Biotic and abiotic factors

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Biotic and abiotic factors

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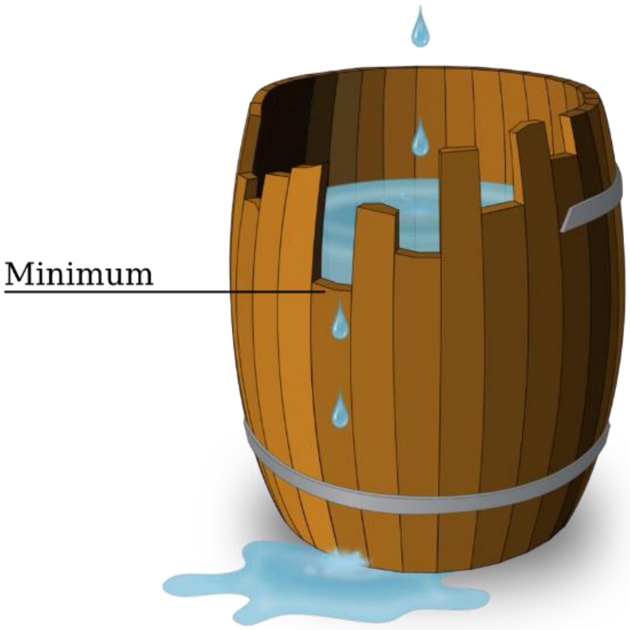
Introduction

Plant growth is influenced by many different factors. We can differ between biotic and abiotic factors.

- Abiotic = non-living environmental factors (light, temperature, water, nutrients, soil pH, wind)

- Biotic = living factors (plants themselves, pests, pathogens, weeds, beneficial organisms, soil organisms)

The limiting factor determines the plant's performance. For example, if a plant has sufficient temperature and light but the soil is too dry, the plant will be restricted by this deficiency and will not be able to grow as well. This follows Liebig's Law of the Minimum. It can be illustrated well using a barrel.



Von DooFi - Eigenes Werk, Gemeinfrei,
https://commons.wikimedia.org/w/index.php?curid=6627159

Abiotic factors - light

Light is very important for plants, as they need light energy for photosynthesis. How well a plant grows therefore also depends on how much light it receives. This principle is used in agriculture, for example, to keep weeds at bay by covering bare soil – such as between rows of plants – with mulch material (e.g. straw, green waste, mulch film).

In addition, day length (photoperiod) also plays a role in some plants. For example, many cannabis strains only start to flower when day and night are of equal length, i.e. exactly 12 hours of light and 12 hours of darkness.

https://diezukunftsbauern.de/regenerative-landwirtschaft/mulch-im-gemuesebau/

Abiotic factors - temperature

Temperature is another crucial factor in plant growth. On the one hand, plants sometimes require specific temperatures for their development to proceed correctly. On the other hand, the total temperature accumulated over the entire growth phase is also crucial, depending on the stage of development the plant is at.

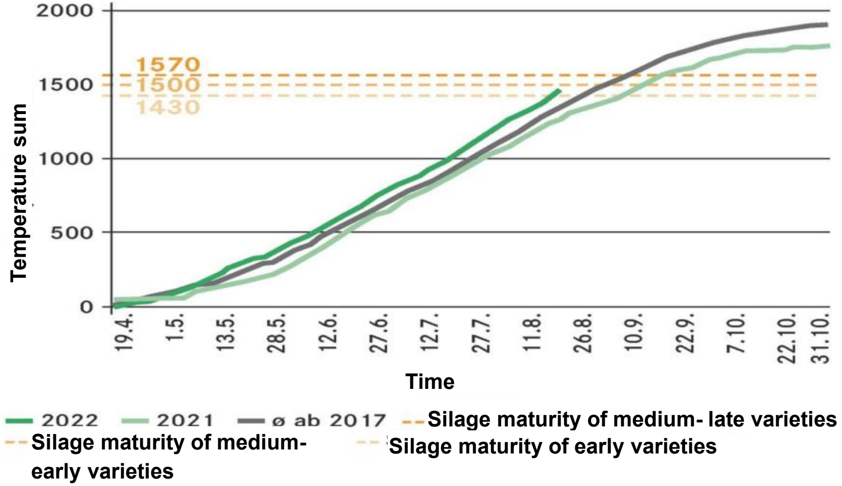
Take winter wheat, for example: winter wheat is sown in the autumn and requires a cold stimulus (several weeks below 8 °C) to trigger ear formation later on. This process is known as vernalisation. If, for example, it is too warm in winter due to climate change, fewer grains are formed and this can lead to significant yield losses.

Abiotic factors - temperature

In the case of maize, for example, the principle of temperature sum can be easily understood. Depending on the maize variety, there is a specific temperature sum that indicates when the maize is ripe. To calculate the temperature sum, the daily average temperatures from sowing onwards are added together.
However, temperature can also cause damage; for example, frost damage and heat damage can occur if plants are unable to cope with temperatures that are too low or too high at their current stage of growth.

Temperature sum trend

At the Ruhstorf site



https://www.wochenblatt-dlv.de/feld-stall/pflanzenbau/um-erntereife-mais-bayern-steht-570165

Abiotic factors - water

Plants consist largely of water. It acts as a reaction medium, a transport medium and helps regulate turgor. Turgor refers to the pressure exerted by the cell sap on the cell wall. This gives a plant its stability. You can see this, for example, when you under-water a plant and its leaves become completely limp and drooping.

Water is also a key component in photosynthesis. If there is too little water, photosynthesis is reduced. To protect itself from unnecessary water loss and dehydration during water stress (water shortage), the plant automatically closes its stomata (pores). An excess of water is also detrimental. As there is then too little oxygen in the soil, the roots may die.

Abiotic factors - nutrients

Nutrients are divided into two categories: macronutrients and micronutrients. The key factor in this classification is the quantity required by plants; only small amounts of micronutrients are essential for plant metabolism.

Macronutrients include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S). Micronutrients include, for example, iron (Fe), manganese (Mn), zinc (Zn), boron (B) and copper (Cu).

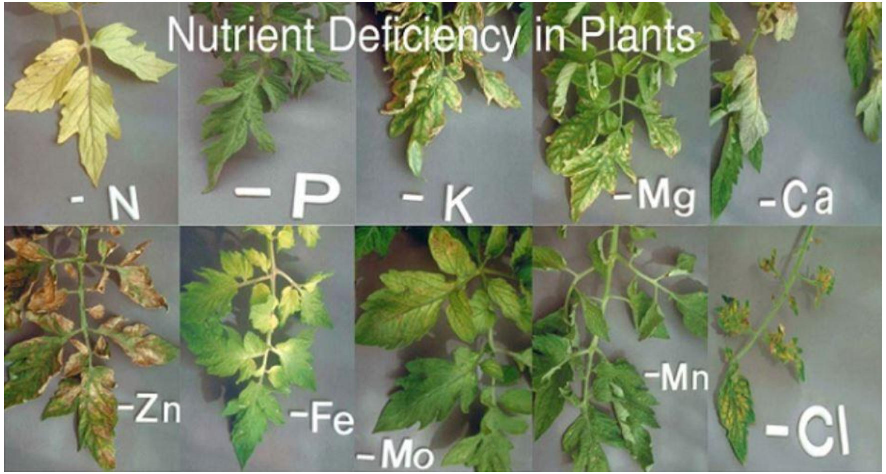
All nutrients have specific roles within the plant:

Nutrient Element	Nutrient Symbol	Uptake Form	Nutrient Biological Functions in Plants [Ref.]	Deficiency Symptoms of Nutrients [Ref.]
Nitrogen	N	NH_4^+ and NO_3^-	Constituent of amides, amino acids, proteins, nucleic acids, nucleotides, coenzymes, chlorophyll, etc. [47]	Inhibits plant growth; yellowing or chlorosis of leaves due to a collapse in chloroplasts [48]
Phosphorus	P	$H_2PO_4^-$; HPO_4^{2-}	Constituent of nucleic acids and lipid membranes, ATP, etc. [49]	Dark greenish-purple leaves, with necrotic spots and malformed [49]
Potassium	K	K^+	Controls more than 60 enzymes, mainly of photosynthesis and respiration [50]	Chlorosis of older leaves; shorter internodes in stems; inhibiting protein synthesis [49]
Calcium	Ca	Ca^{2+}	Ca-pectate is main constituent of cell wall; controls elongation and division of cells; activates many enzymes [47]	Small and younger leaves; deformed and chlorotic, bitter pit (apple); black heart (celery) [50]
Magnesium	Mg	Mg^{2+}	Component of chlorophyll and polyribosomes; enzyme cofactor [51]	Chlorosis of intervein and streaked or patchy effects on leaves [50]
Sulfur	S	SO_4^{2-}	Component of amino acids (i.e., cysteine, cystine, and methionine), CoA and vitamins (biotin; thiamine), and glucosides in onions [44]	Interveinal chlorosis. S-deficiency chlorosis in all leaves at the same time; yellowish-green [49]
Boron	B	$H_2BO_3^-$	Involved in many processes: proteins synthesis, respiration, sugars transport metabolism of RNA, plant hormones, and carbohydrate [52]	Mainly appears on younger leaves; malformed and bluish-green; retaining flowers, forming of pollen [47]
Copper	Cu	Cu^{2+}	Essential respiration and photosynthesis of mitochondria; component of major enzymes Cu-Zn-SOD [52]	Necrosis, spots at tips of younger leaves, white tips, die back, and reclamation disease [49]
Chlorine	Cl	Cl^-	Essential for osmoregulation and photosynthesis; increases resistance	Leaf chlorosis, curling of leaves, plant wilting, and restricted

https://www.researchgate.net/figure/A-list-of-nutrient-biological-functions-in-plants-and-suggested-deficiency-symptoms_tbl1_361820052

Abiotic factors - nutrients

Deficiencies or excesses lead to certain symptoms, which are often visible from the outside. When plants turn pale, this is known as chlorosis. When parts of the plant die off, this is known as necrosis. Other symptoms can include wilting and discolouration. Here are a few examples:



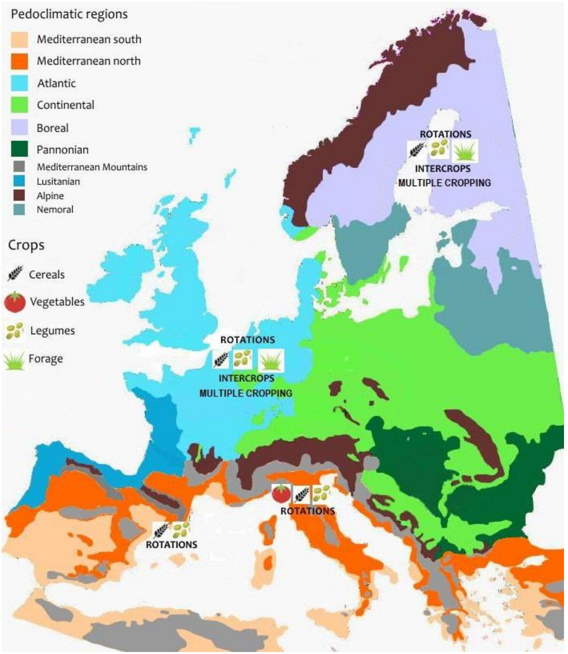
https://www.wellgrowseeds.com/blog/identifying-nutrient-deficiency-in-plants?srsltid=AfmBOoqr45bKTkYsb0xyDDmm1eUUPYepduwC65ui1quShUeQ7UaGR93R

Abiotic factors – soil and soil pH

The soil and its pH value also play an important role, as we saw in the previous chapter.

Abiotic factors - climate

Climate as a whole – encompassing temperature, precipitation and wind – also has a significant influence on plants. Differences in climate mean, for example, that pineapples and bananas cannot (as yet) grow in Europe. When climate and soil are combined, this gives rise to pedoclimatic regions. These are characterised by different types of agriculture. In some regions, several crops are grown in a single year, whilst in others, a single crop is grown over two years. The crops that are mainly grown also vary. Here is a possible representation of the pedoclimatic zones of Europe:



http://publications.europa.eu/resource/cellar/e1d06bc3-58c4-43a3-b2bc-6ad6d53d7953.0001.01/DOC_1

Biotic factors

Pests = organisms that cause economic damage, including animal pests, diseases and weeds.

Most pests (fungi, insects) find it much easier to thrive on plants that are stressed or poorly nourished. It is therefore extremely important how well plants are nourished and how they are affected by biotic factors.

As a general rule, plants belonging to the same family are often susceptible to the same pests. Therefore, a sufficient interval should be maintained between successive crops of the same type or from the same family.

Biotic factors – animal pests

Pests damage plants in a variety of ways. On the one hand, there is direct damage caused by feeding; on the other, there is indirect damage, such as the transmission of viruses.

Examples: aphids, pollen beetles, corn rootworms, nematodes, slugs

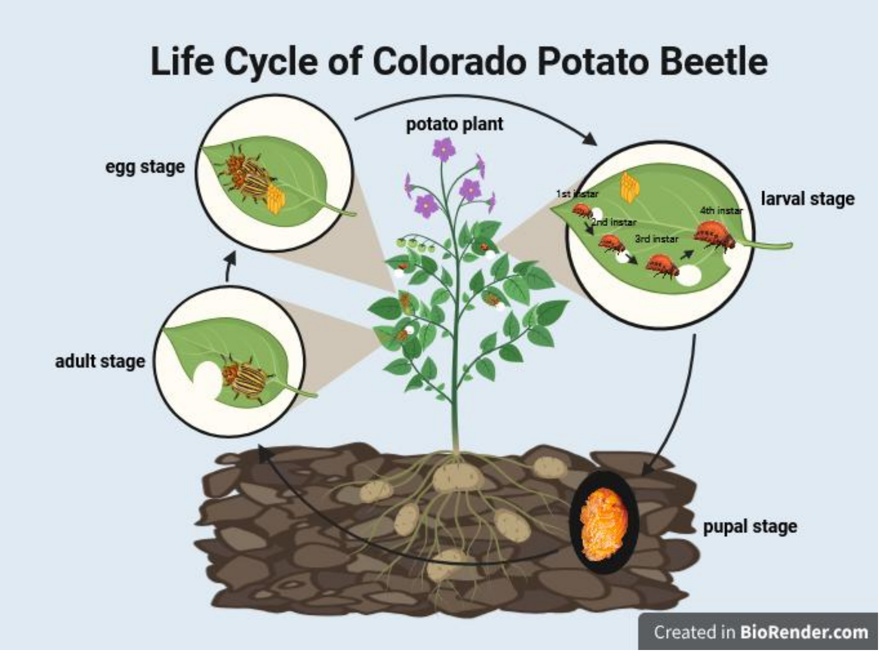
Two examples are provided to illustrate the different types.

Biotic factors – animal pests

Colorado potato beetle:

Both the adult beetle and the larvae damage the plant by feeding on its leaves, leaving it with no foliage left to carry out photosynthesis.

The Colorado potato beetle does not only attack potatoes but can also infest other nightshade plants (Solanaceae) such as tomatoes and tobacco.



Created in https://BioRender.com

https://www.oekolandbau.de

Biotic factors – diseases (pathogenic organisms)

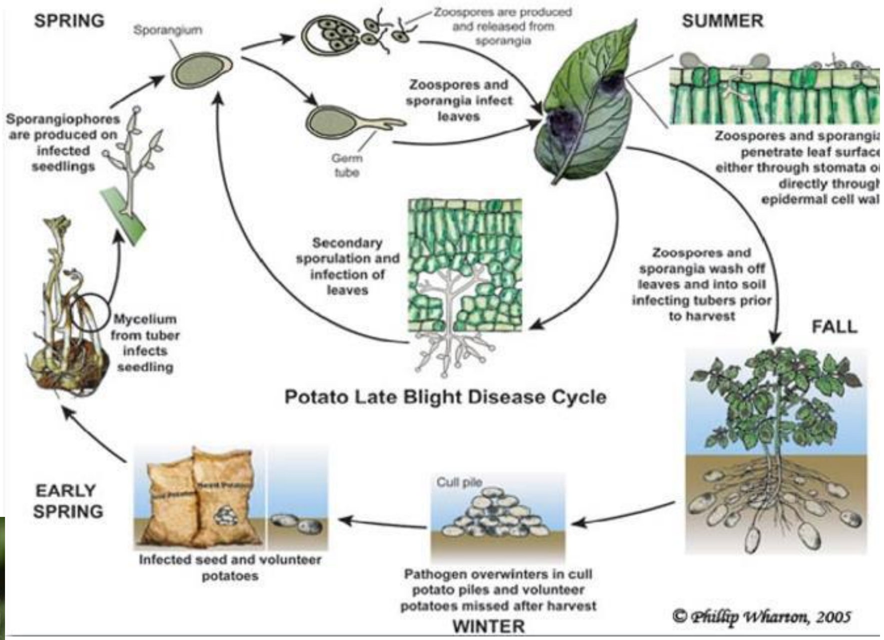
Diseases include fungi, bacteria and viruses.
Examples for bacterial diseases: blackleg, stem rot, bacterial wilt (Pectobacterium carotovorum ssp./Dickeya spp.)

https://www.lfl.bayern.de/ips/blattfruechte/107656/index.php

Biotic factors – diseases (pathogenic organisms)

Example for fungal disease: Phytophthora infestans

Phytophthora infestans, the pathogen responsible for late blight, overwinters mainly as mycelium in infected potato tubers (seed potatoes, waste). In spring, the fungus grows into the stems and, in damp conditions, produces spores (sporangia) which are carried by wind or rain onto leaves, where they germinate and trigger new infection cycles within a few days, leading to rapid spread.



https://www.researchgate.net/figure/The-life-cycle-of-the-late-blight-pathogen-Phythophtora-infestans-Source-18_fig1_353043085
https://www.researchgate.net/figure/The-life-cycle-of-the-late-blight-pathogen-Phythophtora-infestans-Source-18_fig1_353043085

Biotic factors - weeds

Weeds damage crops because they compete with them for light, water, nutrients and space. This can reduce yields or make harvesting more difficult.

Weeds have various reproduction strategies that make them highly resilient and can sometimes lead to very rapid spread. The Canada thistle and Broadleaf dock, for example, have very persistent roots, allowing them to sprout again. Nettles can spread quickly via runners, whilst other plants produce seeds that can sometimes travel very far and remain viable for a very long time. For example, Broadleaf dock seeds: remain viable for 40–70 years

https://agrar.bayer.de/Agrar%20Magazin/Das_Einmaleins_der_Unkrautbekaempfung_im_Mais

Biotic factors – Beneficial organisms and antagonists

- Ladybirds, parasitic wasps, predatory mites, soil fungi (e.g. Trichoderma
- Beneficial insects are often used in organic farming and can be released by hand (in greenhouses) or using drones (in maize fields).

The lacewing, a predatory natural enemy of the Colorado potato beetle: a lacewing egg (left), a larva feeding on Colorado potato beetle eggs (centre) and a Colorado potato beetle larva (right).

Outlook – Integrated Pest Management (IPM)

What is IPM?

Integrated Pest Management is a holistic approach that combines various measures to keep pests below the economic damage threshold – whilst minimising the use of chemical pesticides.

Definition: Damage threshold vs. control threshold

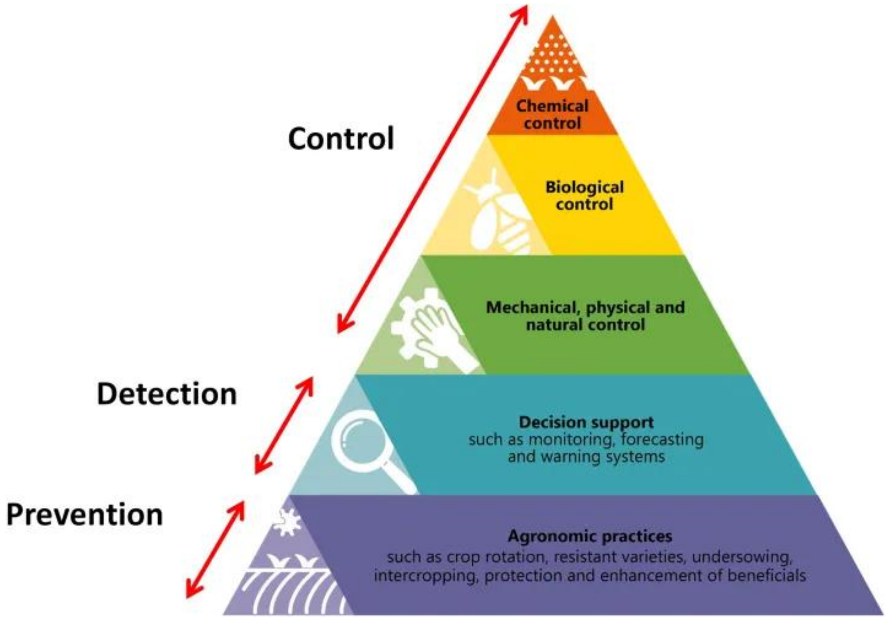
(Economic) damage threshold: The pest or disease population level at which the yield loss caused by them is equal to the cost of the control measure.

Control threshold: The population level at a given point in time at which direct control measures must be taken to ensure that the expected damage does not exceed the economic damage threshold.

Outlook – Integrated Pest Management (IPM)

The 8 principles of IPM (according to the FAO)

1. Prevention is better than control
2. Monitoring
3. Decision-making based on damage thresholds
4. Prioritising non-chemical methods
5. Selective and low-impact control measures
6. Reducing the frequency and amount of application
7. Resistance management
8. Evaluation of the measures



The IPM pyramid
https://www.frontiersin.org/journals/horticulture/articles/10.3389/fhort.2023.1159375/full

Thank you very much for your interest!

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