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A Review: Field Crop Physiology

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Abstract

Crop field physiology term is a crucial area of plant science which focuses on understanding and comprehending the biological and physical processes occurring within a community of crop plants in a field environment. It examines how individual plant physiological complex processes, for example photosynthesis, respiration, transpiration, nutrition as well as hormone regulation, interact and contribute to the overall growth, development, yield, and quality of the entire crop stand.

Here's a review of key aspects and recent trends in crop field physiology.

Keywords: *photosynthesis, carbon assimilation, chloroplasts, plant physiology*

1. Introduction

1.1. Fundamental Processes in Crop Physiology:

1.1.1. Photosynthesis and Carbon Assimilation: This remains the cornerstone of crop productivity. Research continues to focus on enhancing photosynthetic efficiency at the leaf and canopy levels (Dongliang, 2024**)**, understanding the impacts of environmental factors (light, CO2, temperature), and exploring genetic modifications to improve carbon fixation (Araus et al., 2021).

- These two interconnected processes are fundamental to life on Earth, forming the basis of most food webs and playing a crucial role in regulating the planet's atmosphere figure 1(Stasik et al., 2016).

Here's a breakdown of the key aspects:

Figure 1. *(Stasik et al., 2016)*

1.2. Photosynthesis: Capturing Light Energy

Definition: Photosynthesis is the process of using light energy to chemical energy as glucose (a sugar) by green plants, algae, and some types of bacteria. The process also releases oxygen as a byproduct (Alberts et al., 2002).

Location: In plants and algae, photosynthesis primarily occurs within special organelles known as chloroplasts that contain the pigment of chlorophyll. Chlorophyll works to absorb light energy, especially in the blue and red wavelengths of the visible spectrum (Riddhipratim and Gorachand, 2020).

Overall Equation:

$$6CO_2 + 6H_2O \xrightarrow{\text{light energy}} C_6H_{12}O_6 + 6O_2$$

1.3. Photosynthesis Stages

1.3.1. Light-Dependent Chemical Reactions (photo Reactions):

Occurred in the thylakoid membranes within the chloroplasts.

Plant absorbed Light energy via chlorophylls and other types of pigments, exciting electrons.

The plants required energy for:

- Decompose molecules of water by photolysis into electrons, protons (H+), and oxygen (O2). Oxygen evolved (Atale et al., 2023).
- Generate energy-carrying moieties: ATP (adenosine triphosphate) and NADPH (nicotinamide adenine dinucleotide phosphate). These moieties conservate for capturing light energy in chemical form (Rosa et al., 2023).

1.3.2. Light-Independent Chemical Reactions (Calvin Cycle or Dark Reactions)

Occurred in stroma, the fluid-filled space within chloroplasts (Li et al., 2023).

Do not directly require light reactions but rely on the ATP and NADPH phorto synthesized during light-dependent photo reactions (Feng et al., 2023).

Involved as a series of enzymatic reactions which use carbon dioxide (CO2) from atmosphere to build glucose and other organic molecules (Snehith and Dimple, 2022).

1.3.3. Carbon Assimilation: Incorporating Carbon into Organic Molecules

Definition: Carbon assimilation is the process. Through it the inorganic carbon molecules (primarily CO_2 gas) are directly turned into organic compounds by reactions in living organisms. Photosynthesis is the primary mechanism of carbon assimilation in most ecosystems.

The Calvin Cycle (C3 Pathway): This is the most common pathway for carbon assimilation in plants. It involves three main stages:

Carbon Fixation: Carbon dioxide obtained from atmosphere enters the stroma and combined with a five-carbon moiety known as **ribulose-1,5-bisphosphate (RuBP)** which catalyzed by the enzyme RuBisCO (ribulose-1,5-bisphosphate carboxylase/oxygenase). This had resulted of an unstable six-carbon moiety that decomposes into two molecules of a three-carbon compound known as 3-phosphoglycerate (3-PGA) figure .2 (Lopez and Barclay, 2017).

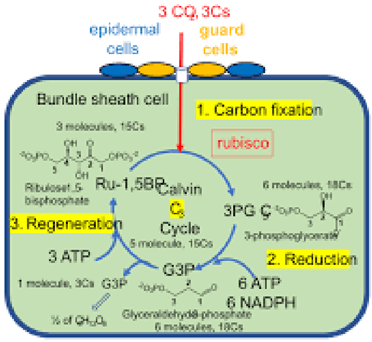

Figure 2. *(Lopez and Barclay, 2017).*

Reduction: ATP and NADPH generated in light-dependent chemical reactions) and used in the conversion of 3-PGA to another three-carbon moiety called glyceraldehyde-3-phosphate (G3P). Some G3P moieties exit the cycle and are used in the synthesis of glucose and other organic molecules (Mohammad, 2021).

Regeneration: The remaining G3P molecules are used in a series of reactions that regenerate the initial RuBP molecule, allowing the cycle to continue (Dennis, 2021).

1.4. Alternative Carbon Fixation Pathways

While the C3 pathway is prevalent, some plants have evolved alternative mechanisms to overcome limitations, particularly in hot and dry environments:

C4 Pathway:

- Found in plants adapted to hot, sunny climates (e.g., corn, sugarcane).
- Involves an initial fixation of CO2 in mesophyll cells into a four-carbon moiety (oxaloacetate) using the enzyme PEP carboxylase (which possesses a higher affinity for CO_2 gas than RuBisCO) (Dusenge et al., 2019).
- This four-carbon moiety is then moved to cell membrane, it decarboxylated, evolving CO_2 gas that in turn enters the Calvin cycle (Peguero-Pina et al., 2020).
- The separation of initial CO_2 gas fixation and the Calvin cycle helps to increase CO_2 around RuBisCO in the cell membrane, minimizing photorespiration figure .3 (Lopez and Barclay, 2017).

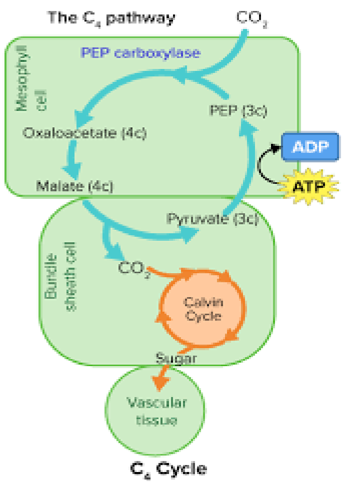

Figure3. *(Smith and winter, 2018).*

1.5. CAM (Crassulacean Acid Metabolism) Pathway

- Found in succulent plants adapted to very arid conditions (e.g., cacti, pineapple) (Smith and Winter, 2018).
- Involves a temporal separation of CO2 fixation and the Calvin cycle (Yiotis and Digalakis, 2022).
- At night, stomata open, and CO2 is fixed into a four-carbon acid (malate) and stored in vacuoles (Pessarakli, 2021).
- During the day, stomata close to conserve water, and the stored malate is decarboxylated, releasing CO2 that then enters the Calvin cycle (Heyduk et al., 2016).

1.6. Importance of Photosynthesis and Carbon Assimilation

- **Primary Production:** Photosynthesis is the foundation of most food webs, converting light energy to the chemical energy that conservate almost all life on Earth (Blankenship, 2021).
- **Oxygen Production:** The oxygen released during light-dependent reactions is essential for the respiration of most aerobic organisms, including animals and plants (Ort and энергии,2019).
- **Carbon Cycle:** Photosynthesis plays an important crucial role in the global cycle of carbon by

eliminating CO_2 gas from the atmosphere and serves it into the synthesis of organic molecules. This assists in the Earth's climate regulation (Beerling et al., 2018).

- **Fuel and Materials:** The organic moieties synthesized through photosynthesis reactions work as a source of food, fuel (e.g., wood, fossil fuels), and raw materials for various industries (Hopkins and Hüner, 2019).
- **Water Relations and Transpiration:** With increasing water scarcity, understanding and improving water use efficiency (WUE) is critical. Studies focus on stomatal regulation, root water uptake, transpiration rates, and developing drought-tolerant varieties through physiological and genetic approaches. Precision irrigation techniques are also closely linked to optimizing water relations (Lawson et al., 2018).
- Let's delve into the crucial processes of Water Relations and Transpiration in plants. These are fundamental for plant survival, growth, and overall ecosystem function, especially in a location like Baghdad where water availability can be a significant factor (Yiotis and Digalakis, 2022).

1.7. Water Relations: The Movement and Status of Water in Plants

Water relations encompass how plants absorb, transport, and utilize water within their bodies. It's governed by physical principles, primarily water potential (Pessarakli, 2021).

- **Potential of Water (Ψ):** Is a measure of water free energy per unit of volume relative to pure water at standard conditions (Nobel, 2017). Mostly water moving from higher water potential area to lower water potential area (Hopkins and Hüner, 2019). Water potential is affected by some factors.
- **Potential of Solute (Ψs) (Osmotic Potential):** The lowering in water potential because of the presence of dissolved solutes. Normally solutes work to bind water molecules, minimizing the number of free water molecules and thus reducing the potential of water (always negative or zero) (Pessarakli, 2021).
- **Pressure Potential (Ψp) (Turgor Pressure):** The physical pressure applied on water from cell wall. In turgid cells, Ψp is positive. In wilting cells, it can be zero or even negative (tension) (Zwieniecki and Holbrook, 2010).
- **Matric Potential (Ψm):** The reduction in water potential due to the water molecules adhered to solid surfaces (e.g., particles of soil, wall of the cell). Usually negative (Pessarakli, 2021).
- **Gravitational Potential (Ψg):** The gravity does effect upon potential of water. Significant for tall trees (Taiz and Zeiger, 2010). The total potential of water in a plant cell or tissue represents the summation of these components:
- $\Psi = \Psi s + \Psi p + \Psi m + \Psi g$
- **Water Absorption:** Plants absorb water primarily through their root hairs, which greatly increases the surface area for absorption. Water flows from the soil (higher water potential) to the root cells (lower water potential) via osmosis (Frensch and Steudle, 2019).

1.8. Pathways of Water Movement in the Root

- **Apoplast Pathway:** Water transported in the walls of cell and intercellular spaces without crossing any cell membranes. This pathway is blocked by the Casparian strip, a band of suberin (a waterproof substance) in the endodermis.
- **Symplast Pathway:** Water moves from cell to another through the cytoplasm via **plasmodesmata** (small channels connecting adjacent plant cells) (Frensch and Steudle, 2019).
- **Transmembrane Pathway:** Water moves across cell membranes from one cell to the next.
- Once water reaches the xylem vessels in the vascular cylinder of the root, it enters the transpiration stream (Frensch and Steudle, 2019).
- **Water Transport in the Xylem:** Water and dissolved ionic minerals are transported from the roots plant to the shoots in the xylem, a specialized vascular tissue composed of dead hollow cells (tracheids and vessel elements) (Brodribb and Cochard, 2017). The primary driving force for this movement with a theory known as transpiration-cohesion-tension:
- **Transpiration:** The evaporation of water from plant leaves creates a negative water potential

(tension) in the mesophyll plant's cells.

- **Cohesion:** Water molecules are cohesive due to physical force known as hydrogen bonds, leading to the forming of continuous column of water throughout the xylem (Hacke et al., 2015).
- **Tension:** The pressure generated by transpiration pulls the cohesive column of water upwards from the plant's roots.
- **Adhesion:** Water molecules also work to adhere to the walls of the xylem vessels, helping to counteract gravity.
- **Water Movement into Cells:** After water reaches the leaves, water moves out of the xylem and into the surrounding cells (mesophyll) based on water potential gradients. Turgor pressure presents within these cells is necessary for maintaining plant rigidity and driving cell expansion for growth (Taiz and Zeiger, 2010).

2. Transpiration: The Loss Of Water Vapor From Plant's Tissue

- **Definition:** The process of losing water from plants as water vapor, essentially through small pores on the leaf surface called stomata (Lawson et al., 2018).
- **Mechanism:** Water can evaporate from moisturized cell walls of mesophyll cells into the air spaces within the leaf (Pearcy et al.,2012). At the water vapor concentration in the air spaces is higher than in the surrounding atmosphere (which is usually the case), water vapor diffuses out through the stomata.

2.1. Factors Affecting Transpiration Rate

- **Light:** Light stimulates stomatal opening in most plants, leading to increase transpiration (Buckley, 2019).
- **Temperature:** At high temperatures this maybe increase the rate of evaporation and diffusion, thus increasing transpiration (Wang et al., 2017).
- **Humidity:** At lower humidity, dry air can create a steeper vapor concentration of water gradient from the leaf and the atmosphere, increasing transpiration (Dusenge et al., 2019).
- **Wind:** Wind works to remove humid air from the surface of leaf, maintaining a steeper concentration gradient and increasing transpiration.
- Availability of Soil Water: at dry dry soil, the plant cannot replace the water lost through transpiration, leading to stomatal closure and reduced transpiration (Lal, 2018).
- Stomatal Opening and Closure: The size of the stomatal opening is actively regulated by guard plant's cells in response to various environmental and internal signals (e.g., light, CO2 concentration, stress of water) (Lawson et al., 2018).

2.2. Transpiration Functions

- **Transport of Water:** Transpiration of water can create the tension that pulls water up the xylem (Inoue et al., 2019).
- **Nutrient Transportation:** The flow of water through the xylem also carries dissolved minerals from the roots to the shoots (Buckley et al., 2019).
- **Cooling:** The evaporation of water molecules from the leaves has a cooling effect on plants, like sweating in animals. This is somewhat important in hot environments like Baghdad (Fahad et al., 2017).
- **Turgor Pressure:** The flow of water driven by transpiration can assist in the maintaining of turgor pressure, this is important and necessary for cell expansion, maintaining of plant structure, and preventing wilting.
- **Nutrient Uptake and Utilization:** Research in Baghdad aims to optimize nutrient acquisition from the soil, transport within the plant, and sufficient utilization for growth and development. This involves studying root architecture, nutrient transporters, and the effect of fertilization strategies on plant physiology and environmental sustainability.
- **Essential Plant Nutrients:** Plants require a variety of elements to grow healthy which are classified based on the quantities needed:

- **Macronutrients:** Required for large quantities. These involve:
- **Carbon (C), Hydrogen (H), Oxygen (O):** Obtained primarily from air (CO_2) and water (H_2O) through photosynthesis (Baday et al., 2025).
- **Nitrogen (N):** critical for proteins, nucleic acids, chlorophyll, and enzymes figure .4 (Zayed et al., 2023).

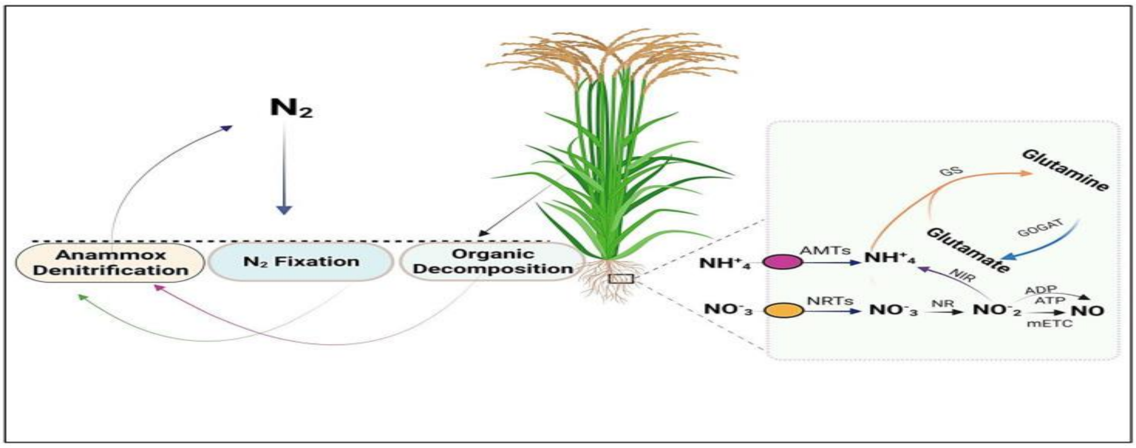

Figure 4. *(Zayed et al., 2023)*

Phosphorus (P): Important for nucleic acids, ATP (energy currency), phospholipids, and root development (Wang et al., 2024).

Potassium (K): Involved in enzyme activation, water balance, stomatal regulation, and disease resistance (Iftikhar et al., 2024).

Calcium (Ca): Essential and important for structure of cell wall, division of cell, and signal transduction (Anas et al.,2020).

Magnesium (Mg): A component of chlorophyll and an activator of many enzymes (Wang and Wu, 2017).

Sulfur (S): Found in some amino acids and proteins (Taiz et al., 2018).

Micronutrients (Trace Elements): Required in very small quantities. These involve:

Iron ion (Fe): Involved in chlorophyll synthesis and electron transport.

Manganese (Mn): Activator of several enzymes involved in photosynthesis and respiration.

Boron (B): Important and essential for the synthesis of cell wall, transporting of sugar, and development of pollen.

Zinc (Zn): Involved in enzyme activation and hormone metabolism.

Copper (Cu): A component of some enzymes involved in redox reactions.

Molybdenum (Mo): Essential and basic for nitrogen metabolism (reduction of nitrate).

Chlorine (Cl): Involved in water splitting during photosynthesis and ion balance.

Nickel (Ni): Involved in nitrogen metabolism (urease enzyme) (Alan et al., 2024).

2.3. Nutrient Uptake from the Soil

Plants absorb mineral nutrients primarily from the soil solution through their roots, especially the root hairs. The uptake process involves several mechanisms:

Passive Transport: Movement of ions across cell membranes down their electrochemical gradient (concentration gradient and electrical potential). This does not require direct energy expenditure by the plant. Examples include the movement of some ions through ion channels (Morgan and Connolly, 2013).

Facilitated Diffusion: Passive transport aided by membrane proteins (channel proteins or carrier proteins) that bind to specific ions and facilitate their movement across the membrane (Carlos et al., 2025).

Active Transport: Movement of ions through cell's membrane against their electrochemical tendency. This requires energy costs by the plant, mostly in the form of ATP. Active transport is critical for accumulating nutrients materials that are present in low percentages in the soil solution or for maintaining specific ion gradients across membranes. This often involves proton pumps (H+-ATPases) that make an electrochemical gradient that drives the uptake of other ions via supporters (moving ions in the same direction as H+) or antiporters (moving ions in the opposite direction to H+) figure .5 (Lowell et al., 2025).

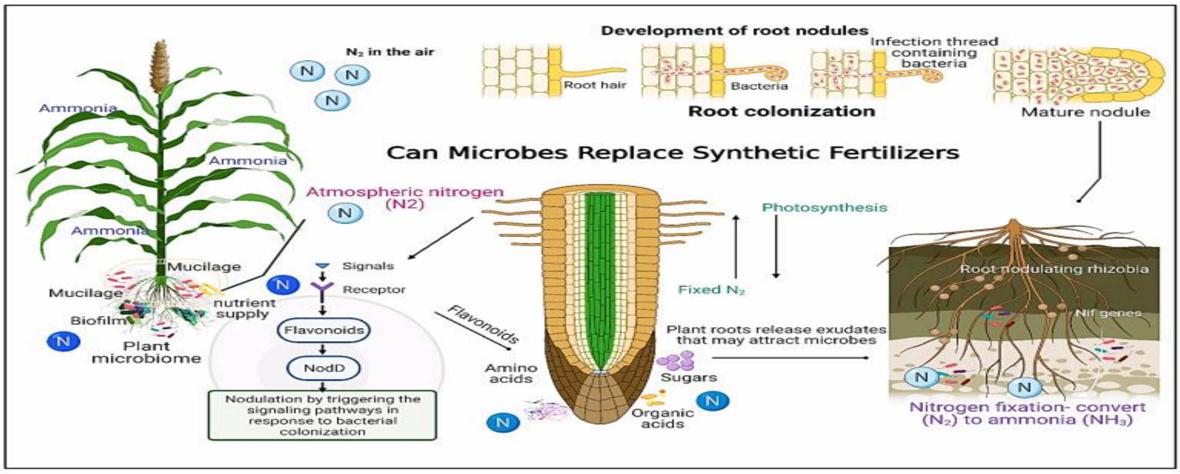

Figure5. *(Lowell et al., 2025)*

2.4. Factors Affecting Nutrient Uptake

- **Nutrient Availability in the Soil:** The concentration of nutrients in the soil solution is a primary factor. Soil composition, organic matter content, pH, and the presence of other ions can influence nutrient availability (Akira et al., 2025).
- **Root Growth and Morphology:** A well-developed root system with extensive branching and root hairs provides a larger surface area for nutrient absorption (Wei et al., 2025).
- **Soil pH:** Soil pH significantly affects the solubility and availability of many nutrients. For example, iron and manganese are more soluble under acidic conditions, while phosphorus availability is optimal around neutral pH. Baghdad's soil can be alkaline, which can impact the availability of certain micronutrients (Yuhei et al., 2025).
- **Soil Aeration:** Adequate oxygen levels in the soil are necessary for active transport processes, which require energy generated through respiration. Waterlogged or compacted soil can limit oxygen availability (Javier rt al., 2025).
- **Soil Temperature:** Temperature affects the rate of metabolic processes in roots, including nutrient uptake (Azizullah et al., 2024).
- **Mycorrhizae:** These are symbiotic associations between plant roots and fungi. The fungal hyphae extend far beyond the root system, increasing the surface area for water and nutrient absorption, particularly phosphorus and some micronutrients (Frederico et al., 2024).
- **Nutrient Interactions:** The presence of one nutrient can affect the uptake of another. For example, high levels of potassium can sometimes interfere with magnesium uptake (Evandro et al., 2024).

2.5. Nutrient Transport within the Plant

Once absorbed by the root cells, nutrients are transported throughout the plant via the vascular tissues:

- **Xylem:** Primarily responsible for the upward transport of water and dissolved mineral nutrients from the roots to the shoots (leaves, stems, flowers, fruits). The movement in the xylem is driven by the transpiration stream (Xu et al., 2024).
- **Phloem:** Responsible for the transport of sugars (produced during photosynthesis) and other organic molecules (including some nutrients) throughout the plant, from source tissues (e.g., leaves)

to sink tissues (e.g., roots, developing fruits, growing shoots) (Emmanuely et al., 2024). Phloem transport is an active process driven by pressure flow.

2.6. Nutrient Utilization within the Plant

Once transported to different parts of the plant, nutrients are utilized in various metabolic processes and structural components:

- **Nitrogen:** Incorporated into amino acids, which are the building blocks of proteins (enzymes, structural proteins). Also, a component of nucleic acids (DNA, RNA) and chlorophyll (Igor et al., 2024).
- **Phosphorus:** Part of nucleic acids (DNA, RNA), ATP (the energy currency of the cell), phospholipids (cell membranes), and various coenzymes. Essential for energy transfer and storage (Akira et al., 2024).
- **Potassium:** Acts as a cofactor for many enzymes involved in protein synthesis, photosynthesis, and respiration. Plays a crucial role in maintaining cell turgor by influencing ion balance and water movement. Involved in stomatal opening and closing (Pooja et al., 2024)
- **Calcium:** Essential for cell wall structure (calcium pectate), involved in cell division and elongation, acts as a second messenger in signal transduction pathways, and influences the activity of certain enzymes (Brent et al., 2024).
- **Magnesium:** The central atom in the chlorophyll molecule, essential for light absorption during photosynthesis. Also activates many enzymes involved in carbohydrate metabolism and nucleic acid synthesis (Julian et al., 2024).
- **Sulfur:** A component of some amino acids (cysteine, methionine) and therefore essential for protein structure and function. Also found in some vitamins and coenzymes (Nicodème et al., 2024).
- **Micronutrients:** While needed in small amounts, each micronutrient plays a specific and vital role in various enzymatic reactions, cofactor functions, and other metabolic pathways. Their deficiency can lead to specific and often severe symptoms (Javier et al., 2024).

2.7. Nutrient Management in Baghdad's Environment

Considering the potential environmental conditions in Baghdad:

- **Alkaline Soils:** If the soils are alkaline, the availability of certain micronutrients (e.g., iron, manganese, zinc) and even phosphorus can be limited. Soil testing and appropriate amendments (e.g., sulfur, organic matter) might be necessary (Xiao et al., 2024).
- **High Temperatures and Evaporation:** These conditions can lead to salt buildup in the soil if irrigation water contains high levels of dissolved salts. This salinity can interfere with nutrient uptake and water absorption. Proper irrigation management and leaching of salts may be required (Camila et al., 2024).
- **Water Scarcity:** Efficient use of fertilizers is crucial to maximizing nutrient uptake and plant growth with limited water resources. Techniques like drip irrigation can deliver water and nutrients directly to the root zone (Felipe et al., 2024).
- **Organic Matter:** Maintaining or increasing soil organic matter content is beneficial as it improves soil structure, water retention, and nutrient availability (through decomposition)
- Understanding the principles of nutrient uptake and utilization is essential for successful agriculture and maintaining healthy vegetation in Baghdad. Addressing potential soil issues and optimizing nutrient management practices will contribute significantly to plant productivity and resilience in this environment (Subhadip et al., 2024).
- **Source-Sink Relationships:** Understanding how photosynthates (sugars) are produced in source tissues (leaves) and transported to sink tissues (developing grains, fruits, roots) is vital for maximizing yield. Research explores the physiological and molecular mechanisms regulating these

processes and how they are affected by environmental conditions and management practices in plants, a fundamental concept for understanding how photosynthetic products (sugars) is transported and allocated to different parts of the plant. This is particularly relevant in Baghdad, where environmental conditions and agricultural practices can influence these relationships and ultimately impact plant growth and yield figure .6 (Marcos et al., 2024).

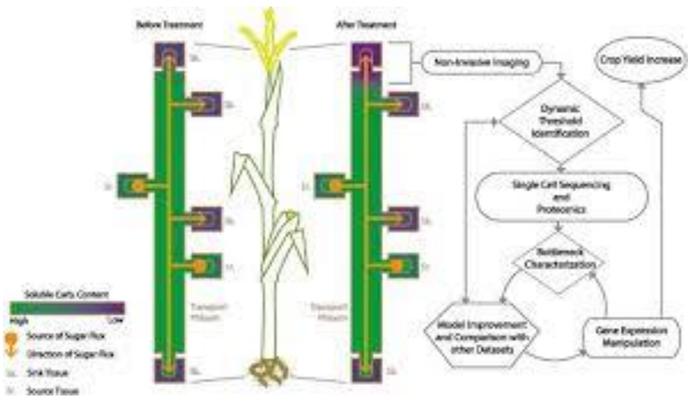

Figure 6. *(Marcos et al., 2024)*

2.8. Defining Sources and Sinks:

- **Source:** A plant organ that produces more sugars (primarily sucrose) than it consumes. Mature, photosynthetically active leaves are the primary sources in most plants. Other sources can include storage organs (like tubers or bulbs) during periods of growth or remobilization of reserves (Jeonggu et al., 2024).
- **Sink:** A plant organ that consumes more sugars than it produces or stores sugars. Examples of sinks include:
- **Growing tissues:** Developing leaves, shoot tips, root tips, young fruits, and seeds. These require sugars for cell division, cell expansion, and the synthesis of new tissues.
- **Storage organs:** Roots, tubers, bulbs, and developing fruit/seeds accumulate sugars for later use.
- **Metabolically active tissues:** Respiring cells throughout the plant that need sugars for energy (Chloe et al., 2024).
- **Phloem Transport: The Highway for Sugar Movement:**
- The movement of sugars from source to sink tissues occurs through the phloem, a specialized vascular tissue composed of living cells called sieve tube elements connected by sieve plates. The driving force for phloem transport is the pressure flow hypothesis (also known as the mass flow hypothesis):

2.9. Loading at the Source

- In source leaves, sugars (mainly sucrose) produced during photosynthesis are actively transported into the companion cells and then into the seven-tube elements of the phloem (Yiotis and Digalakis, 2022).
- This active loading of sugar increases the solute concentration within the sieve tube elements at the source.
- According to water potential principles, water from the adjacent xylem moves into the sieve tube elements by osmosis, increasing the turgor pressure (hydrostatic pressure) at the source end (Alogaidi et al., 2019).

2.10. Translocation (Movement in the Phloem)

The high turgor pressure at the source end and the lower turgor pressure at the sink end create a pressure gradient along the phloem.

This pressure gradient drives the bulk flow of the sugar-rich phloem sap from the source towards the sink.

2.11. Unloading at the Sink

At the sink tissues, sugars are actively or passively unloaded from the sieve tube elements into the surrounding cells.

The removal of sugars decreases the solute concentration within the sieve tube elements at the sink.

Water then moves out of the sieve tube elements by osmosis back into the xylem, decreasing the turgor pressure at the sink end (Cankui and Robert, 2018).

3. Factors Influencing Source-Sink Relationships

Several factors can influence the strength and direction of source-sink relationships:

- **Proximity:** Sinks that are closer to a source may receive a greater supply of sugars. For example, upper leaves might primarily supply developing fruits near them.
- **Developmental Stage:** The strength of a sink changes throughout the plant's life cycle. During vegetative growth, shoot and root tips are strong sinks. Through reproductive development, flowers, fruits, and seeds become predominant sinks.
- **Vascular Connections:** The pattern of connections of vascular between sinks and sources can affect the sugar transport direction.
- **Sink Strength:** The demand and metabolic activity in a sink tissue for sugars determine its sink strength. Speedily growing tissues or storage organs that have high sink strength.
- **Source Strength:** The photosynthesis rate in a source leaf which serves in the determining of its source strength. Factors such as light intensity, concentration of CO_2, and age of leaf affect source strength.
- **Environmental Conditions:** conditions of Stress (e.g., drought, heat, lack of nutrient) could affect the relation of source-sink because of affecting photosynthesis, growth rates, and the allocation of resources. For example, under drought stress, plants could prioritize resource allocation to roots for uptake of water.
- **Hormonal Signals:** Hormones of plant can play a role in the regulation of source-sink relationships through the activating influencing sink and phloem loading/unloading (Smith et al., 2018).

4. Implications for Plant Growth and Yield in Baghdad

Source-sink relationships understanding is important particularly in the context of Baghdad's agricultural practices and environment:

- **Sunlight and High Temperatures:** While the abundance of sunlight will enhance photosynthesis (source strength), high temperatures may increase rates of respiration (sink demand) and lead to higher water stress, affecting both sink activities and source.
- **Water Availability:** Water stress can reduce rates of photosynthetic (source strength) and growth inhibition in sink tissues. Best irrigation practices are crucial to maintain balanced source-sink relationships.
- **Nutrient Availability:** Adequate nutrient supply is important and essential for sources (production of chlorophyll for photosynthesis) and sink (storage and growth) activities. Nutrient deficiencies can collapse both sinks and sources.
- **Crop Management:** Agricultural practices like pruning, thinning fruits, and optimizing planting density can manipulate source-sink relationships to enhance the yield of desired plant parts (e.g., larger fruits, more grains).
- **Salinity:** If irrigation water or soil conditions lead to salinity in Baghdad, this can negatively impact both photosynthesis and nutrient uptake, disrupting source-sink balance and reducing overall plant productivity. Salt-tolerant varieties and soil management strategies are important (Yiotis and Digalakis, 2022).
- **Seasonal Changes:** In Baghdad, the distinct seasons will influence source-sink dynamics. During cooler months, storage organs might become sources for new growth.

4.1. Examples of Source-Sink Dynamics

- **Early Vegetative Growth:** Young leaves are sinks, relying on sugars transported from older, mature leaves (sources). As the young leaves mature and become photosynthetically active, they transition into sources.
- **Flowering and Fruiting:** Developing flowers and fruits become strong sinks, drawing sugars from the leaves. For numerous cases, vegetative growth may be lowered down as resources are directed towards reproduction (Hassan et al., 2019).
- **Development of Storage Organ:** During the tubers' development (potatoes), bulbs (onions), or puffy fruits, these organs can act as essential sinks, leading sugars produced to accumulate in the leaves.
- In conclusion, relationships of source-sink are dynamic processes that rule the photosynthetic products allocation within a plant. These relationships can be understood with the factors that influence them. They are critical for plant growth optimizing, development, and yield percentage, especially in the context of Baghdad's specific environmental vigorous challenges and high agricultural needs (Abed et al., 2017). By management of water, nutrients, and important cultural practices, maybe it's possible to influence dynamics of source-sink to obtain desired goals in plant productivity (Wogene et al., 2024).
- **Plant Growth Regulators (Hormones):** These compounds play critical and important roles in the regulation of various aspects of plant growth and development, including germination, flowering, fruiting, and stress responses. Physiology of crops studied to investigate the synthesis, transport, and action of these hormones in the context of field conditions and agricultural practices (Nasrallah et al., 2015).

The plant growth regulators (Hormones) also can be defined as phytohormones. These chemical messengers regulate different aspects of plant growth, development, and responses to environmental stimulus. Their roles are critical in the plant context life in Baghdad and agricultural practices their figure .7 (Baday, 2018).

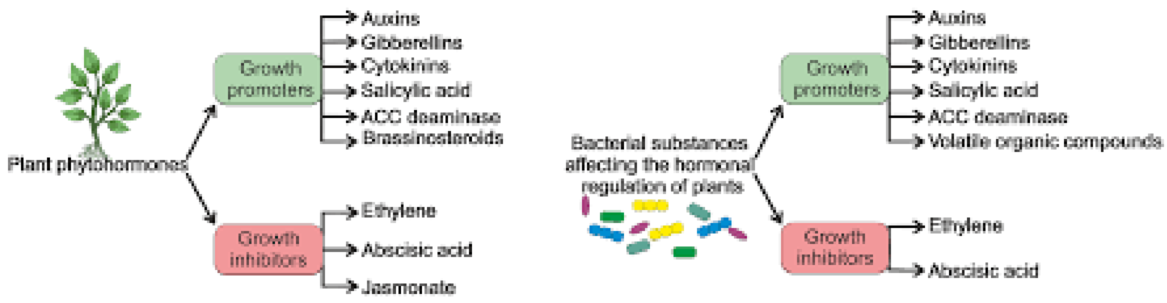

Figure7. *(Baday, 2018)*

5. DEFINITION AND GENERAL CHARACTERISTICS

- **Definition:** Plant hormones are naturally occurring organic compounds that are synthesized in one part of the plant and transported to other parts, where they elicit specific physiological responses at very low concentrations (Lama and Neamah, 2023**)**.
- **Key Characteristics:**
- **Low Concentration:** Effective at very low concentrations (micromolar to nanomolar range).
- **Site of Synthesis vs. Action:** Often synthesized in one tissue and act in another.
- **Multiple Effects:** A single hormone can have different effects depending on the concentration, the target tissue, and the developmental stage of the plant (Hamza and Ali, 2017).
- **Interactions:** Hormones often interact with each other, and the overall response is often a result of the balance or ratio of different hormones.
- **Signal Transduction:** Hormones bind to specific receptors, triggering signal transduction pathways that lead to changes in gene expression and cellular activities (Khierallah, and Jawad, 2017).

5.1. Major Classes of Plant Hormones

Here are the five classical plant hormones and some of the more recently recognized ones:

Auxins:

- **Primary Natural Auxin:** Indole-3-acetic acid (IAA).
- **Sites of Synthesis:** Apical meristems of shoots and young leaves.
- **Major Functions:**
- **Cell Elongation:** Promotes the elongation of cells in shoots and coleoptiles.
- **Apical Dominance:** Inhibits the growth of lateral buds, maintaining the dominance of the apical bud (Al-Jubori et al., 2023).
- **Root Initiation:** Promotes the formation of adventitious roots and lateral roots at low concentrations.
- **Tropic Responses:** Involved in phototropism (growth towards light) and gravitropism (growth in response to gravity).
- **Fruit Development:** Stimulates fruit development and can prevent premature fruit drop (**Baday, 2020)**.
- **Vascular Differentiation:** Influences the differentiation of xylem and phloem.
- **Relevance to Baghdad:** Auxins are crucial for overall plant growth and development, including root establishment in potentially challenging soils (Al-Jubori and Al-Amery, 2022**)**.

Gibberellins (GAs):

- **Primary Natural Gibberellic Acid:** GA3 is the most well-studied.
- **Sites of Synthesis:** Apical meristems of shoots and roots, young leaves, and developing seeds.
- **Major Functions:**
- **Stem Elongation:** Promote internode elongation, leading to taller plants.
- **Seed Germination:** Break seed dormancy and promote germination by inducing the synthesis of hydrolytic enzymes (Al-Jubori et al., 2025).
- **Flowering:** In some plants, stimulate bolting (rapid stem elongation before flowering) and flowering.
- **Fruit Development:** Can increase fruit size and promote parthenocarpy (fruit development without fertilization).
- **Relevance to Baghdad:** Gibberellins can be important for overcoming seed dormancy in local plant species and potentially enhancing stem growth in certain crops (Al-Rubaie and Al-Jubouri., 2023).

Cytokinins:

- **Common Natural Cytokinins:** Zeatin, isopentenyladenine (iP).
- **Sites of Synthesis:** Primarily in root tips, but also in young fruits and seeds.
- **Major Functions:**
- **Cell Division (Cytokinesis):** Promote cell division in shoots and roots.
- **Lateral Bud Growth:** Counteract apical dominance and promote the growth of lateral buds, leading to bushier plants.
- **Leaf Senescence:** Delay the aging (senescence) of leaves by maintaining chlorophyll and protein content (Toma, 2022).
- **Nutrient Mobilization:** Can direct nutrient movement towards cytokinin-rich areas.
- **Relevance to Baghdad:** Cytokinins can play a role in branching patterns, potentially beneficial in stress conditions, and in maintaining leaf longevity during hot periods.

Abscisic Acid (ABA):

- **Site of Synthesis:** Mature leaves, roots, and developing seeds in response to stress.

- **Major Functions:**
- **Stress Response:** Involved in responses to drought, salinity, and cold stress. Promotes stomatal closure to reduce water loss.
- **Seed Dormancy:** Maintains seed dormancy and inhibits premature germination.
- **Inhibition of Growth:** Generally, it inhibits shoot growth but can promote root growth under water stress.
- **Embryo Development:** Plays a role in embryo maturation and desiccation tolerance.
- **Relevance to Baghdad:** ABA is likely very important for plants in Baghdad to cope with high temperatures, potential water scarcity, and soil salinity. Its role in stomatal regulation is critical for water conservation (Baday, 2024).

Ethylene (C2H4):

- **Site of Synthesis:** Produced in virtually all parts of the plant, especially during stress, senescence, and fruit ripening.
- **Major Functions:**
- **Fruit Ripening:** Triggers the ripening process in many fruits.
- **Senescence and Abscission:** Promotes the aging of leaves and flowers and the shedding (abscission) of leaves, fruits, and flowers.
- **Stress Response:** Involved in responses to flooding, wounding, and pathogen attack.
- **Root and Shoot Growth:** Can inhibit shoot elongation and promote lateral expansion and can promote adventitious root formation under anaerobic conditions (Hassan et al., 2018).
- **Relevance to Baghdad:** Ethylene plays a role in fruit production and the plant's response to various stresses that might be prevalent in the Baghdad environment (Alshugeairy et al., 2023).

5.2. Other Important Plant Hormones/Regulators

- **Brassinosteroids (BRs):** Involved in cell elongation and division, vascular differentiation, stress tolerance, and pollen tube growth.
- **Jasmonates (JAs):** Play a key role in plant defense against herbivores and pathogens, as well as in responses to wounding and abiotic stress.
- **Salicylic Acid (SA):** Primarily involved in plant defense against pathogens (systemic acquired resistance) and plays a role in responses to abiotic stress.
- **Strigolactones (SLs):** Inhibit shoot branching (like auxins) but also play a crucial role in symbiotic interactions with mycorrhizal fungi and in the perception of phosphate deficiency.
- **Peptide Hormones:** A diverse group of small signaling peptides involved in various developmental processes and stress responses.

5.3. Hormonal Interactions and Balance

It's crucial to understand that plant responses are rarely controlled by a single hormone. Instead, they are often the result of complex interactions and the balance between different hormones. For example:

- **Auxin and Cytokinin:** The ratio of auxin to cytokinin plays a key role in controlling apical dominance and lateral bud development, as well as root and shoot meristem maintenance (Odhaib and Hassan, 2024).
- **Gibberellins and ABA:** These hormones often have opposing effects on seed germination and dormancy.

5.4. Relevance to Plant Life in Baghdad

- **Stress Tolerance:** Hormones such as ABA, jasmonates, and salicylic acid are important for native and cultivated plants in Baghdad to survive, helping these plants cope with heat, drought, and potential salinity.
- **Efficiency of Water Use:** The role of ABA's in stomatal closing directly impacts conservation of water, a vital adaptation in a highly dry climate (Hadi et al., 2019).
- **Growth and Development:** Auxins, gibberellins, and cytokinins regulate the fundamental

processes such as development of roots, elongation of shoots, and branching, that are essential for plant development and productivity

- **Flowering and Fruiting:** The balance of hormones influences the timing and success of reproduction, development, critical for crop yields production.

5.5. Applications in Agriculture in Baghdad

- **Synthetic Plant Growth Regulators:** Farmers maybe seriously use synthetic auxins, gibberellins, or cytokinins to stimulate rooting of cuttings, increase the size of fruit, induce flowering, or exceed dormancy in some crops. but they should be used carefully in the local context.
- **Stress Management:** Hormones' role understanding in stress responses can inform breeding programs aimed at developing more stress-tolerant crop varieties suitable for Baghdad's conditions.
- **Optimizing Yield:** Manipulating hormonal balance through appropriate agricultural practices (e.g., pruning, irrigation) can help maximize the yield of desired plant parts.
- **Reproductive Physiology:** This area focuses on the physiological processes involved in flowering, pollination, fertilization, and seed/fruit development. Understanding these processes is essential for improving reproductive success and ultimately, crop yield (Hassan, 2016).
- in plants, focusing on the processes involved in sexual reproduction. This is a critical area of plant biology, especially when considering agriculture and the propagation of plant species in a location like Baghdad.

6. Conclusion

Crop field physiology is a dynamic and important propriety to ensure high food security and sustainable production of agricultural. By understanding the intricate physiological processes of crops in their natural environment and leveraging modern technologies, researchers and practitioners can develop strategies to optimize crop performance, enhance resource use efficiency, and adapt to the challenges of a changing world.

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