FARMER'S HANDBOOK OF SYNTHETIC BIOLOGY

CONTENTS

CHAPTER 01

Introduction

In this chapter, we introduce you to this handbook and go through what iGEM is, who we are, and why we have created this handbook.

Why are we creating this Handbook?

This Handbook is an initiative from the following iGEM Teams: Aboa, Patras and TecCEM, participating in the iGEM Competition 2022. Our countries (Finland, Greece and Mexico) are characterized by important occupation of agriculture, a sector that is dealing with different issues. Following the iGEM philosophy, where "Local people solve local problems", we aim through our Projects to provide a solution to these problems and help through Synthetic Biology to achieve this. Since the final users and target group are farmers, we attempt via this Handbook to offer beneficial information regarding the problems faced in agricultural sector as well as provide solutions that ensure a positive environmental impact.

Who is it for?

The goal is for every farmer in our countries to have a guide about Synthetic Biology in agricultural practices, as well as other important matters, such as plant diseases and sustainable agriculture.

The Handbook aspires to become a guide for farmers all around the world, introducing Synthetic Biology and its contribution to agricultural development. We will introduce our Projects as examples and try through a simplified and understandable way to describe the problems that we try to address regarding the primary sector.

Also, we included a few plant diseases, the responsible pathogens and the symptoms according to our research.

Since our projects aim to promote sustainability and make a positive impact on the world, we introduce the term of Sustainable agriculture and suggest solutions for agricultural practices, that are environmentally friendly and respective towards biodiversity and the consumers.

At the end of the Handbook you will find a Synthetic Biology Glossary, that explains some words mentioned in this handbook. The words that can be found in the glossary are underlined in the handbook texts.

What is iGEM?

The iGEM (International Genetically Engineered Machine) Competition is a competition that has been held annually since 2003 and is organized by the Massachusetts Institute of Technology (MIT). What started as an academic class, has now evolved to be a global competition, organised by iGEM Foundation, where high school, undergraduate and overgraduate students from all over the world form interdisciplinary teams and travel together in the enchanting world of Synthetic Biology.

What are the goals of iGEM?

The main objective of the Competition is highlighting innovative ideas in the field of Synthetic Biology, when solving everyday problems, with a view to the implementation of the 17 Sustainable Development Goals (SDGs). More than 350 interdisciplinary teams worldwide participate in the competition annually, and the achievements of the 2022 competition projects will be presented in Paris in the autumn.

Who are we?

Team ABOA from Finland consists of 14 students from the University of Turku.

ABOA

We are creating a detection system for plant pathogens to improve food scarcity and provide an easy-to-use test for agriculture

Team Patras from Greece consists of 27 members, represents University of
Patras and is a collaboration between the Laboratories of Pharmacogenomics
& Personalized Therapy and Mechanical Engineering & Oscillations.

Our goal is soil improvement and the increase of the agricultural yield through an innovative protocol, providing advice for farmers and experts in the field of agriculture.

Who are we?

"Team TecCEM from Mexico consists of 34 studnents from the University of Monterrey Institute of Technology and Higher Education.

Our project this year is mainly focused on catching and degrading Endocrine Disruptors on residual water used in agriculture by the help of the immobilized laccase enzyme on a filter. We are also working on a biosensor that can quantify the amount of Endocrine Disruptors on the water."

CHAPTER 02

Synthetic biology

In this chapter, we go through the basics of Synthetic Biology. This chapter gives you basic knowledge to better understand our projects and the field of synthetic biology in relation to agriculture.

What is Synthetic Biology?

Synthetic Biology has become a relevant factor for the elaboration of different beneficial products for both humans and the environment. According to the National Human Genome Research Institute, Synthetic Biology is defined as a science area that deals with the design or the re-design of biological systems modifying their genetic structure, which allows them to be of great use and to have different beneficial purposes for human beings, through the use of engineering.

One of the main objectives of Synthetic Biology is the improvement of genetic engineering processes combining different disciplines such as engineering in Biology, Chemistry, Electrical, Mathematics and Biophysics. Also, it encompasses other different areas such as genomic programming, proteomics, metabolomics, bioinformatics, DNA synthesis, among others that have a fundamental role within the biotechnology industry, including the agricultural sector.

The use of the different disciplines involved in synthetic biology, mainly within the industry, has allowed the development of a large number of products for the benefit of human beings, such as chemical products, enzymes in the food industry, biofuels, bio-pesticides, among others, which are generated thanks to the genetic modification of microorganisms and the optimization of the their fermentation, talking a big role in agriculture as well (Katz, L. et al. (2018)).

Nowadays, a strong pillar of support in Synthetic biology is the use of microorganisms to obtain synthetic products, beneficial for plants and vegetables, with more and more projects being involved in the advancement of beneficial products for humanity through plants and crops sources.

CHAPTER 03

Project introductions

In this chapter, we introduce you to our iGEM projects, which all aim to improve agriculture from the farmer's point of view. All the projects are utilizing synthetic biology to resolve local and global problems.

CropFold

Problem
Plant diseases are an ever rising threat to global food scarcity. Infected crops cause great losses to farmers and plant disease outbreaks can even have an impact on the economic system of a whole country. Plant disease outbreaks also have an enormous global impact on the current deficit of food and different countries do not have the same resources to deal with plant pathogens.

When the first symptoms of a plant disease arise, the crop might already be lost. This often leads to excessive pesticide use as a precaution, since there is rarely an easy way to test and confirm if the insects seen on the plants are carrying a plant-infecting pathogen or not. Excessive pesticide use is shown to lead to loss of diversity and loss of pollinators - not to mention health problems resulting from the presence of pesticide residues in food.

Solution
Our solution for tackling food security is CropFold. An easy, on-site detection system, that allows the detection of a pathogen early on, even before the plant shows any visible signs of infection. The cell-free solution ensures biosafety, since no living cells are used in the system. A test with CropFold does not need any specific laboratory equipment or expertise, but instead everyone can use the test at their own farm by following simple steps provided in the package.

Paggaia

Problem
Greece's population stands at almost 11 million people, 10% of which is involved in Primary Agricultural Production, according to Eurostat.

1. A major issue in the field of Agriculture is the low efficiency of crop inputs including fertilizers, tillage, pesticides, and irrigation water.
2. To a great degree, a determining factor is the lack of important data regarding soil physical and chemical properties in large and isolated areas.
3. Research on the existing literature data has concluded that there is insufficient information regarding the combination between Precision Agriculture tools and other technological advancements.

Therefore, in the field of Agriculture there is a thoughtless and unnecessary use of pesticides and fertilizers, due to the lack of financial resources, as well as specialized knowledge about addressing the above problems.

Solution
Project PAGGAIA → Precision AGriculture using Genomics, Artificial Intelligence and Aerotransportable equipment

Precision agriculture is an innovative farming management concept aiming to revolutionize agriculture and soil improvement, both by optimizing crops return and at the same time preserving resources. In recent years, the practice of precision agriculture has been enabled by the advent of GPS that facilitates the farmer's ability to locate their precise position in a field allows for the creation of maps of the spatial variability of as many variables as can be measured, such as crop yield, terrain features/topography, organic matter content, moisture levels, nitrogen levels, pH, minerals, etc.

The goal of the project is soil improvement and increasing the quality of the agricultural yield, via the creation of an innovation protocol. Sampling has been performed at different locations of an experimental field area that has been cultivated with tomatoes (*Solanum lycopersicum*) and where selected bacterial strains of Bacillus Sp were added to the soil near the transplanted tomato plants. The sampling procedure can also be automated with custom-made soil sampling Drones.
The samples were analyzed with Next Generation Sequencing (NGS) and the metagenomics data will be included in a protocol analyzed by a Machine Learning model that combines molecular, physicochemical, and agronomic characteristics, in order to propose tailor-made interventions to farmers and specialists in the field of agriculture, in a sustainable way, while protecting consumers' health.

Hydro Deffense

Problem
Microplastics, also known as endocrine disruptors (EDCs), are chemical substances capable of resembling human, plant and animal hormones. These can be found in different places, including irrigation water for agricultural crops, which comes from water residues that contain these EDCs, and when used in irrigation systems for plants, can affect their development, such as causing a reduction in their growth, root development and photosynthetic activity.

These disruptors can accumulate in tissues and cause problems in human health when consuming vegetables or plants irrigated with water containing EDCs, which could lead to the development of cancer, diabetes or infertility. Due to this situation, it is crucial to analyze the presence of these endocrine disruptors in the agricultural irrigation water, and tackle the problem in an innovative way.

Solution
For the solution of this problem, a process which includes quantification, entrapment and degradation of these EDCs will be done, using first a biosensor responsible for quantifying these compounds using a receptor protein (hER alpha) of endocrine molecules, and then, making use of a filtration system, which is responsible for the degradation of endocrine disruptors through the use of the protein laccase. The biosensor and filter do not require expert assistance to be manipulated, since it's considered to be easy to use.

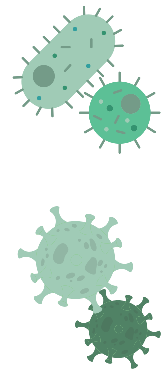
CHAPTER 04

"Plant diseases"

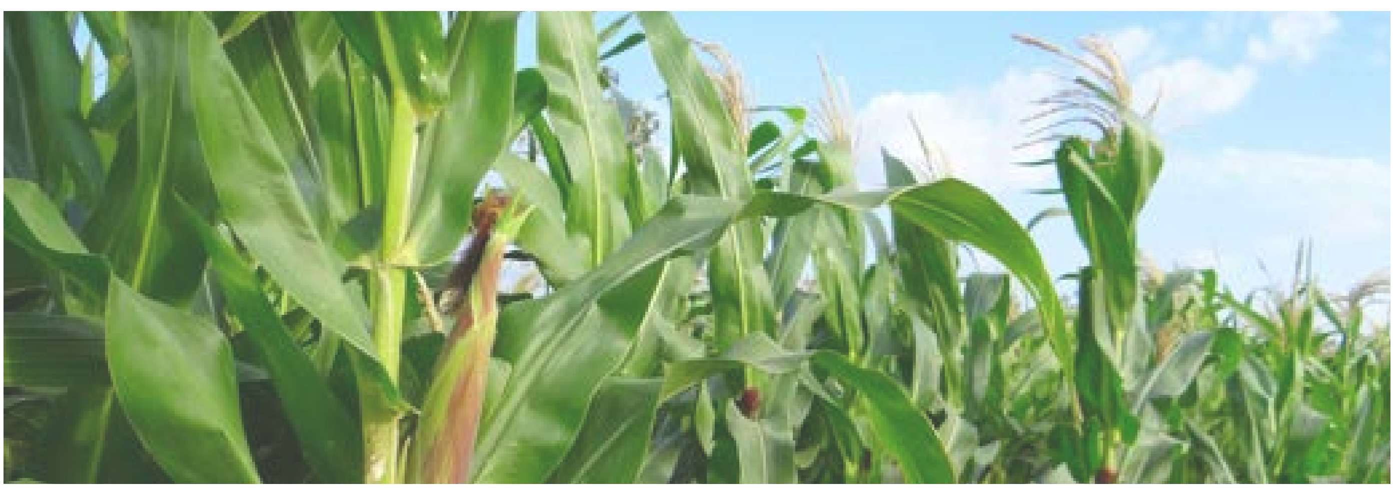
In this chapter, we will talk about plant diseases and their impact on agriculture globally, as well as introduce a few plant diseases and pathogens around the world.

Introduction to plant diseases

There is a wide range of pathogens that can infect plants and cause different symptoms. These pathogens may be for example viruses, bacteria, fungi or oomycetes, and all of them can lead to severe outcomes for crops (Al-Ani and Furtado 2020). Viruses are small particles that contain genetic information, but cannot survive outside a host such as animals or plants, whereas bacteria are free-living small organisms. Fungi and oomycetes are even more complex in their structure and function than the aforementioned. All of these groups of pathogens contain thousands of different species with unique pathogenic effects.

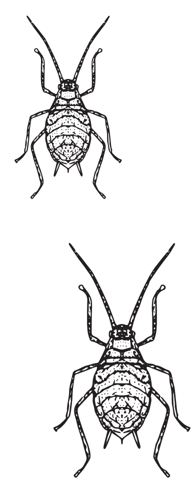


Plant pathogens have different strategies for infections. Biotrophs absorb nutrients and multiply in living plant tissues while necrotrophs kill the plant cells and then take nutrients from dead or dying cells. In comparison, hemibiotrophic pathogens are biotrophic in the beginning but later become necrotrophic. The interactions and responses between plants and pathogens vary depending on the infection type. (Prasad et al 2022)



Symptoms of plant disease infection can take many forms. The symptoms can be local and caused by the plant's defense reactions against the pathogen or more general if the pathogen disturbs the availability of nutrients or other essential resources for the plant. Viral infections can also interfere with the plant's genetic regulation, which can bring about detrimental effects on all functional levels of the plant. Visual symptoms of plant diseases include colored marks on seeds, leaves or stems of the plant. As the disease progresses these stains can change size, shape and even color. (Camargo and Smith 2009)

Many crops are infected by pathogens that are carried by insects such as aphids. In these cases the use of insecticides, chemicals to kill insects, can be used to control the spread of a pathogen. Another method that is rapidly gaining popularity is biocontrol agents, i.e. the use of other organisms to repel pathogens. These organisms can attack pathogens, compete with the pathogen, accelerate the plant's defense mechanisms or act through a combination of these and they have proven to be a useful tool in the combat against fast pathogen spread.



Next, we will introduce a few plant diseases and pathogens from around the world.

Barley Yellow Dwarf (BYD)

Barley Yellow Dwarf (BYD) is a plant disease that is caused by different viruses in the Luteoviridae family, that are transmitted to the plants by aphis (Walls et al 2019). Due to the wide range of plants that can be infected by the virus (such as maize, wheat, oat, barley and rye), the viral disease is one of the most serious viral diseases in cereal crops and grasses worldwide (D'arcy 1995).

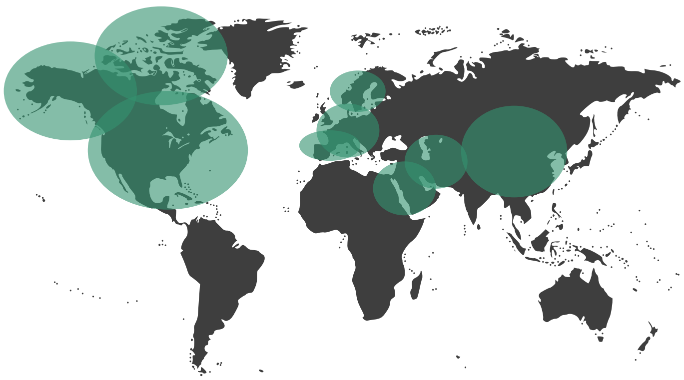
The symptoms of BYD include discoloration of the leaves and reduction in plant size, and the symptoms progress the most when the temperature is 25 C or higher. Often when the symptoms show, it is too late to manage the virus (Nancarrow et al 2014).

BYD is commonly referred to as barley yellow dwarf virus (BYDV), maize yellow dwarf virus (MYDV) and cereal yellow dwarf virus (CYDV).

The preventative measures for Barley Yellow Dwarf Virus infection mainly include changing the sowing date to avoid aphid invasion and removing stubble and cereal growth.

Tomato Brown Rugose

Tomato Brown Rugose Fruit Virus (abbr. ToBRFV) is a plant virus causing a disease affecting the fruits of tomatoes. It was first found in Jordan and Israel in 2014. ToBRFV is able to overcome a particular resistance gene found in tomatoes, thereby causing an infection. The disease has spread throughout the Middle East, Europe, America, and China. (Kabas et al. 2022)



At its worst, the infection leads to a non-marketable product due to yellow spots and brown and necrotic areas in the tomato fruit. The disease can be transmitted via mechanical contacts, which is the main pathway for the virus to infect the plant. It can also spread also via contaminated fruits or seeds over long distances and bumblebees in a greenhouse. (Kabas et al 2022)

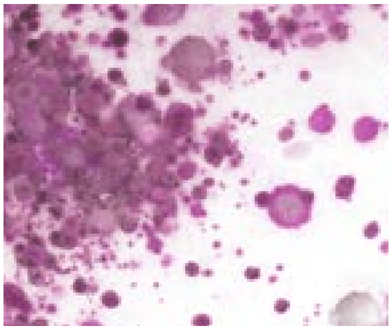
Tomato Yellow Disease

Tomato chlorosis virus (ToCV) and Tomato infectious chlorosis virus (TICV) are two whitefly transmitted viruses, which are linked to Tomato yellows disease (TYD) epidemics (Wisler et al., 1998a). These two viruses were identified firstly in Greece around 2 decades ago (Dovas et al., 2002).

Both of the viruses cause yellowing symptoms in tomato plants and result to severe crop losses. As the name suggests, Tomato yellows disease (TYD) causes yellowing of the leaves and also interveinal chlorosis and necrotic spots. Even though they do not affect directly the tomato fruits and flowers, they cause a decrease in the quantity of the crops, because of loss of photosynthetic area, that eventually lowers the production of the fruits (Orfanidou et al.,2014)

The management of ToCV and TICV is done with the use of chemical and cultural practices that aim the whitefly vectors, as the viruses cannot be spread without them. These methods do not seem really effective as the viruses can still be transmitted from the vectors, before the effect of the insecticides (Tzanetakis et al, 2013).

Fusarium Head Blight



Fusarium head blight (also called scab) is a disease caused by a few species of Fusarium fungi. There are many Fusarium species, some of them pathogenic. Fusarium infects some cereal plants, such as wheat, oat and maize, causing Fusarium head blight. The Fusarium often produces mycotoxins, and the toxin residues can even affect human and animal diets. (Asam 2017)

Fusarium can spread through infected seed, but it can also survive in the soil over winter. The fusarium spores can also be carried long distances by the wind (Keller et al. 2014). The symptoms of fusarium head blight often include changes in the kernels. It can cause the kernels to shiver up and become white. (Parry et al. 1995)

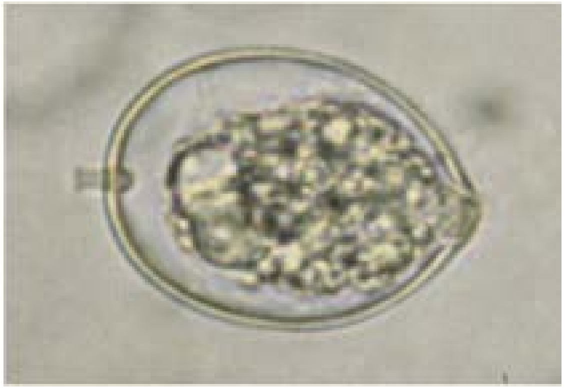
The most efficient control measures for Fusarium ear blight are cultivars resistant to the disease (Steiner et al. 2017). Agricultural practices can also affect the probability for fusarium infection. Most often fusarium spreads from previous crop residues, especially maize is a high risk crop. Proper ploughing and can reduce this risk. Chemical control is also an option for fusarium management, but the effectiveness of fungicides may vary, and non-optimal application time may even increase the risk of infection. There are also some biological control strategies, but none of the control measures for FHB are completely effective. (Dill-Macky and Jones, 2000)

Some fusarium species cause Fusarium Wilt of Banana, also known as Panama disease

Phytophthora cinnamomic (Avocado)

The fungus that causes root rot in the majority of avocado soils is sometimes referred to as "The Sadness of the Avocado Tree."

The signs of an assault by Phytophthora cinnamomi include the death and rotting of the roots, a reduction in the size of the leaves, chlorotic leaves, defoliation (usually beginning with the upper half), necrosis in tissue, undersized fruits, and in the worst case, the death of the tree. Phytophthora typically thrives in soils that have poor drainage, little organic matter, are shallow, and have poor irrigation management in the crop.



Antracnosis (colletotrichum gloesporoides)

Fruit rot is the result, both in the field and after harvest. Young shoots, buds, branches, blooms, and fruits are all targets for it.

The infection can appear in the fruit at any stage of its growth and cause it to appear slightly sunken, with 0.5 to 3 cm long, black lesions without definite borders. The spots grow in size, connect with one another, and cover a sizable portion of the fruit.

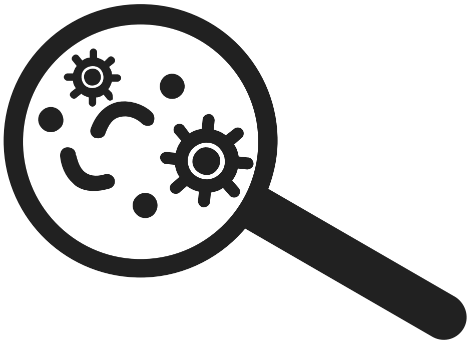
The presence of various fungi and high humidity levels encourage the sickness.

Scab (Sphaceloma persea)

Fruits, leaves, and stems can all be harmed by this fungus. Scab can attack the fruit at any point during its growth.

The leaves are spooned on the edges and turn to a light brown color when attacked. This disease causes round, irregular, brown or light brown lesions on the fruit that are corky and slightly elevated. When these lesions join together, they create a crust but the damage is just superficial, therefore the pulp quality is unaffected.

The lesions are uneven, 1 to 2 cm in diameter, black, and have well-defined, slightly depressed crimson margins on the fruits.



Black spot (Cercospora purpura)

Fruits, leaves, and stems can all be harmed by this fungus. Scab can attack the fruit at any point during its growth.

Small, dark brown lesions are created when it affects the leaves. If the attack is severe enough, the tree will topple and get defoliated. It causes tiny, black lesions with jagged edges and rind splitting on the fruits. Lesions on the fruit and leaves both make it easier for other organisms, such Colletotrichum, to invade.

Corn stunting or red leaf

Leafhoppers of the Dalbulus maidis, D. elimatus, and other species spread the disease. These pick up the virus by consuming a sick plant and pass it on till they pass away. Mixed infections are prevalent because many viruses and phytoplasmas can be transmitted by the same vector, including maize fine streak virus. Spiroplasma kunkelii, a helical mollicute, is the pathogen.

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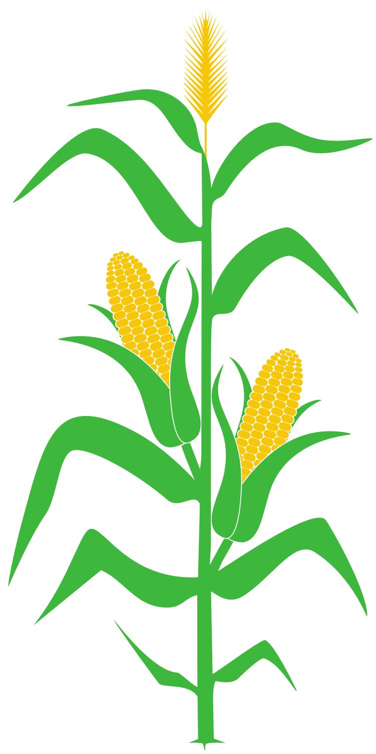


Symptoms displayed by infected plants vary depending on the maize genotype. The most prevalent ones show up as yellowish, chlorotic lines at the base of the youngest leaves, the tips of which may turn reddish purple, and reddish or purplish coloring on the leaves. Foliar symptoms typically start to show up around flowering. Plants that are stunted or dwarfed have shorter internodes.

Ear smut in corn (carbón de la espiga)

The fungus Sporisorium reilianum is the pathogen. It happens when the spike and ear are in the process of blossoming. Early infections damage the plant's growth and prevent the formation of spikelets; instead, a black mass of spores is seen. The ear is also affected, similarly being covered in black spores. Stunting of the plant is a side effect of the virus. The spores from diseased agricultural residues can remain viable in the soil for up to 10 years, making them a valuable source of inoculum.

Leaf spots or blight

Caused by a number of different fungus, including Helminthosporium, Leptosphaeria, Phaeosphaeria, Hyalothyridium, Curvularia, and Septoria.

They cause lesions that resemble burns in appearance. If the infection occurs before flowering, the reduction of leaf area reduces sunlight capture (photosynthesis), which leads to loss of grain weight and losses of up to 30%.

High relative humidity and temperatures between 20 and 30 degrees encourage the spread of infection.

Stem rots

It is brought on by bacteria like Erwinia as well as fungi from the genera Fusarium, Diplodia, Pythium, and Macrophomina. But Fusarium is thought to be the primary source.

The plant completely wilts, and dries out quickly after. The complex of fungi that harms the plant's stem at the base causes the plants to settle as a result of the weight of the cob and the strong wind, making it difficult for the thresher to lift them during harvest, which results in losses. Insect damage can make them easier to penetrate. They are a continuation of ear rot and a succession of root rots.

Aerial pythium (Beans)

Some species of Pythium, such as P. aphanidermatum, P. ultimum, and P. debaryanum, are also capable of infecting above-ground plant portions, leading to what is known as cottony leak, Pythium leak, or aerial Pythium. Pythium are typically recognized for causing root and seedling infections on beans. Longer (48 to 72 hours) periods of moist foliage and splashing water that can spread soilborne inoculum up into the canopy are conducive to disease development. Pythium spp. can infect pods that are resting on damp soil.

Infected pods develop a white, cottony mold growth that resembles the early stages of white mold infection and become water-soaked and covered with it. However, this disease that resembles a fungus and is a member of the water mold genus does not produce sclerotia.

Alternaria solani (Tomato)

It is a fungus that shows symptoms on the leaves, stems, and fruits of the plant, among other components. appears at any stage of crop growth; at the seedling stage, they display a rot of the stem's neck at ground level.

In mature plants, the affected leaves show as angular or circular patches of dark brown to black color that might impair the entire leaf. Certain fruits that have been exposed to sunburn may have dark oval or circular lesions that are sunken with concentric rings, typically at the base or on the sides; this rot has an aspect to it and on it, the mushroom sporulation appears as black velvet. The lesions are elongated dark ovals with concentric rings that appear on stems and branches; the attack typically begins on the older leaves.

Cladosporium fulvum

This fungus primarily infects the upper portion of the leaves, where small pale or slightly yellow spots can be seen. As these spots grow, they turn brown in the center. The underside of these lesions is coated with a thin coating of gray or dark brown, like velvet.

CHAPTER 05

Sustainable agricultural practices

In this chapter the concept of Sustainable Agriculture will be introduced, as well as some alternative ways for farmers to practice agriculture in an environmentally friendly way, regarding the fertilizers and pesticides.

Sustainable Development Goals (SDGs)

The Sustainable Development Goals (SDGs), known as the Global Goals, were adopted by the United Nations in 2015 as global initiatvie to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity.

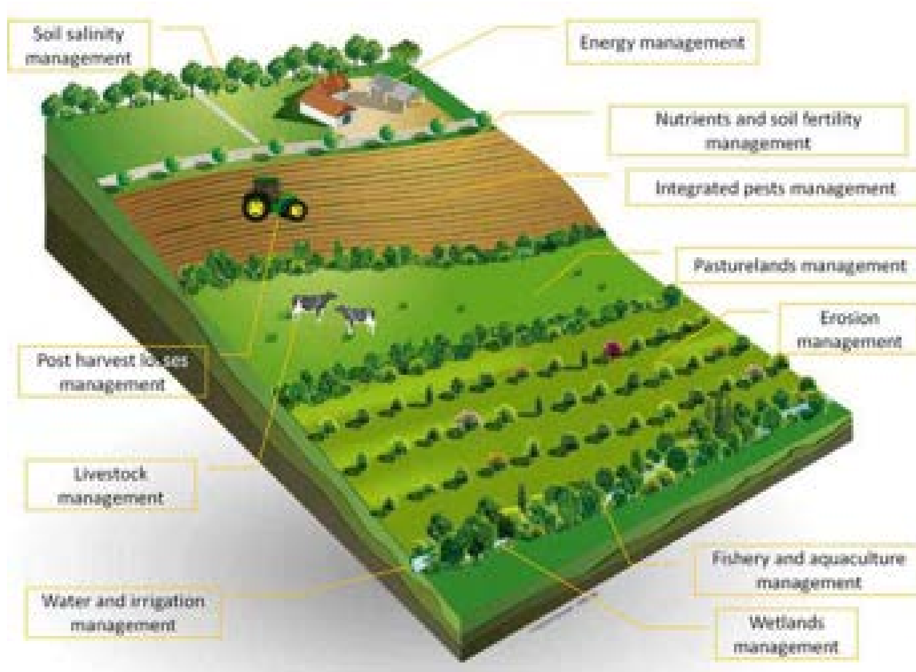
What is Sustainable Agriculture?

Sustainable agriculture is farming responding to society's present needs, without compromising the ability for current or future generations to meet their needs.

Practitioners of sustainable agriculture seek to integrate these main objectives into their work: a healthy environment, economic profitability and social and economic equity.

Every person involved in the food system - growers can play a role in ensuring a sustainable agricultural system.

Growers may use methods to promote soil health, minimize water use, and lower pollution levels on the farm.



Usage of fertilizers & Substitutes

Sustainable agriculture must produce enough food and fiber to satisfy changing human needs. In the developed countries in Europe and to some extent in USA, chemical fertilizer are responsible for environmental pollution.

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Crop rotation

Crop rotation is a farming method that is used to manage the nutrients in soil in a natural way. When the same crop is grown repeatedly in the same place, the soil lacks specific nutrients. In this way, the plant feeding is enabled.

Organic Fertilizers

Organic fertilizers derive from natural sources. Examples are manure, blood and bones, guano, compost and kelp products and increase the organic component of the soil. This improves the physical structure of the soil.

Manure

Manure is a solid waste product from animals and decomposes over time through bacterial and microbial action and in the process releases these nutrients into the soil.

Plants can only absorb nutrients that are dissolved in water. When manure decomposes, the nitrates it includes can dissolve, making it easier for the plants to absorb the compounds.

Guano

Guano is the excretion of seabirds, bats and sealsand and inludes high concentration of nitrates. The high levels of phosphorus also make this an effective fertilizer.

Lime

Agricultural lime, can be used as an alternative fertiliser, making the soil less acidic, and more soluble for nitrogen, potassium and phosphorus compounds. These nutrients will therefore be more readily available for absorption by plants

Potash

Potash is the common name for salts that contain potassium in the water-soluble form. The name is from pot ash, which was the method of manufacturing potassium salts before the industrial era. Potash is a rich source of potassium.

CHAPTER 06

Sources

Every information provided in this Handbook is based on bibliographical research. In this chapter you can find the sources.

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CHAPTER 07

Glossary

Here you will find a glossary for all the important words in this Handbook; feel free to turn to this page whenever you come across a word you do not recognize!

A-M

Bacteria: Single-celled microorganisms that are found all over the world and can be either harmful, neutral or beneficial.

Biosafety: Specific measures, such as the use of safety equipment and specially designed spaces, that ensure the safety of workers, the public and the environment from infectious agents, toxins and biological hazards.

Biosecurity: Specific measures to prevent the introduction and the spread of infectious agent to reduce the risk of transmission of infectious disease in plants and animals.

EDC´s: Endocrine Disrupting Chemicals (EDC) are exogenous agents that disrupt the body function by interfering with endocrine functions, affecting their synthesis, transport, metabolism, and release by blocking hormones.

GMO: The alteration of target organism’s genome using specific techniques, for example, for research purposes or development of synthetic organisms.

Genomics Field of biology focusing on the structure, function, evolution, mapping, and editing of genomes. A genome is an organism's complete set of DNA, including all of its genes.

Infection: A state in which the pathogen invades tissues and multiplies and the host organism reacts to the infectious agent and the toxins it produces.

Interveinal chlorosis: A plant disease symptom, which refers to the yellowing of the leaf between the veins.

Machine Learning Subfield of Artificial Intelligence, which is broadly defined as the capability of a machine to imitate intelligent human behavior.

M-S

Metagenomics The study of the structure and function of entire nucleotide sequences isolated and analyzed from all the organisms (typically microbes) in a bulk sample, to study a specific community of microorganisms, such as those residing on human skin, in the soil or in a water sample.

Microorganisms An organism that can be seen only through a microscope, including bacteria, protozoa, algae, and fungi. Although viruses are not considered living organisms, they are sometimes classified as microorganisms.

Mycotoxins: Small toxic compounds that are naturally produced by fungi. They can enter the food chain when crops get infected by fungi.

Next Generation Sequencing The technology is used to determine the order of nucleotides in entire genomes or targeted regions of DNA or RNA.

Oomycota: Fungus-like eucaryotic microorganism that can be pathogenic.

Pathogen: An organism that brings a disease to its host. Bacteria, viruses and fungi, for example, can be pathogenic.

QCM: A Quartz Crystal Microbalance is a piezoelectric system capable to detect mass changes through the variations in resonance frequency.

Strain A genetic variant or subtype of a microorganism.

Synthetic biology: A multidisciplinary field that combines the knowledge of different biological fields and engineering principles to produce organisms with new abilities by means of genetic modifications.

V-Z

Virus: An intracellular parasite that is either pathogenic (causing a disease), neutral or even beneficial.

Zeolites: Hydrated aluminosilicates of the alkaline and alkaline-earth metals. Minerals composed of aluminum and silicon that have a hollow box shape with holes. Generally used as catalysts, in ion exchange and absorption such as removing contaminants from water.

This handbook is made for you who are working with agriculture, and are interested in Synthetic Biology. Here we introduce you to the basic principles of Synthetic Biology, and how it can be utilized in agriculture. We want to spread the knowledge about Synthetic Biology and its applications all over the world.