source here

Source [here]


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Unit 2.13 Use of sterile insects in pest management

Rumen Tomov,
Roxana Ciceoi

The concept of using sterile insects in pest control programes is to introduce large numbers of sterile insects into a target population, with the intention of reducing or eradicating that population over time. The sterile insects mate with wild counterparts, but since they are unable to produce viable offspring, the overall reproductive rate decreases. If applied consistently and on a large scale, this can lead to a significant reduction in the population size of the target insect species. Several pest control methods are based on the use of sterile insects: (1) the sterile insect technique (SIT), (2) chemical sterilization, (3) incompatible insect technique (IIT), (4) genetic engineering technique

The sterile insect technique (SIT) is an environmentally-friendly insect pest control method involving the mass-rearing and sterilization, using radiation, of a target pest, followed by the systematic area-wide release of the sterile males by air over defined areas, where they mate with wild females resulting in no offspring and a declining pest population (IAEA, 2023). The use of gamma radiation is known as sterile insect technique (SIT) and it is the most efficient means of sterilizing the insects prior to release (Tomas, 2007).

The other methods for insect sterilization are often referred to as SIT in a broader sense, although the underlying mechanisms are different (Dobson, 2021). (Kapranas et al. 2022) but according to IAEA (2023) Sterile insect technique is referred to as the use of insects sterilized by irradiation (gamma rays and X-rays). SIT does not involve transgenic (genetic engineering) processes.

2.13.1 The sterile insect technique (SIT)

The Sterile Insect Technique (SIT)
is a method used in pest control and population management, primarily targeting insect pests such as mosquitoes, fruit flies, and tsetse flies.

Benefits of the Sterile Insect Technique include its environmentally friendly nature, as it does not rely heavily on chemical pesticides. It also specifically targets the pest species without causing harm to other organisms. A comprehensive overview of the Special Issue "Sterile Insect Technique (SIT) and Its Applications" is presented by Bourtzis & Vreysen (2021).

This special Issue on "Sterile insect technique (SIT) and its applications", which consists of 27 manuscripts (7 reviews and 20 original research articles), provides an update on the research and development efforts in this area.

(https://www.mdpi.com/journal/insects/special_issues/mr_sit). Kapranas et al. (2022) made review of the role of sterile insect technique within biologically-based pest control and existing regulatory frameworks.

SIT uses ionizing radiation to sterilize insects by damaging their DNA and interfering with their ability to reproduce. Radiation sterilization is commonly used for (SIT), where sterile insects are released into a target population, mating with wild insects, and producing non-viable offspring. Radiation sterilization has been used successfully against numerous insect pest species, including tsetse flies, mosquitoes, and fruit flies. (Dyck et al., 2005) Irradiation, such as with gamma rays and X-rays, is used to sterilize mass-reared insects so that, while they remain sexually competitive, they cannot produce offspring. Breaking the pest's reproductive cycle, this method is also called autocidal control, and is by definition species-specific. (IAEA, 2023). Exposure to ionizing radiation causes chromosomal damage due to random dominant lethal mutations. Utilization of the appropriate radiation dose ultimately results in sterile insects that remain sexually competitive (Bakri et al., 2021)

The sterile insect technique (SIT) aims to reduce populations of a target pest insect by mass-producing, sexually sterilizing, and subsequently releasing conspecific individuals (Dyck et al., 2021). Sterile insects produced by irradiation can be considered beneficial and their deployment can be supported as a biologically based intervention for controlling agricultural and public health pests. (Kapranas et al., 2022)

The sterile insect technique (SIT) aims to reduce populations of a target pest insect by mass-producing, sexually sterilizing, and subsequently releasing conspecific individuals (Dyck et al., 2021). Sterile insects produced by irradiation can be considered

Examples for applied SIT

SIT is being used as a component of area-wide integrated pest management for: suppression, eradication, containment and prevention. (Hendrichs et al. 2021, IAEA, 2023) and integrated pest management (IPM) approaches and is compatible with other sustainable control methods, such as mating disruption. Kapranas et al. (2022). Some common horticultural pests present in Europe that can be controlled by SIT include the follow.

The SIT is widely used for control of Tephritid fruit flies. This family of fruit flies includes many important pests of horticultural crops, such as the Mediterranean fruit fly, the olive fly, and the cherry fruit fly. Irradiation has been used successfully to control populations of these pests in several European countries.

Mediterranean fruit fly (*Ceratitis capitata*):

In the Netherlands, radiation sterilization of male Mediterranean fruit flies was used to replace the use of pesticides in an apple orchard. Sterile males were released to mate with wild females, resulting in reduced egg laying and a population decline. Similar results were seen in a pilot study in Spain. (Houbraken et al. 2009)

https://images.app.goo.gl/oECH9avoE26EWiUi7

Olive fruit fly (*Bactrocera oleae*):

https://images.app.goo.gl/oECH9avoE26EWiUi7

The technique of radiation sterilization was used in Greece to control the olive fruit fly in olive groves. Male olive fruit flies were sterilized using gamma rays and then released in the olive groves to mate with wild females. This led to a reduction in the population of the pest and the production of infertile eggs. (Economopoulos, & Vaitsos, 1978)

In Spain, radiation sterilization was tested as a control method for the olive fruit fly in combination with other control methods such as chemical treatment and mass trapping. The use of sterile males in combination with these other methods led to a reduction in the population of the pest and the production of infertile eggs. (Jacas et al. 1991)

The SIT is used for control of some Lepidoptera pests.

Codling moth
(*Cydia pomonella*)

https://images.app.goo.gl/oECH9avoE26EWiUi7

Radiation sterilization has been used as part of a wider integrated pest management program in apple orchards in Italy. Sterile male codling moths were released to mate with wild females, which led to a reduction in the number of eggs laid and eventually a decline in the overall population. (Trematerra et al. 2003)

False codling moth
(*Thaumatotibia leucotreta*)

Irradiation has been evaluated as a control method for false codling moth and has been shown to be effective at reducing populations of this pest.

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Pink bollworm (Pectinophora gossypiella)

https://images.app.goo.gl/oECH9avoE26EWiUi7

Irradiation sterilization has been used for pink bollworm control in cotton fields in Greece. Sterile male pink bollworm moths were released to mate with wild females, resulting in a decline in the population of the pest. (Tsiropoulos et al. 2013)

https://images.app.goo.gl/oECH9avoE26EWiUi7

European grapevine moth (*Lobesia botrana*)

The technique of irradiation sterilization was used in Italy to control the European grapevine moth in vineyards. Male moths were irradiated with gamma rays and then released in the vineyards to mate with wild females.

The technique led to a significant reduction in the population of the pest and the production of infertile eggs. (IAEA. (2013).)

In Greece, radiation sterilization was tested as a control method for the European grapevine moth in combination with other control methods such as pheromone traps and cultural practices. The use of sterile males in combination with these other methods led to a reduction in the population of the pest. (Barazi-Masri et al. 2000)

2.13.2 Chemical Sterilization

Chemical sterilization involves exposing insects to chemicals that disrupt their reproductive systems, making them infertile or reducing the viability of their offspring.

The chemicals used can be synthetic or natural and can be applied by different methods, such as bait stations, insecticide sprays, or fumigation. Chemical sterilization has been used to control a broad range of insect pest species, including fruit flies, mosquitoes, and moths. (Gavriel et al., 2017)

Chemical insect sterilization can be a valuable tool in integrated pest management programs, particularly when used in conjunction with other methods such as mechanical control, cultural control, and biological control. It can target specific insect species without harming non-target species, and can reduce the overall pest population in a given area over time. When insects come into contact with the sterilizing chemical, it interferes with their reproductive systems, either by disrupting the development of reproductive organs or by preventing successful mating and reproduction.
sorting to topping.

Some of the commonly used chemical sterilants include insect growth regulators (IGRs), radiation-mimicking compounds, and pheromones. IGRs can disrupt the development of reproductive organs and reduce the mating ability of insects, while radiation-mimicking compounds can cause genetic damage and reduce the viability of offspring. Pheromones can be used to confuse or trap insects or to disrupt their mating behavior.

Chemical insect sterilization can be effective in controlling insect populations, particularly in areas where other methods of control are not feasible or insufficient. It can be used for both male and female insects, depending on the target species, and can reduce the need for repeated insecticide applications. Gavriel et al. (2017) tested the effectiveness of a combination of an IGR and a radiation-mimicking compound for controlling populations of the Mediterranean fruit fly (Ceratitis capitata). The results showed that the combination treatment reduced the mating ability of male fruit flies and decreased egg production by females.Kim et al. (2016) investigated the use of a novel chemical sterilant based on the volatile components of ginger for controlling populations of the common housefly (Musca domestica). The results showed that the ginger-based sterilant reduced the mating ability of male houseflies and decreased the hatching rate of eggs.

Examples for applied chemical sterilization technique

Some common horticultural pests present in Europe that can be controlled by SIT include:

Red palm weevil (*Rhynchophorus ferrugineus*):

Chemical sterilization has been used to control the red palm weevil, which is a major pest of date palms and other palm species. In Spain, the use of a synthetic pheromone in combination with a chemical sterilant significantly reduced red palm weevil population growth and damage in treated date palm plantations (Sánchez-Peña et al., 2009).

https://images.app.goo.gl/6f3dpiDqwV5Bvhj56

Olive fruit fly (*Bactrocera oleae*):

https://images.app.goo.gl/oECH9avoE26EWiUi7

Chemical sterilization has also been used to control the olive fruit fly, which is a significant pest of olive orchards. Iin Italy, the application of an insect growth regulator with sterilizing properties significantly reduced olive fruit fly populations and fruit damage in treated olive groves (Caleca et al., 2006).

Codling moth (*Cydia pomonella*)

https://images.app.goo.gl/oECH9avoE26EWiUi7

Chemical sterilization has been employed as part of integrated pest management strategies to control the codling moth, a major pest of apple and pear crops. In one study conducted in Switzerland, the use of a pheromone-based mating disruption technique coupled with a chemical sterilization agent significantly reduced codling moth populations, fruit infestation, and the need for insecticide applications in treated orchards. (Boller et al., 2005). Chemical sterilization is not commonly used for the control of diamondback moth Plutella xylostella in Europe. However, there have been some studies on the use of chemical sterilization for the control of moth populations. Liu et al. (2014) investigated the efficacy of methoprene, a juvenile hormone analog, in suppressing diamondback moth populations in crucifer crops. Methoprene was found to have efficacy as a sterilant, significantly reducing the fecundity and fertility of treated females, leading to a reduction in offspring production.

2.13.3 Incompatible insect technique (IIT)

The Incompatible Insect Technique (SIT) is a biotechnological approach that holds significant promise for managing insect pests in agriculture, including potential applications in the context of plant micropropagation and biodiversity conservation. The technique involves the mass rearing, sterilization, and release of male insects into the target population. These sterile males mate with wild females, leading to the production of non-viable offspring, thereby reducing the overall pest population.

Here are some **key advantages** of the Incompatible Insect Technique:

1. **Species-Specific Targeting**
SIT allows for precise and species-specific pest control, as it primarily affects the targeted insect species without harming other non-target organisms.
2. **Environmental Compatibility**
The method is environmentally friendly, as it does not involve the use of chemical pesticides that may have adverse effects on ecosystems, including the micropropagation environments of plants.
3. **Reduced Pesticide Dependency**
SIT offers an alternative to conventional chemical pesticides, contributing to a reduction in pesticide dependency and minimizing the associated ecological and health risks.

4.**Minimized Resistance Development**
Since SIT operates through a mechanism that does not involve chemical toxins, it helps mitigate the development of resistance in target pest populations over time.
5.Conservation of Biodiversity
Given your interest in biodiversity conservation, it's noteworthy that SIT can play a role in preserving beneficial insects and maintaining a more balanced ecosystem by specifically targeting pest species.
6.Integration with Plant Micropropagation Practices
The technique can be integrated into plant micropropagation protocols, enhancing the overall pest management strategy in the context of in vitro plant multiplication.
7.Long-Term Effectiveness
SIT has demonstrated long-term efficacy, offering sustained pest control benefits after its initial implementation.
8.Application in Integrated Pest Management (IPM)
SIT complements the principles of Integrated Pest Management, providing a holistic approach that combines various strategies for effective and sustainable pest control.

These advantages underscore the potential of the Incompatible Insect Technique as a valuable tool in the realm of plant micropropagation, biodiversity conservation, and biotechnological approaches to pest management.

Cytoplasmic incompatibility (CI) is a phenomenon that plays a crucial role in the success of the Sterile Insect Technique (SIT). CI is a form of reproductive manipulation induced by intracellular bacteria called *Wolbachia*, which naturally infect various insect species. *Wolbachia* can cause alterations in the reproductive processes of its host, and when harnessed strategically, it becomes a powerful tool in SIT programs.

*Mechanism of Cytoplasmic Incompatibilit*y is quite simple and involve *Wolbachia* who induces CI by manipulating the host insect's reproductive system. When a *Wolbachia*-infected male mates with an uninfected female or a female carrying a different strain of Wolbachia, the incompatible cytoplasmic factors lead to embryonic lethality. In contrast, mating between infected males and females with a matching *Wolbachia* strain results in normal offspring. CI induced by Wolbachia is highly species-specific, contributing to the precision of SIT applications. It allows for targeted control of specific pest species without affecting non-target organisms.

The presence of *Wolbachia* in a targeted pest population can enhance the effectiveness of SIT. By releasing sterile males infected with a compatible *Wolbachia* strain, the resulting cytoplasmic incompatibility ensures that wild-type females produce non-viable eggs when mating with these sterile males and using *Wolbachia*-induced CI in SIT aligns with principles of sustainable pest management by providing a biological and environmentally friendly alternative to chemical pesticides. Despite its advantages, challenges such as the potential for *Wolbachia* to naturally spread in wild populations and the need for careful strain matching in laboratory settings require consideration.

2.13.4 Genetic engineering technique

The genetic engineering method involves using genetic engineering techniques to produce populations of insects that are unable to reproduce. This can be achieved by introducing dominant lethal genes into insect populations that result in either male-biased sex ratios or the production of sterile offspring.

This sterilization has the potential to be a highly effective and sustainable control method but requires extensive research and development before widespread deployment. (Isabel et al., 2017)

Genetic engineering techniques as use of RNAi (Whyard et al., 2015) and of gene-drive technology (Kandul et al., 2019) are not yet in a stage of application and still face regulatory challenges as well as limited public acceptance (Romeis et al., 2020). Insects created with genetic engineering techniques fall under the scope of the Cartagena protocol (Marshall, 2010) and the regulations for genetically modified organisms (Beech et al., 2012) and thus have to be treated separately from SIT using irradiated insects.

There are currently no examples of horticultural crop insect pests controlled by genetic sterilization in Europe. The use of genetic sterilization, specifically the release of genetically modified insects with sterile traits (e.g. RIDL technology), is still being researched and evaluated for its effectiveness in controlling pest insects in horticulture.

However, there are some ongoing research projects exploring the use of genetic sterilization to control specific crop pests in Europe. For example, the research project "IPM-4-Med Fruit Fly" is investigating the use of genetic sterilization to control the Mediterranean fruit fly in horticultural crops such as olives and citrus in the Mediterranean region. The project is still in its early stages, and the results are yet to be published. (IPM-4-MED Fruit Fly)

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Unit 2.14 Harvesting

Vera Petrova

2.14.1 Timing of harvesting

Harvesting refers to the process of gathering or collecting crops or plants, typically for agricultural, industrial, or commercial purposes. It involves the removal or cutting of mature or ripe crops, such as grains, fruits, vegetables, or timber, from the fields, orchards, forests, or other natural habitats where they have grown.

Harvesting is an essential step in the agricultural cycle, marking the culmination of the growth and development of crops or plants. It is typically carried out when the produce has reached its optimal stage of maturity, ensuring the best quality and yield. The timing of harvesting varies depending on the type of crop and its intended use. Overall, harvesting involves the systematic collection or extraction of crops or plants to fulfill human needs and requirements, whether they are related

Harvest time - the correct determination of the time for harvesting is important for the quality of the obtained production.
The timing of harvesting can be an important aspect of pest management control in agricultural practices.

In some cases, harvesting crops earlier than usual can help minimize pest damage. This approach is especially relevant when pests reach their peak population levels closer to the end of the crop's maturity. By harvesting early, you can remove the crop before pests have a chance to cause significant damage.

On the other hand, delaying the harvest can be beneficial if pests are more prevalent during the earlier stages of crop growth. Allowing the crop to mature further can result in reduced pest populations, as some pests may have completed their life cycle or migrated elsewhere.

Regular monitoring of pest populations is crucial to determine the optimal timing of harvesting. By closely observing pest activity and population dynamics, farmers can make informed decisions about when to harvest to minimize potential losses. This monitoring can involve the use of traps, visual inspections, pheromone monitoring, or automated pest detection systems. By coordinating these practices with the timing of harvesting, farmers can effectively manage pests while minimizing the use of chemical pesticides.

It's important to note that the specific timing considerations for pest management control may vary depending on the type of crop, the region, and the specific pest species involved.

Therefore, farmers should consult with agricultural experts, extension services, or local pest management guidelines for the most suitable timing strategies in their specific circumstances.

For most vegetable species, the optimal time is indicated - when the production has reached its optimal size, shape, and color when they have accumulated enough sugars or dry matter. However, in certain cases, it is practiced to harvest earlier - in case of danger of pest attacks. Early harvesting can be used to avoid the mass multiplication of pests by disturbing their habitat.

Manipulating the timing of planting and harvest can disrupt the synchronization between crop growth and major pest activity, leading to substantial reductions in damage. This can be achieved by adjusting cultural practices, such as planting dates. Early planting can help crops establish themselves before pests become problematic, as they are either less appealing to herbivores or more tolerant of higher pest densities without significant yield loss. Early harvest can create phenological differences that disrupt pest life cycles, allowing crops to be harvested before damaging stages occur.

Early harvesting

For example, planting maize early in East Africa reduces issues with sweet maize earworm and stem borer. The sweet maize plants reach a more mature stage when the female stem borers lay fewer eggs, minimizing damage. Additionally, early-planted can be harvested before fully grown pre-diapause larvae cause lodging and yield losses. Similarly, early-planted tomatoes in the western USA are less susceptible to infestations by tomato fruit worms compared to those planted later in the season. Early-maturing varieties of cotton and soybeans also avoid certain pest populations.

Caldwell, et all (2013) indicates early harvest as a cultural method against diseases and pests in some crops, eg: Harvest early leek to avoid both damage by larvae of the last flight of Acrolepiopsis assectella and population build-up for the next season. Against Sclerotium cepivorum is recommended to stimulate the sclerotia to germinate by growing scallions and harvesting before the disease completes its life cycle. About the corn: since the pest is usually not a problem until mid to late summer, try to avoid injury by planting early and harvesting before the expected arrival of Helicoverpa zea. Using short-season varieties also helps.

Many authors recommended having the timing of sowing and harvesting carrots to avoid peak flights of carrot fly *Psila rosae*. But for good timing, it is necessary to know the biology and behavior of the carrot fly (Hill, S. 1990 a, b). Early harvesting can be used to disrupt the survival of the pest in its habitat. Also, clipping or early harvesting can help destroy immature insects that are in the foliage.

2.14.2 Selective harvesting

Hand picking

Selective Harvesting

As the name suggests, selective harvesting is selecting only the ripest coffee fruit by hand. You've heard of the phrase 'cherry picking'? It's the same process. This leaves the unripe coffee on the tree for future harvesting. Pickers go back again and again until it's deemed no longer worthwhile to continue the harvesting. With this method, only the red fruit is harvested. Pickers then perform a post-harvest sorting and weigh their haul. As you can imagine, this takes quite some time to do, but it's worth it.

The advantages of this selective harvesting method are that only the ripest fruit is picked, weighed, and dried. Plus, the trees can be planted on land with inclines, which farms in mountainous and volcanic regions already have. This helps the farm remain efficient with its planting practices. One major disadvantage is that it requires people that can work for minimal pay.

https://www.koffeekult.com/blogs/blog/selective-vs-strip-harvesting

The term "selective harvest" refers to the practice of only picking fruit that is at optimal ripeness while leaving unripe fruit behind to be picked later. Being selective requires more labor and time but it pays off as it results in a much higher quality coffee
https://www.dancinggoats.com/pages/harvesting-coffee

Selective coffee picking (hand picking)
Selective picking involves hand-picking only ripe coffee cherry, and returning numerous times to each coffee tree to again pick just the ripe berries. This results in less costs sorting the coffees afterward, as well as higher prices because of consistency with the harvested coffees. It also results in a higher yield of coffee beans, since fewer harvested coffees need to be discarded. https://espressocoffeeguide.com/all-about-coffee-2/harvesting-coffee/

2.14.3 Strip harvesting

The entire crop is harvested at one time. This can be done either by machine or by hand. In either case, all of the cherries (under ripe, ripe and over ripe) are stripped off of the branch at one time.

https://www.dancinggoats.com/pages/harvesting-coffee

With this method, all the fruit is stripped off the trees mechanically at one time. As you can imagine, this means a mix of ripe and not-so-ripe fruit being picked. There are two main ways to strip harvest: mechanical stripping and using mechanical harvesters.

With mechanical stripping, a device (picture a rake attached to your hand) is used to strip the branches with the fruit landing on canvases placed on the ground. All of it is taken and weighed at the end of the day. Mechanical harvesters are machines that knock fruit off a tree with large rotating mallets into collection units. This type of harvesting is quicker, but you need flat ground for the machine to go through the farm.

The advantages of strip harvesting are that it requires less time and labor to complete. Some disadvantages are the mix of mature and not so mature fruit and what it means to the overall product. For the best quality crop, the coffee producer has to add the use of pulpers and optical sorters post-harvest.

Strip Picking

Strip picking means that all coffee cherries are picked from the tree at the same time with large machinery regardless of maturity level. This method is a lot quicker and easier, but there is a higher risk of unripe and defective coffee being taken to the next level of processing. This method is mostly used on large coffee plantations.

https://thecoffeeofficina.com/learn/harvesting-processing/

STRIP PICKING COFFEE

Strip picking involves taking hold of a branch of the coffee tree and using a single motion to pull off all of the coffee cherry (fruit) on the branch at once. Strip picking is often used on dry processed coffees and on plants whose coffee cherry ripen all at the same time. Additional sorting is still required afterwards since 100% of the coffees don't ripen at the same time. https://espressocoffeeguide.com/all-about-coffee-2/harvesting-coffee/

Strip picking and selective picking also requires that trees are pruned so that the coffee cherries remain within easy reach during harvest season, but the requirements are a little more lax than machine harvesting.

Tailer-made harvesting

Pre-harvest bagging Pre-harvest bagging of grape clusters as a non-chemical physical control measure against certain pests and diseases of grapevines

Pest management doesn't end with harvesting. Proper post-harvest handling, storage, and transportation practices are crucial to prevent pest infestations and maintain the quality of harvested crops. Prompt removal of damaged or infested produce, proper cleaning, and appropriate storage conditions can help minimize post-harvest losses due to pests.

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ISBN 978-606-072-356-1

ISBN 978-606-072-358-5