PLANT BIOCHEMISTRY

NIRUPAMA TYAGI
SHAKULI SAXENA

Plant Biochemistry

Plant Biochemistry

Nirupama Tyagi
Shakuli Saxena

BLACK PRINTS
NEW DELHI

Plant Biochemistry

Nirupama Tyagi & Shakuli Saxena

This edition published by BLACK PRINTS INDIA INC.,
Murari Lal Street, Ansari Road, Daryaganj, New Delhi-110002

Edition: 2022 (Revised)

ISBN: 978-93-82036-45-6

BLACK PRINTS
Excellence in Academic Publishing

Editorial Office: 116-A, South Anarkali, Delhi-110051.
Ph.: 011-22415687

Sales & Marketing: 4378/4-B, Murari Lal Street, Ansari Road, Daryaganj, New Delhi-110002.
Ph.: +91-11-23281685, 41043100 Fax: +91-11-23270680

Production: A 2/21, Site-IV, Sahibabad Industrial Area Ghaziabad, U.P. (NCR)
e-mail: blackprintsindia@gmail.com

CONTENTS

CHAPTER 1

EXPLORING THE MOLECULAR FOUNDATIONS OF PLANT LIFE: A BIOCHEMICAL PERSPECTIVE

Shakuli Saxena, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- shakuli2803@gmail.com

ABSTRACT:

Water and soil are important natural resources. Water is a liquid that is essential for all living organisms. It is used for drinking, cleaning, growing crops, and sustaining life in various ways. Soil is a mixture of minerals, organic matter, water and air. It provides a medium for plant growth, holds nutrients, and helps to filter and purify water. Both water and soil are crucial for the survival and well-being of living organisms. place in the plant to another is called nutrient transport.Moving from one plant cell to another plant cell basically involves crossing a cell barrier. Transport refers to the movement of people, goods, and materials from one place to another. It involves various modes such as cars, buses, trains, planes, and ships.Things can move across the cell membrane in three different ways: diffusion, facilitated transport, or active transport. Water is essential for life. It is a substance that is necessary for living beings to surviveplants is transported by phloem.The plant's leaves are moved to other parts of the plant using a part called phloem. Passive transport means the movement of molecules through a cell membrane without needing energy. This can happen through diffusion, which is when molecules spread out from an area of high concentration to an area of low concentration. Osmosis is a type of diffusion that specifically refers to the movement of water molecules across a cell membrane.

KEYWORDS:

Cells, Molecules, Minerals, Plant, Pressure, Water.

INTRODUCTION

The way living things are made and how they change over time has resulted in two different ways of understanding biology that seem impossible to bring together. The two perspectives were based on two different ways of organizing life forms and phenomena. One is described as a whole organism, while the other is described at the level of cells and molecules. The first one led to the study of ecology and related subjects. The second one led to the study of how the body works and the chemical processes.

The chapters in this unit explain how certain processes happen in plants, specifically in flowering plants. The way plants get nutrients, make food, move substances, breathe, and grow are explained using small parts called molecules.

These processes happen inside cells and even throughout the entire plant. Whenever suitable, we also talk about how our body's functions relate to the world around us. Calvin suggested that plants convert light energy into chemical energy by moving an electron in a structured group of pigment molecules and other substances. He won the Nobel Prize in 1961 for figuring out how carbon is taken in and used during photosynthesis. Calvin's principles of photosynthesis are currently being applied in research on renewable energy and materials, as well as in the study of solar energy[1], [2].

Transport in plants means the movement of water, nutrients, and other important substances inside a plant's tissues. Plants need this transport system to survive because it helps them take in water and minerals from the soil and send them to different parts of the plant, like the leaves, stems, and roots. Transpiration is when plants soak up water from the ground using their roots and then move it through their bodies to their leaves. The water then turns into vapor and goes into the air through small holes in the leaves called stomata. This process helps plants keep the right amount of water and also helps them get water and nutrients from the soil because of how water molecules stick together. Transpiration happens when plants release water through their leaves due to actions like sunlight, temperature, humidity, and wind.Plants need water and carbon dioxide (CO_2) from the air for a process called photosynthesis. During photosynthesis, plants make sugars and other organic stuff. Carbon dioxide goes into the plant through tiny openings called stomata and moves to the chloroplasts in the leaves. In the chloroplasts, it helps with the process of photosynthesis. Oxygen, which is made by plants when they make food, also comes out of tiny holes in the leaves called stomata[3], [4].

Water and nutrients move through special parts of the plant to keep it healthy and growing.Xylem is a plant tissue that carries water and minerals from the roots to other parts of the plant. This thing is made of cells that are long and have a hollow inside. These cells are made strong with a substance called lignin, which helps them carry water in one direction. Water in the xylem moves mainly because of transpiration and the forces of cohesion and adhesion.Phloem is a type of tissue in plants that helps move sugars made during photosynthesis from the leaves to other parts of the plant where they are used for growth and energy. Phloem cells make tubes that transport things in two directions. They use energy to move substances from places where they are made to places where they are needed like roots or storage parts.The way water and nutrients move in plants is a complicated process that includes physical forces, cellular structures, and mechanisms that actively transport them. It is an important part of how plants grow, develop, and work.In living things like plants and animals, there are different ways for important substances to move around inside the body. These methods of transportation make sure that important substances like food, air, waste, and other necessary things are brought to the right places in our bodies and taken away from where they are not needed anymore[4], [5].

Diffusion is when molecules move from a place where there are lots of them to a place where there are fewer of them. This process is important for moving gases and small molecules through cell membranes, and it doesn't need any energy.Facilitated diffusion is a way for molecules to move through the cell membrane with the help of special proteins. Although it doesn't need energy, it uses proteins to help molecules move across the lipid bilayer when they couldn't do it on their own.Active transport is a process where molecules move from an area where there is not a lot of them to an area with a lot of them. This process needs energy (usually from ATP) and is often done by special protein pumps in the cell membrane. Sodium-potassium pumps in animals and proton pumps in plants are ways that cells move things around.Endocytosis and exocytosis are ways that cells move big molecules or particles in and out of themselves. Endocytosis is the process in which substances are taken into the cell by forming small pockets called vesicles from the cell membrane.

Exocytosis is a process where substances are released from a cell by combining small sacs called vesicles with the outer cell membrane.Circulatory systems are important in animals, especially those with many cells, because they help move fluids that contain nutrients, gases, and waste all around the body. In people, the cardiovascular system is made up of the heart, blood vessels, and blood. This system carries oxygen, nutrients, hormones, and waste to different body parts.Plants have tubes inside them called xylem and phloem. These tubes help to carry water, nutrients, and other substances inside the plant. The xylem is like a transportation system in plants that moves water and minerals from the roots to other parts of the plant. On the other hand, the phloem is another transportation system in plants that moves sugars and other organic molecules throughout the plant.Transpiration is when water moves from the roots to the leaves of a plant, and then evaporates from the leaves.Different ways to travel are very important for living things to survive, grow, and work properly. They help bring necessary things to the cells and tissues and get rid of waste products effectively.

DISCUSSION

Water is necessary for all the processes and functions of a plant's body and is very important for all living things.Organisms are living beings such as plants, animals, and bacteria. It is a substance that is used to dissolve many other substances. Cells are mostly made up of water with different molecules and some particles floating in it.A watermelon is mostly made up of water, with over 92 percent of its total volume. On the other hand, most plants that have a soft and green stem contain only about 10 to 15 percent water.When something's weight is decreased by drying it, it's referred to as its dry matter. Of course, how water is spread within a plant is different in woody parts.There is not much water in hard parts, but soft parts have a lot of water. may still contain life. Despite its appearance, a seed has the potential to grow into a plantof water from the soil through their roots.Every day, plants lose most of the water they drink through evaporation from their leaves, which is called transpiration. A fully grown corn plant takes in almost three liters of water every day, whereas a mustard plant also absorbs water.Equal to its own weight in about 5 hours means that something weighs the same as how much it weighs in approximately 5 hours. that water prices have increased significantly over the years. The increased need for water has caused the cost of water to go up[6], [7]. Water is often the main thing that stops plants from growing well in farms and nature.Environments are the places where living things, like plants and animals, live. They can be different types of places, such as forests, deserts, or oceans. Environments provide resources and conditions that support life and help organisms survive.The term "water potential" refers to the measure of how likely water molecules are to diffuse or move from one area to another. It is influenced by various factors, such as the concentration of solutes in the water and the pressure applied to it. A higher water potential means that water molecules are more likely to move, while a lower water potential means they are less likely to move.To understand how plants and water are connected, you need to know some basic words. Water is a substance that is essential for life. It is a transparent, tasteless, odorless liquid that can be found in oceans, lakes, rivers, and even in the air as vapor. It is made up of molecules that consist of two hydrogen atoms and one oxygen atom (H2O). Water plays a crucial role in various biological processes and is necessary for the survival of all living organisms[8], [9].

Potential (Ψw) is an important concept for understanding how water moves. Solute potential (Ψs) refers to the measurement of the strength at which solutes can attract water.Water potential is determined by two main components: solute potential and pressure potential. Water is a liquid that is found in oceans, rivers, lakes, and rain. It is necessary for all living things to survive and is used for drinking, cleaning, and growing plants.Tiny particles called molecules have energy because they are moving. chaotic and unpredictablefast and steady. The more water there is in a system, the more energy it has.Or, in simpler terms, the measurement of how freely water can flow in a particular environment. So, it's clear that regular water has the highest water potential. If two peopleWhen water systems are connected, the water molecules move around randomly and this movement will create an overall flow.Water molecules move from an area with more energy to an area with less energy. ThereforeWater will flow from a place with lots of water to a place with less water.Water potential is a measure of the ability of water to move or flow in a certain direction. It depends on various factors such as pressure, gravity, and the concentration of solutes dissolved in the water. Diffusion is when substances move from an area of high concentration to an area of low concentration. Water potential is a way to measure the pressure of water and is represented by the Greek letter Psi or Ψ. It is measured in units of pressure.If something is not being pushed or forced, it is considered to be nothing or zero. text means that if you mix something in water,The solution has less water particles that are not attached to anything, and the amount of water decreases.The measure of how much something is lowered when a solute dissolves in it is called solute potential or Ψs. always changingThe concentration of solute molecules in a solution determines the water potential.The pressure in the atmosphere, or the water's potential, is equal to the pressure from dissolved substances. If there is a higher amount of pressure thanWhen pure water or a solution is exposed to atmospheric pressure, its water potential goes up. When substances move from an area of high concentration to an area of low concentration, it creates pressure against the cell wall. This pressure makes the cell firm and swollen.This makes the pressure stronger. Pressure potential is typically high, but in plants it is low.The pressure or pull in the water tube in the plant helps to move water up the stem[10], [11]. Pressure potential is represented as the symbol Ψp. The water potential of a cell is influenced by both the substances dissolved in it and the amount of pressure exerted on it.Possibility or capacity for something to happen or be developed.The connection between them can be explained like this: Ψw is equal to Ψs plus Ψp.Osmosis is the process where water molecules move from an area of high concentration to an area of low concentration through a semipermeable membrane.The plant cell has a protective layer called the cell membrane and a stronger outer layer called the cell wall. The cell wall allows things to pass through easily.Water and substances dissolved in it do not act as a barrier to movement. In plants, the cells normally haveA big part of a plant cell called the central vacuole holds a liquid called vacuolar sap. This liquid helps determine the solute potential.Cell a small unit that makes up all living organisms. Together, in plant cells, the cell membrane and the vacuole membrane (called the tonoplast) work together.of water molecules from an area of low solute concentration to an area of high solute concentration through a selectively permeable membrane.This means the movement of water through a membrane that allows some things to pass through but not others.Osmosis happens naturally in response to a pushing force. The way and speed at which water molecules move through a membrane is called osmosis.It relies on both the difference in pressure and the difference in concentration. Water will flow from one area to another.Equilibrium is when things are balanced and stable. At equilibrium, both chambers should have a similar level of water potential.

Imbibition is when things like absorbent polymers or porous solids soak up water and get bigger. This puffiness happens because water molecules and molecules in the absorbent thing like to stick together. Absorption is important in different aspects of life and has many practical uses.Seed germination is a process where seeds begin to grow. Imbibition is really important for this process. When a seed gets wet, it gets bigger and softer. This bump helps crack the seed cover, so the baby plant can come out and start to grow.In plants, imbibition is when seeds absorb water and water moves through the soil. Water is taken in by the roots and moves through the plant's tissues because of certain forces. These forces include the capillary action of water and the cohesive and adhesive properties of water.In simple words, when paper and wood get wet, they can soak up the water and get bigger. This is the reason why materials made of paper often bend or crease when they come into contact with water.When substances absorb water, they can turn into gels. This process is called imbibition. For example, when some types of materials that like water touch it, they can soak up the water and become like a gel.Hygroscopic substances easily soak up water from their surroundings because they naturally attract moisture. This absorption happens because of soaking forces.In cooking and preparing food, imbibition happens when dry ingredients absorb water while being cooked. For instance, when dried beans, rice, or pasta soak up water, they become bigger and softer.The imbibition process happens because of the forces between the material that absorbs water and the water molecules. These forces can be hydrogen bonding, weak forces between molecules called van der Waals forces, and interactions between electrically charged particles called electrostatic interactions. When water goes into the tiny holes of the material, the material gets bigger and might change its size, shape, or feel.Overall, imbibition is a basic idea that has importance in different scientific, industrial, and everyday situations, especially where the soaking up of water and the swelling that follows are important.

In the past, you might have done an experiment where you put a twig with white flowers in colored water and saw it change color. After a few hours, when you looked at the cut end of the twig, you noticed where the colored water had traveled. This experiment shows that water moves through the veins in plants, especially through the xylem. Now, we need to keep going and attempt to comprehend how water and other substances move upward in a plant. Substances can't travel long distances within a plant just by spreading out through the plant. Diffusion happens slowly. It can only explain molecules moving short distances. For instance, it takes about 2.5 seconds for a molecule to move across a regular plant cell, which is around 50 micrometers in size. Can you figure out how long it would take for molecules to move 1 meter in a plant just through diffusion. In big and complicated organisms, things often need to be moved far distances. Sometimes, the places where things are made or taken in and the places where they are stored are too far apart. Just spreading out or moving them around would not be enough. We need special ways to transport things over long distances quickly. Water, minerals, and food are often transported in a system where they are moved together in large amounts. Mass flow is when substances move in large amounts from one place to another because of differences in pressure. Mass flow is when things, like substances in liquid or solid form, are carried along together at the same speed, like objects floating downstream in a river. This is different from diffusion because substances move on their own depending on how concentrated they are. Bulk flow is when a liquid or gas moves in a certain direction. It can happen because of either high pressure or low pressure. The pressure can be like the force of water coming out of a hose or from sucking on a straw. Translocation is the term used to describe the movement of substances in plants through their conducting or vascular tissues. Do you remember learning about the insides of plant roots, stems, and leaves, and studying the special tubes that carry water and nutrients. These tubes are called xylem and phloem and are found in higher plants. The xylem helps move water, minerals, organic nitrogen, and hormones from the roots to the rest of the plant. The phloem moves different types of nutrients, both from the leaves to other parts of the plants. We understand that the roots take in most of the water that plants receive. That's why we water the soil and not the leaves. The job of taking in water and minerals is mainly done by tiny hairs on the ends of roots, called root hairs. Root hairs are long, skinny parts of root skin cells that make the surface bigger so it can absorb more. Water is taken in by the root hairs along with mineral solutes through a process called diffusion. The apoplast is a network of cell walls that goes all the way through the plant, except for at the casparian strips in the roots. Water movement in plants can happen in two ways: symplastic movement and apoplastic movement. Apoplastic movement specifically occurs through the spaces between cells and the cell walls. Moving through the apoplast doesn't require going through the cell membrane. This movement is based on how steep the slope is. The 'apoplast' does not stop water from moving, and water moves in a mass flow. When water turns into vapor and moves into the air or spaces between cells, it creates tension in a continuous flow of water. This tension causes water to move because of how it sticks together and to other surfaces. The symplastic system is a system where the cells are connected to each other. Cells next to each other are linked by tiny strands in the cytoplasm. In simple terms, during symplastic movement, water travels through the cell's cytoplasm. The movement between cells happens through the plasmodesmata. The cell membrane lets water enter cells, so it takes longer for the water to move inside. Movement is once again going in a downward direction based on the difference in potential. Cytoplasmic streaming can help with moving things within cells. You might have seen how the chloroplasts move in the cells of a Hydrilla leaf. This movement is called cytoplasmic streaming and it is easy to see. Most of the water in the roots moves through the apoplast because the cells in the outer layer are not tightly packed, so water can easily flow through them. However, the inner part of the cortex, called the endodermis, cannot let water pass through because of a layer called the casparian strip. Water molecules cannot go through the layer, so they go to the regions of the wall that are not protected, and enter the cells through the membranes. The water then goes through the cells and moves across a barrier to reach the cells of the xylem. Water moves through the layers of roots in a way called symplastic movement, with the endodermis being the final layer. This is the only way that water and other substances can get into the vascular cylinder. Once water enters the xylem, it can freely move both within cells and through them. In young roots, water goes straight into the tubes that carry water called xylem vessels or tracheids. These are things that are not alive and are also part of the apoplast. Some plants have extra parts that help them absorb water. A mycorrhiza is when a fungus and a root system work together and help each other out. The fungal filaments make a web around the new root or they go inside the root cells. The hyphae, which are like small threads, can absorb minerals and water from the soil more effectively than roots can because they have a larger surface area. The fungus gives minerals and water to the roots. In return, the roots provide sugars and compounds containing nitrogen to the mycorrhizae. Certain plants depend on a close relationship with mycorrhizae. For instance, Pinus seeds cannot grow and develop without the help of mycorrhizae.

Root pressure is when ions from the soil are brought into the roots and make the pressure higher inside the xylem along with it. This force that pushes water up in the stem is called root pressure. It can make the water go up to short distances. How can we know if there is root pressure. Find a little plant with a soft stem and lots of moisture in the air. Cut the stem at the bottom using a sharp knife early in the morning. You will see liquid come out of the cut stem because of the pressure from the plant's roots. If you attach a rubber tube to the severed stem like a sleeve, you can collect and measure the rate at which liquid comes out, and also figure out what the liquid is made of. We can see the effects of root pressure at night and early in the morning when there is not much evaporation happening. During this time, extra water gathers in small drops around special openings on grass blades and leaves of many plant parts. When a plant loses water in liquid form, it is called guttation. The pressure from the roots can only give a small push in moving water. They clearly do not have a significant impact on the movement of water up tall trees. The main benefit of root pressure is that it helps to mend the long chains of water in the xylem, which can sometimes break due to the strong pulling caused by transpiration. Most plants get water by using transpiratory pull instead of root pressure. Even though plants don't have a heart or a system for transporting fluids like humans do, water can still move up through the xylem in plants at relatively fast speeds, up to 15 meters per hour. How does the movement happen. People have been wondering for a long time whether water is being pushed or pulled through the plant. Many scientists agree that water is mostly "pulled" through the plant, and the main reason for this is the leaves losing water through transpiration. This is called the cohesion tension-transpiration pull model of how water moves. But, what causes this pulling of water. Water moves through plants temporarily. Less than 1 out of every 100 water that reaches the leaves is used for photosynthesis and plant growth. Most of it is released through the tiny holes in the leaves. This loss of water is called transpiration. In a previous class, you learned about transpiration. This involved putting a healthy plant in a plastic bag and noticing the water droplets that formed inside the bag. You could also learn about water loss from a leaf by using cobalt chloride paper. This paper changes color when it absorbs water. Transpiration is when plants lose water through evaporation. stoma, which are tiny openings on the surface of leaves and stems. Stoma is a tiny hole. In addition to losing water vapor through transpiration, the leaf also exchanges oxygen and carbon dioxide through these stomata. Usually, the small openings on the surface of plant leaves called stomata are open during the day and closed at night. The main reason why stomata open or close is because the guard cells change their shape. The inside wall of every guard cell, close to the opening or hole, is thick and can stretch. When the guard cells on either side of the stomatal pore become more filled with water, their thin outer walls push outward and bend the inner walls into a curved shape. The way the microfibrils are positioned in the walls of the guard cells helps the stomata to open. Cellulose microfibrils are arranged in a circular pattern instead of a straight line, which helps the stoma to open more easily. When the guard cells don't have enough water, their inner walls bounce back to their original shape. This makes the guard cells weak and causes the stoma to shut. Normally, a leaf that is dorsiventral has more stomata on its lower surface. In contrast, a leaf that is isobilateral has a similar number of stomata on both surfaces. Transpiration is influenced by different things outside, like temperature, light, humidity, and wind speed. Some things about plants, like how many stomata they have and where they are located, how many stomata are open, how much water the plant has, and the shape of the plant, can all affect how much water is lost through transpiration.

After the mineral ions have entered the xylem by either active or passive uptake, or a mix of both, they are then carried up the stem and distributed to all parts of the plant through a process called transpiration stream. The main places where plants absorb mineral elements are the parts of the plant that are actively growing, like the tips of the stems and the sides, new leaves, young flowers, fruits and seeds, and the parts of the plant where nutrients are stored. Mineral ions are unloaded from the fine vein endings by moving from an area of high concentration to an area of low concentration. The cells also actively take up these mineral ions. Mineral ions often move around, especially from older and dying parts. Older leaves that are dying transfer many of their nutrients to younger leaves. Similarly, before the leaves fall off of deciduous plants, minerals are taken away to different parts of the plant. The elements that move most easily are phosphorus, sulfur, nitrogen, and potassium. Some parts of our bodies, like calcium, are not moved around or reused. A study of the liquid that comes out of the xylem shows that while some of the nitrogen travels as small particles, most of it is carried in the form of amino acids and similar substances. Also, tiny amounts of P and S are transported as organic substances. Also, a small amount of materials are exchanged between xylem and phloem. So, we can't simply say that xylem carries only inorganic nutrients and phloem carries only organic materials, like people used to believe. Food, especially sugar called sucrose, is moved from its starting point to where it is needed using a special kind of tissue called phloem. Typically, the source is the leaf, which makes food, and the sink is the part that uses or stores the food. However, depending on the season or the needs of the plant, the source and sink can be switched around. Sugar that is stored in roots can be moved to provide food for trees in the early spring. During this time, the buds of trees need energy to grow and develop their photosynthetic apparatus. Because the relationship between the source and sink changes, the movement in the phloem can go up or down, meaning it can go both ways. This is different from the movement in the xylem, which always goes in one direction, specifically upwards. So, unlike the one-way movement of water in transpiration, food in phloem sap can move in any needed direction as long as there is a source of sugar and a place that can use, store, or get rid of the sugar. Phloem sap is mostly made up of water and sucrose, but it also carries other sugars, hormones, and amino acids.The pressure flow hypothesis is the way sugars move from where they are made to where they are used in plants. Glucose, which is made through photosynthesis, gets changed into sucrose, another type of sugar. The sugar is transferred into the companion cells and then into the living phloem sieve tube cells using active transport. This way of loading at the start makes the phloem have too many substances and becomes too concentrated. Water from the nearby xylem goes into the phloem by a process called osmosis. As the pressure inside the phloem increases, the sap will flow to regions with less pressure. At the sink, the pressure caused by osmosis needs to be decreased. Once again, active transport is needed to move sucrose out of the phloem sap and into the cells that will use the sugar. These cells will then convert the sucrose into energy, starch, or cellulose. When sugars are taken away, the pressure decreases and water leaves the phloem. To put it simply, sugars start moving in the phloem from where they are loaded into a sieve tube at the source. The movement of water in the phloem is made easier by a difference in water pressure. Phloem tissue is made up of cells called sieve tube cells. These cells form long columns and have holes in their end walls called sieve plates.

Threads in the cytoplasm go through the openings in the sieve plates, creating long, connected strings. When the pressure inside the sieve tube of phloem increases, pressure flow starts and the sap flows through the phloem. Meanwhile, at the sink, sugars that come in are moved out of the phloem and taken away as complex carbohydrates. When solute is lost in the phloem, it makes the water have a lot of potential. This causes the water to leave and eventually go back to the xylem. We did a simple experiment called girdling. This helped us find out which tissues carry food in plants. You can take off a circle of the outer layer of a tree trunk called bark if you're careful. When food cannot move down, the bark above the ring on the stem gets bigger after a few weeks. This easy experiment proves that phloem is the tissue that moves food around; and that the movement happens in one direction, towards the roots. Plants can't move food around their bodies just by diffusion. They are taken to another placea large amount of substance being transported from one place to another.Pressure differences between two points mean that there is a change in pressure from one point to another. Water that is taken in by root hairs goes into the inside of the rootby two different routes, namely through the spaces between cells and through the living portions of cells. Different charged particles and water found in the soil can also be.Transported up a little bit in stems by the pressure of the roots. The transpiration pull model is the most widely accepted explanation.Water transport is a way to move water from one place to another, and it is considered acceptable. Transpiration means water turning into vapor and being lost.The plant parts release gases through small holes called stomata. This text talks about different factors that affect the weather. These factors include temperature, how warm or cold it is, light, how much sunlight there is, humidity, how much moisture is in the air, wind speed, how fast the wind is blowing, and the number of something.Stomata control how much water is released from plants through transpiration. Plants also get rid of extra water through the ends of their leaves.Through a process called guttation. Phloem is in charge of carrying food, mainly sucrose, from where it is produced to where it is needed.The movement of substances in the phloem can go in both directions. The relationship between where the substances come from and where they go can change. The movement of substances in the phloem is described by the pressure flow theory.

CONCLUSION

Nutrients can be transported across cell membranes in living organisms through two ways: passive transport and active transport.Organisms are living things such as plants, animals, and humans.Energy always flows in the direction of decreasing concentration, which is driven by entropy. This spreading out ofThe characteristics of substances depend on how big they are and if they can dissolve in water or organic solvents. Osmosis is a specific type of process.The spread of water through a membrane that allows only certain substances to pass, and this depends on the difference in pressure.The term 'concentration gradient' refers to the difference in the amount of a substance between two areas. In active transport, the cell uses energy from ATP to move things around.Molecules moving against a difference in their amount across membranes. Water potential is the amount of energy that water has.Water molecules help water move. is influenced by the concentration of solutes in a substance.When the solution around a cell is very concentrated, it causes the cell to shrink. Seeds soak up water.Drywood absorbs water through a special process called imbibition. The vascular system is made up of xylem and phloem, and it helps move things around in plants. Water minerals are important substances found in water.

REFERENCES:

[1] K. Zhao, D. Valle, S. Popescu, X. Zhang, and B. Mallick, “Hyperspectral remote sensing of plant biochemistry using Bayesian model averaging with variable and band selection,” *Remote Sens. Environ.*, 2013, doi: 10.1016/j.rse.2012.12.026.

[2] EB Moullin, “Plant Biochemistry,” *Nature*, 1951, doi: 10.1038/168004a0.

[3] J. Porter, “in Methods in Plant Biochemistry-Plant Phenolics,” *Harb. Dey J. B.*, 1989.

[4] Y. Qi and G. J. Hannon, “Uncovering RNAi mechanisms in plants: Biochemistry enters the foray,” *FEBS Letters*. 2005. doi: 10.1016/j.febslet.2005.08.035.

[5] N. Dudareva, E. Pichersky, and J. Gershenzon, “Biochemistry of plant volatiles,” *Plant Physiology*. 2004. doi: 10.1104/pp.104.049981.

[6] Inderjit, R. M. Callaway, and J. M. Vivanco, “Can plant biochemistry contribute to understanding of invasion ecology?,” *Trends Plant Sci.*, 2006, doi: 10.1016/j.tplants.2006.10.004.

[7] T. Acamovic and J. D. Brooker, “Biochemistry of plant secondary metabolites and their effects in animals,” *Proc. Nutr. Soc.*, 2005, doi: 10.1079/pns2005449.

[8] N. J. Gallage and B. L. Møller, “Vanillin-bioconversion and bioengineering of the most popular plant flavor and its de novo biosynthesis in the vanilla orchid,” *Molecular Plant*. 2015. doi: 10.1016/j.molp.2014.11.008.

[9] N. Dudareva, E. Pichersky, and J. Gershenzon, “Update on Biochemistry of Plant Volatiles Biochemistry of Plant Volatiles,” *Plant Physiol.*, 2004.

[10] P. J. Facchini, “Alkaloid biosynthesis in plants: Biochemistry, cell biology, molecular regulation, and metabolic engineering applications,” *Annu. Rev. Plant Biol.*, 2001, doi: 10.1146/annurev.arplant.52.1.29.

[11] D. Sofrová, “Dashek, W.V. (ed.): Methods in Plant Biochemistry and Molecular Biology,” *Photosynthetica*, 1998, doi: 10.1023/a:1006903712815.

CHAPTER 2

PLANT CELLULAR ORGANIZATION AND COMPARTMENTALIZATION

Praveen Kumar Singh, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- dr.pksnd@gmail.com

ABSTRACT:

The chapter about how plants are organized and how their cells work talks about the detailed structure and function of plant cells. It explains what makes them special and how different parts of the cell work together. Plant cells have a specific way of being organized. They have strong walls, green chloroplasts, and big vacuoles in the center. These features help to make the plant structure stronger, allow the plant to make food using sunlight, and help the plant store things.This chapter mainly talks about how cells are divided into different parts, called organelles, which are surrounded by a membrane. Each organelle has a specific job or function. The nucleus is like a control center for cells. It helps to control what happens in the cell. Chloroplasts are where photosynthesis happens, and mitochondria are responsible for making energy. Also, small compartments called peroxisomes and a part of cells called the endoplasmic reticulum are very important for how the body uses fats and makes proteins.The chapter talks about how cells communicate with each other through something called plasmodesmata. This allows them to share molecules with each other. In addition, it looks at how the endomembrane system helps move things inside cells and release them. Vacuoles are special parts of a plant cell that have multiple uses. They are known for their ability to store things and help the plant grow.Knowing how plants are organized at the cellular level is very important for understanding how they grow and develop, as well as how they respond to their surroundings. This chapter explains in simple terms how plants have special structures in their cells that help them survive and grow in different environments.

KEYWORDS:

Cell Wall, Cytoplasm, Chloroplast, Outer Layer, Plant Cell.

INTRODUCTION

Different parts inside a cell called compartments need to be formed. This is important because it helps separate different chemical reactions, their products, and different ions using walls made of membranes. dividing different tasks into different parts inside cells was really important for life to develop on Earth. Keeping dangerous substances or processes separate within cells is crucial for cells to work properly. These proteins help regulate the movement of water and ions across the membrane. Scientists studied how particles called ions move and how certain proteins help them move. Marchand and his colleagues. In simpler terms, the ability to create a special type of energy force across barriers between liquids helps in making ATP, which gives energy to living things. There are three main types of organelles that are typically identified. The text is about different types of compartments in cells, which are either made up of membranes, proteins, or formed through endosymbiosis. Recent studies have shown that there are compartments in both simple and complex organisms. However, these compartments are more advanced in complex organisms, such as plants and animals, which have specialized parts that are specific to certain lineages, tissues, or cells.

Photosynthetic eukaryotes have special parts and processes that are different from other organisms. The wide variety of plant chemicals is believed to have developed because plants cannot move and need to protect themselves from animals that might eat them and from bad environmental conditions[1], [2].

Some instances of this are when certain harmful chemicals are made in a controlled way and kept separate, or when certain compounds stop other reactions from happening. Examples include condensed tannins. They do this by creating certain chemicals or signals that help them coordinate their actionsThe process of making red crocins, which are special compounds found in saffron, starts with a substance called zeaxanthin in a part of the plant called the chloroplast. However, the endoplasmic reticulum and cytoplasm also play a role in moving zeaxanthin to another part of the plant called the vacuole. This process happens along a structure called the cytoskeleton. Saffron is considered the most expensive spice in the world. In simple words, the condensed tannins, which are very toxic and can break down proteins, are made up of smaller building blocks. These building blocks are made in a part of the cell called the endoplasmic reticulum. They are then put together in special organelles called tannosomes, which are surrounded by a membrane.

The tannosomes are transported to another part of the cell called the cytoplasm, and from there, they are taken to their final storage place called the vacuole. Since Antonie van Leeuwenhoek first started looking at tiny things in the 17th century, scientists have made big advancements in studying cells. They have discovered new parts of cells and learned more about how cells work. Newly discovered small parts of cells called microcompartments have been found in plants.

These microcompartments are made up of proteins that interact with each other and are involved in different processes inside the cell, including redox signaling. It is important to know how plant cells work and communicate with each other and their environment. This knowledge can help improve plant productivity, which is important for agriculture, food industry, medicine, and the environment. Furthermore, having a better understanding of how cells are structured can lead to advancements in synthetic biology. Synthetic biology is a growing field that involves creating compartmentalized protocells or artificial cells. These protocells have the potential to produce fascinating substances[3], [4].

This topic called Plant Cell Compartments contains articles about different areas of studying cells in plants that do photosynthesis. Because there isn't enough space and other restrictions, this compilation can't include everything about compartments. It only talks about a few chosen topics. We mainly studied specific parts of plant cells like the cell wall, vacuole, plastids, and plant peroxisomes.. These plasmodesmata play a crucial role in communication and transportation within plant cells.

Hormones can move and be shared between cells. Plasmodesmata are like highways that allow cells in plants and recently discovered in animals and bacteria to communicate with each other. They help with things like sensing the environment, signaling stress, and responding to it at different levels within the plant or even the entire organism. In this situation, compartmentalization is important both inside and outside of cells.

It helps separate different processes within cells, but also helps separate specific cells from surrounding tissues during certain phases of their development when they need to be completely separate from their environment. cells involved in sexual reproduction undergo a process called synapsis where homologous chromosomes pair up and exchange genetic material through a process known as crossing over. This process ensures genetic variation in offspring. After synapsis, the cells undergo two rounds of division, resulting in the formation of four new cells called gametes. These gametes contain half the number of chromosomes as the parent cell and are ready to combine with another gamete during fertilization to create a new organism.

The cells that produce small and large spores in flowering plants make a protective layer in their outer wall. This layer keeps them separate from other cells when they divide, but it is later broken down or adjusted to control movement during the growth of the reproductive cells. Diplosporic means a species that reproduces asexually. This can happen during the growth of the gametophyte or not. The research paper in this Special Issue shows that callose is only found temporarily in the cell walls of Chondrillabrevirostris during a process called meiotic diplospory.

This example explains another important job of the cell wall in helping plants reproduce and send signals. The cell wall is like a protective wall that stops things from passing through, like ions and water, and it also helps during attacks from harmful organisms. However, the main protection for the cell comes from the plasma membrane. This covering around the cell is an important part that controls how nutrients and signals move in and out of the cell.

These jobs are taken care of by many proteins that can detect and send signals about things like diseases in the environment. In simpler terms, they are important in helping us to respond and adapt to changes happening in our environment. Plasma membrane lipidomics helped us understand and describe the different types of fats in the plant's outer layer (phospholipids, phosphoinositides, sphingolipids, and sterols).

Most lipids in the cell membrane arrange themselves into flat layers when they come into contact with water because of their shape. However, if there are changes or disturbances in how the parts are arranged or the composition of the protective layer surrounding them, it can cause the formation of a different type of structure in the membrane called a cubic phase. Different parts of cells, like compartments, were studied and found to have a network of tube-like structures made of membranes. Reworded: The endoplasmic reticulum, perinuclear space, mitochondria, plastids, and organisms like amoeba, animal, human, and plant cells[5], [6].

DISCUSSION

In this study, scientists discovered a specific arrangement of certain parts of Charainternodal cells' plasma membranes called charasomes. Charasomes have a lot of H+ -ATPases which help make the surrounding area more acidic. We are still unsure about the exact role of this acidification in the area, but it might have something to do with how carbon is used in the process of photosynthesis. Basically, acidification causes more carbon dioxide to be released into the air. We can see a special arrangement of the plasma membranes in angiosperm plant cells, similar to charasomes. This happens when plasmalemmasomes are being formed. These structures are small omega-shaped pockets that start from the outer layer of the cell and go deeper into the inside part called the cytoplasm, and finally into a special compartment called the vacuole. In this special article, the researchers show proof of plasmalemmasome creation and talk about what causes this to happen and how these organelles may help move water between different parts of a cell. Peroxisomes are small parts inside cells that were discovered later compared to other important parts. They are found in many different types of cells. Peroxisomes are still not fully understood, but they are known to mainly help with the breakdown of fats in cells and help maintain a balanced chemical environment within the cell.

This means that they are very important for how cells work and if they don't work right, it can cause problems in how our bodies work. They also have an important job in helping plants grow, develop, and deal with stress. The shape and functions of peroxisomes can change a lot, and they are closely connected to other parts of the cell. Their collection of proteins and metabolic processes are both very big and strictly controlled. This means that by learning more about them, we can create plants that can better resist diseases, pests, drought, and heat. Pathogen means a harmful organism, and abiotic stress refers to environmental factors that can damage plants or organisms. So, researchers are trying to find ways to make plants stronger against harm caused by these factors. They want the plants to grow bigger or have better processes in their body.

The review by Corpas in this Special Issue gives a basic explanation of peroxisomes and is mainly focused on their wide range of functions in metabolism. One important part of evolution was when certain types of simple organisms gained the ability to make their own energy through photosynthesis using sunlight. This included cyanobacteria. Simple words: Eukaryotic cells with mitochondria started using photosynthesis by swallowing ancient cyanobacteria and living together and evolving together with them.

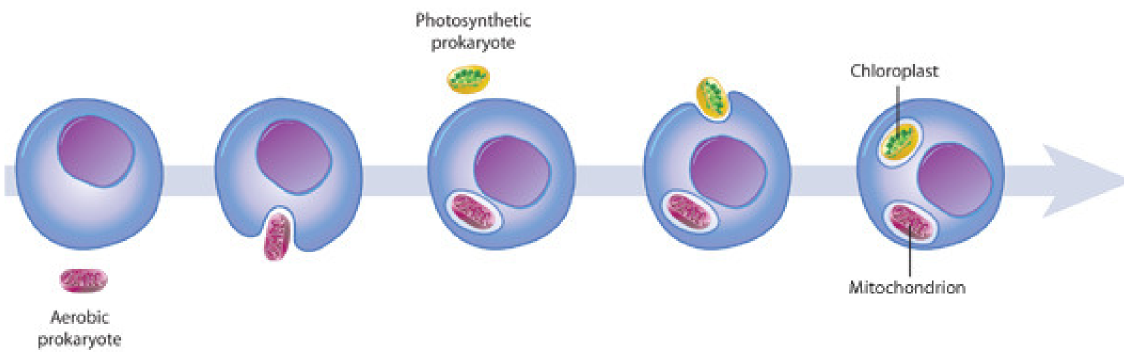

Figure 1: Representing the overview about origin to mitochondria and chloroplast [Nature.Com].

In this process, the cyanobacterialendosymbiont slowly lost its own genes and essentially became a controlled servant of the host cell (Figure 1). Most of the genes from the original endosymbiont have either moved to the host's nucleus or disappeared. Only a small number of genes are still carried by the plastid DNA. This Special Issue discusses and compares how plants on land and a type of green algae called Chlamydomonasreinhardtii use the machinery in their cells to translate genetic information into proteins. Their main finding is that the expression of a small number of genes in the chloroplast genome is mostly controlled after transcription or during translation. The host cell and its metabolism control the development and function of plastids through various processes. This is an important stage when the structure and function of plastids diversify. It happens as algae and plants become more complex in their life cycles and organization. Chloroplasts use sunlight to do photosynthesis. However, when algae cells or plant tissues don't receive any light, they can't develop chloroplasts and instead form etioplasts. Etioplasts have very little of a substance called protochlorophyllide, which is a step towards making chlorophyll. They also have a unique structure called a prolamellar body, which is shaped like tubes and nets in three dimensions.Plant cells are different from other cells because they have special parts inside. In simple words, chloroplasts are parts of plants that help them get energy from the Sun. Cell walls give plants their shape, like wood trunks and flexible leaves. Vacuoles help plant cells change their size[7], [8].

Chloroplasts, like mitochondria, probably came from a long time ago when a cell swallowed a little plant that could do photosynthesis. Yes, chloroplasts are similar to modern cyanobacteria, which are still similar to the cyanobacteria that existed 3 million years ago. But the process of photosynthesis actually started a long time ago, with the very first cells that learned how to take in light and turn it into energy. When these tiny living things learned how to separate water and use its parts, they began making oxygen. This had a big impact on the way all living things on Earth changed over time.Today, chloroplasts have small, round genomes that are similar to those of cyanobacteria, but smaller. Mitochondrial genomes are smaller than chloroplast genomes.

Most coding sequences for chloroplast proteins are gone, so these proteins are now made by the nuclear genome, created in the cytoplasm, and moved into the chloroplast.Chloroplasts are also surrounded by two membranes, just like mitochondria. The outer layer allows small organic molecules to pass through easily, while the inner layer is not as easy to pass through and has transport proteins on it. The inside layer of chloroplasts, known as the stroma, has enzymes that help with metabolism and many copies of the chloroplast genome.Chloroplasts have another layer inside called the thylakoid membrane. This membrane is folded a lot and looks like flat disks when seen under a microscope. The thylakoids have a light-collecting system, which includes pigments like chlorophyll. They also have electron transport chains that are important for photosynthesis.

Plant cells and animal cells are different in two main ways. One, plant cells have chloroplasts while animal cells do not. Two, plant cells have a cell wall while animal cells do not. The cell wall is like a wall that encloses the outer part of plant cells. It gives them strength and protects them from damage caused by pressure and water. It also helps cells build up pressure inside them, pushing against the cell wall. Plant cells have a lot of molecules in their cytoplasm, which makes water flow into the cell and causes the cell's central vacuole to expand and push against the cell wall. When a plant has enough water, turgor pressure helps it stay upright and prevents it from drooping. During a drought, a plant can become limp and droopy, but the cell walls in its stems, leaves, and other parts help them stay strong and intact even when the vacuole shrinks and loses water.

Plant cell walls are mostly made of cellulose, which is a very common substance found in large amounts on Earth. Cellulose fibers are long, straight chains made up of many glucose molecules. These fibers come together in groups of about 40, which are called microfibrils. Microfibrils are placed inside a wet network of other types of sugars. The cell wall is put together in its proper position.

The cell makes precursor parts and puts them together using enzymes near the cell covering (Figure 2).Plant cells also have big, liquid-filled sacs called vacuoles inside them. Vacuoles usually make up around 30 percent of a cell's size, but they can take up as much as 90 percent of the space inside the cell. Plant cells have vacuoles that help them change their size and internal pressure.

Vacuoles help cells change in size when the inside of the cell stays the same.Some vacuoles have special jobs, and plant cells can have more than one kind of vacuole. Vacuoles and lysosomes are similar and do some of the same things. They both have enzymes that break down big molecules. Vacuoles can also store nutrients and metabolites. For example, seeds store proteins in vacuoles. Plants also store rubber and opium in vacuoles.

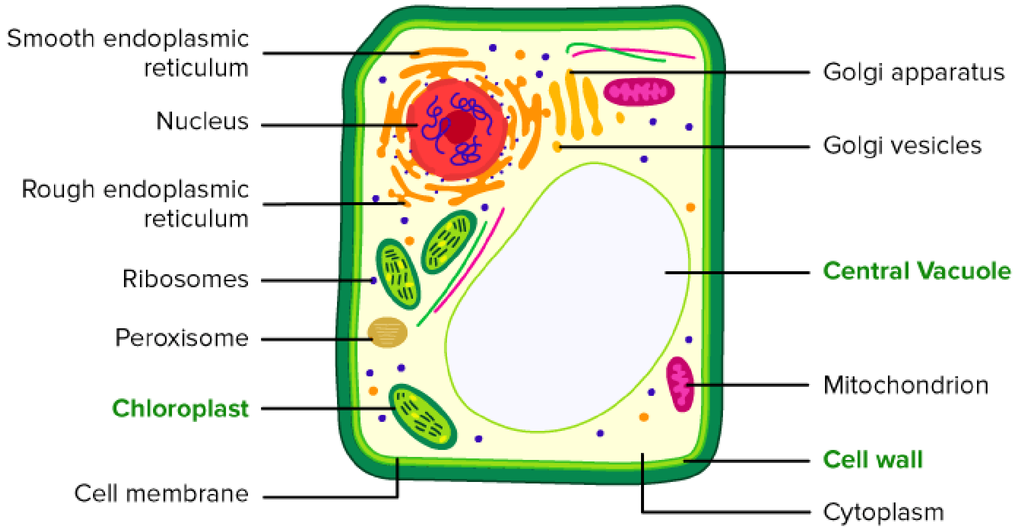

Figure 2: Representing the overview about plant cell structure [CK12-Foundation].

A cell wall is a hard layer that is located on the outside of the cell membrane and encloses the cell. The outer layer of a cell has cellulose, protein, and other types of sugars. The cell wall gives the cell a strong and protective outer layer. Tiny holes in the cell wall let water and nutrients go in and out of the cell. The cell wall stops the plant cell from bursting when water goes inside the cell.Tiny structures inside plant cells called microtubules help in creating the wall of the plant cell. Enzymes make cellulose to create the main part of a cell's outer layer. Some plants have a second layer of cell wall. The secondary wall of a plant cell has a substance called lignin. Lignin is found in cells that are finished growing and expanding.The Central Vacuole is like a large container in a plant cell that stores water and other substances. It helps support the cell and regulates its internal environment.Most fully grown plant cells have a big central vacuole that takes up more than 30% of the cell's size. The big storage space inside some cells, called the central vacuole, can take up to 90% of the cell's volume. The big vacuole in the cell is protected by a layer called the tonoplast. The center vacuole does a lot of things. Apart from storing things, the vacuole's main job is to keep the cell wall firm by maintaining pressure. Proteins in the tonoplast regulate the movement of water in and out of the vacuole. The main storage space in a cell called the central vacuole also keeps the colors that make flowers look pretty[9].

The main vacuole in a cell has a lot of cell sap, a liquid that is different from the liquid inside the rest of the cell. Cell sap is a mixture of water, enzymes, ions, salts, and other things. Cell sap can have harmful substances that have been taken out from the inside of the cell. Toxins inside a part of a plant called the vacuole can stop animals from eating the plant.Plastids are small structures found in plant cells. They perform important functions such as storing and producing various substances needed for the plant's growth and survival.Plant plastids are a bunch of similar parts surrounded by a barrier that do a lot of jobs. They do three important jobs: they help plants make food, store energy, and create important molecules for cells. Plastids can switch and perform different tasks in various shapes. Plastids have their own DNA and some ribosomes. Scientists believe that plastids come from bacteria that could do photosynthesis and helped early eukaryotes produce oxygen. There are different kinds of plastids and each has its own purpose.

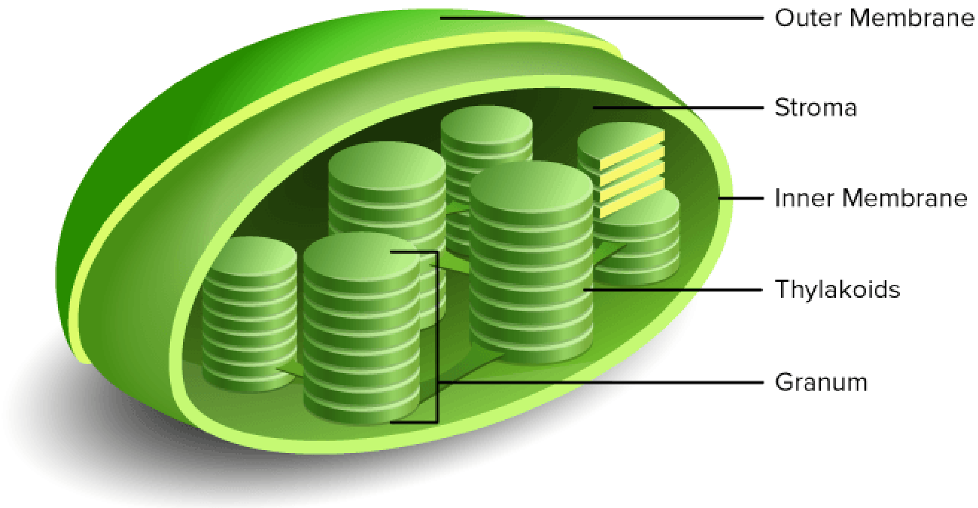

Figure 3: Representing the internal structure of Chloroplasts [Flexs Books].

Chloroplasts are the part of cells that help plants make food through photosynthesis. Plants take in sunlight and combine it with water and carbon dioxide to create food for themselves, known as sugar. The positioning of chloroplasts in a plant's cells can be observed in the picture below.Chromoplasts create and keep pigments that give color to petals and fruit in shades of orange and yellow.Leucoplasts are found in the roots and other parts of plants that do not do photosynthesis. They don't have any color. They can be specialized to store lots of starch, fat, or protein. However, in most cells, leucoplasts are not used to store large amounts of things. Instead, they produce substances like fatty acids and various types of amino acids.Chloroplasts use sunlight, water, and carbon dioxide to make sugars for food. Chloroplasts are tiny, flat, disc-shaped structures that are usually between 2 and 10 micrometers in size. They are also very thin, measuring about 1 micrometer in thickness. The picture below shows a model of a chloroplast. The chloroplast has two layers of lipids an inner and an outer layer (Figure 3). In simpler terms, there is a space between these two layers called the intermembrane space. The liquid inside the chloroplast is called the stroma, and it has a small, circular DNA in it. The stroma contains ribosomes too. In the stroma, there are piles of thylakoids. The thylakoids are organized in stacks called grana. A thylakoid looks like a flat round disk. Inside the thing, there is an empty space called the thylakoid space or lumen.Inside the thylakoid membrane, there is a group of proteins and pigments that can absorb light, including chlorophyll and carotenoids. This place can take in light energy from different colors because chlorophyll and carotenoids can absorb different colors of light.

CONCLUSION

In summary, the chapter about Plant Cellular Organization and Compartmentalization explains the complex connections between the structures and jobs of plant cells. In this chapter, we will learn about the different parts of cells and how they help plants survive in different environments.The hard cell wall, chloroplasts, and big vacuole all work together to make plant cells special. They help with things like keeping the cell strong, making energy, and storing stuff. The idea of compartmentalization is important because it shows how different parts of a cell work together to do specific jobs. For example, the nucleus controls genes while the mitochondria produce energy.The talk about plasmodesmata helps us understand how cells in plants communicate with each other, which is important for plant growth and how they respond to things around them. The importance of the endomembrane system in moving things around and releasing them shows how complex things are inside cells.As this chapter ends, we have learned more about how plants are organized at the cellular level, revealing the complexity of plant life. This information helps us understand how plants grow and develop, and can be useful for farming, technology, and protecting the environment. Basically, this chapter explains how the cells of plants are responsible for their ability to adapt and survive in different environments.

REFERENCES:

[1] L. V. Michaelson, J. A. Napier, D. Molino, and J. D. Faure, "Plant sphingolipids: Their importance in cellular organization and adaption," *Biochim. Biophys. Acta - Mol. Cell Biol. Lipids*, 2016, doi: 10.1016/j.bbalip.2016.04.003.

[2] W. Underwood, "Contributions of host cellular trafficking and organization to the outcomes of plant-pathogen interactions," *Seminars in Cell and Developmental Biology*. 2016. doi: 10.1016/j.semcdb.2016.05.016.

[3] E. Truernit, H. Bauby, B. Dubreucq, O. Grandjean, J. Runions, J. Barthélémy, and J. C. Palauqui, "High-resolution whole-mount imaging of three-dimensional tissue organization and gene expression enables the study of phloem development and structure in Arabidopsis," *Plant Cell*, 2008, doi: 10.1105/tpc.107.056069.

[4] X. Yan and N. J. Talbot, "Investigating the cell biology of plant infection by the rice blast fungus Magnaporthe oryzae," *Current Opinion in Microbiology*. 2016. doi: 10.1016/j.mib.2016.10.001.

[5] R. A. Feagin, X. B. Wu, F. E. Smeins, S. G. Whisenant, and W. E. Grant, "Individual versus community level processes and pattern formation in a model of sand dune plant succession," *Ecol. Modell.*, 2005, doi: 10.1016/j.ecolmodel.2004.09.002.

[6] E. Truernit and J. C. Palauqui, "Looking deeper: Whole-mount confocal imaging of plant tissue for the accurate study of inner tissue layers," *Plant Signal. Behav.*, 2009, doi: 10.4161/psb.4.2.7683.

[7] P. Sarkar, E. Bosneaga, and M. Auer, "Plant cell walls throughout evolution: Towards a molecular understanding of their design principles," *Journal of Experimental Botany*. 2009. doi: 10.1093/jxb/erp245.

[8] G. Paës, "Fluorescent probes for exploring plant cell wall deconstruction: A review," *Molecules*. 2014. doi: 10.3390/molecules19079380.

[9] C. P. Kubicek, T. L. Starr, and N. L. Glass, "Plant cell wall-degrading enzymes and their secretion in plant-pathogenic fungi," *Annu. Rev. Phytopathol.*, 2014, doi: 10.1146/annurev-phyto-102313-045831.

CHAPTER 3

PHOTOSYNTHESIS: LIGHT REACTIONS AND CALVIN CYCLE

Sunil Kumar, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- sunilagro.chaudhary@gmail.com

ABSTRACT:

The chapter explains the complicated processes of photosynthesis in plants in a detailed way. This text explains the two main parts of photosynthesis: the light reactions and the Calvin Cycle, and how they work together.In the beginning of the chapter, it explains how light reactions happen in the thylakoid membranes of chloroplasts. This text explains how chlorophyll and other pigments absorb light energy, which starts the process of making ATP and NADPH. The flow of electrons and the creation of a chemical gradient are important parts of making ATP. At the same time, water molecules are separated, and oxygen is released as a result.After that, we look closely at the Calvin Cycle, which occurs in the stroma of chloroplasts. This process involves using carbon dioxide from the air and turning it into sugars with the help of energy molecules made during the earlier stages.The Calvin Cycle needs the products of the light reactions to get energy. The light reactions need water and a working electron transport chain.This chapter explains photosynthesis and why it is important. It talks about how it works at a molecular level and how it helps life on Earth by making energy-rich things and oxygen. The chapter's findings help us understand how plants work and also how we can find renewable energy sources and protect the environment.

KEYWORDS:

Calvin Cycle.Carbon, Light Reactions, Photosynthesis, Phtotosystem II, Water Molecules.

INTRODUCTION

The chapter starts a journey to learn about photosynthesis, which is a fascinating process in nature. Photosynthesis is a really important process in nature that helps plants make food from sunlight. It also makes sure there is enough oxygen in the air for us to breathe. Without photosynthesis, life on Earth wouldn't be possible.The chapter starts by explaining how important photosynthesis is for transferring energy and keeping the balance of carbon in the environment. This information focuses on how plants, algae, and certain bacteria use light energy to make into a type of energy stored in glucose and other organic molecules. This process helps these organisms to grow and develop. It also affects the environment by releasing oxygen and changing climate patterns.The beginning of the text talks about the parts of cells called chloroplasts, which are where plants make food. This text talks about how chlorophyll and other pigments absorb light energy from different colors of light.

In addition, the introduction prepares for the two main parts of photosynthesis - the light reactions and the Calvin Cycle. It highlights how these parts are connected and how they both help in the overall process.To put it simply, the beginning of the chapter sets the groundwork for an interesting exploration of photosynthesis. This makes us wonder about the ways in which this important process works, which helps ecosystems and affects the air we breathe. As readers dig deeper, they will find out more about light reactions and the Calvin Cycle. They will gain knowledge that goes beyond just plant biology and includes energy innovation and protecting the environment[1], [2].

In plants, chloroplasts are special parts of the cells that do the work of photosynthesis. The process of photosynthesis can be split into two types of reactions. The first type, called light-dependent reactions, happen in the thylakoids. The second type, known as light-independent reactions or the Calvin cycle, happen in the stroma.Chloroplasts have a complicated inside structure, and various reactions happen in different areas of the chloroplast.To understand where the different reactions of photosynthesis happen, it's important to know what the inside of a chloroplast looks like.The chloroplast has two layers of membranes, one on the outside and one on the inside. This looks the same as the two layers of membrane in mitochondria.Inside the inner layer of the chloroplast and around the thylakoids, there is a liquid called the stroma. The part of photosynthesis where sunlight is not needed happens in the stroma. It has enzymes that, along with ATP and NADPH, convert carbon dioxide into molecules that can be used to create glucose. The chloroplast has its own genetic material that is kept in the stroma, which is separate from the cellular genetic material[3], [4].

Inside the chloroplast, there is another membrane called the thylakoid membrane. This membrane is folded to create many stacks of connected discs. Each disc is a small part of a plant cell, and each stack is a group of these discs. Grana is a slang term for money.During photosynthesis, the thylakoids are where the light-dependent reactions occur. These reactions happen when a substance called chlorophyll in the plant absorbs energy from the sun and uses it to break down water molecules.The reactions that depend on light convert light energy into chemical energy.The purpose of the light-dependent reactions in photosynthesis is to gather energy from the sun and separate water molecules into ATP and NADPH. These two molecules that store energy are later used in the reactions that don't require light.Inside the chloroplasts, chlorophyll is the substance that takes in sunlight. This information is kept in special protein groups called photosystem I and photosystem II, which are found in the thylakoid membranes. The process of light-dependent reactions starts when sunlight hits a chlorophyll molecule in photosystem II. This makes an electron get excited, and it leaves the chlorophyll molecule. Then, it travels on the thylakoid membrane with the help of carrier proteins called the electron transport chain.

Then, a remarkable thing occursphotosystem II breaks apart a water molecule to bring back the missing electron and fill the empty space of energy that was created. People have not been able to create the same thing in a lab.Every water molecule splits into two hydrogen atoms and one oxygen atom. Oxygen is produced as a byproduct. Oxygen atoms from broken-down water molecules combine in pairs to make oxygen gas ($O2$).The hydrogen ions become very concentrated in the thylakoid's interior. They go through a special enzyme called ATP synthase, and their movement gives the energy needed to add a third phosphate to ADP (adenosine diphosphate) to make ATP (adenosine triphosphate). This special molecule provides energy for many activities that happen in cells. Actually, the sugar produced in photosynthesis is broken down to make more ATP later in cellular respiration[5].

At the same time, the electron that was let go from photosystem II moves to photosystem I, which also has chlorophyll. The sun's energy makes the electron excited. This excitement helps the electron move through the membrane and into the stroma. In the stroma, the electron combines with a hydrogen ion and an $NADP+$ to make a molecule called NADPH that carries energy.ATP and NADPH transfer from the thylakoid to the stroma, where their stored energy is used to fuel the light-independent reactions.The main aim of the light-independent reactions (or Calvin cycle) is to put together a glucose molecule. This is the process of photosynthesis that needs the carbon dioxide that plants get from the air.Basically, the plant requires carbon from $CO2$ in order to make the basic components of glucose. In the stroma, there is an enzyme called ruBisCo. It combines a five-carbon molecule called RubP with carbon dioxide. This process forms a molecule with six carbon atoms, which then splits into two molecules with three carbon atoms each called 3-phosphoglycerate. This step in the reactions that don't need light is called carbon fixation.Then, the particles that carry energy from the reactions that depend on light play a role. ATP and NADPH provide a hydrogen atom to each 3-phosphoglycerate, resulting in the formation of two molecules of the simple sugar G3P (glyceraldehyde-3-phosphate). In the end, these two molecules of G3P are combined to create one molecule of glucose. This section of the light-independent reactions is usually called reduction (or reducing the sugar) because electrons are added.It's important to know that the Calvin cycle usually uses six molecules of carbon dioxide together. This means that twelve small units called G3P are made. However, out of all the molecules involved, only two are used to make glucose. The others are reused to keep the process going[6].

DISCUSSION

It appears that the carbon atoms in your body came from carbon dioxide molecules in the air. Carbon atoms go into you, and other living things, because of a process called the Calvin cycle, which is part of photosynthesis.

Calvin cycle

In plants, carbon dioxide (CO2) comes into the inside of a leaf through small holes called stomata and moves into the stroma of the chloroplast the place where the Calvin cycle happens and sugar is made. These reactions are also known as light-independent reactions because they do not rely directly on light.In the Calvin cycle, carbon atoms from CO2 (carbon dioxide) are used to build three-carbon sugars. This process needs ATP and NADPH from the light reactions in order to work. The Calvin cycle happens in the inner space of chloroplasts, while the light reactions occur in the thylakoid membrane.The Calvin cycle reactions can be explained in simpler terms.The Calvin cycle has three main parts: carbon gets trapped, then it is used to make sugars, and finally the starting molecule is made again.The nature of this problem is quite complex and requires a thorough understanding of multiple factors in order to find a solution. Carbon fixation is the process by which carbon dioxide from the atmosphere is converted into organic molecules, such as glucose, by plants through photosynthesis (Figure 1). A molecule called CO2 combines with a molecule called ribulose-1,5-bisphosphate (RuBP) which has five carbon atoms. This process creates a compound with six carbons. This compound then breaks apart into two smaller compounds with only three carbons called 3-phosphoglyceric acid. This process is sped up by a special enzyme called rubisco[7], [8].

Reduction means making something smaller or less. In the second step, ATP and NADPH help change 3-PGA into a three-carbon sugar called glyceraldehyde-3-phosphate (G3P). This stage is called the NADPH stage because it gives electrons to a three-carbon substance to create G3P.This step is about providing more information or specific facts about something.The third text is about to be rewritten in simpler words. Regeneration means the process of renewing or replacing something that has been damaged or worn out. Some of the G3P molecules are used to create glucose, while the rest are recycled to make more RuBP. Regeneration needs ATP and involves a series of reactions, known as the carbohydrate scramble according to my biology professor.To make glucose, one G3P needs three CO2 molecules to enter. These CO2 molecules give three new carbon atoms. When three carbon dioxide molecules enter the cycle, they combine with oxygen to produce six G3P molecules (Figure 2). One of the molecules is used to create glucose, while the other five molecules are reused to make three molecules of RuBP.

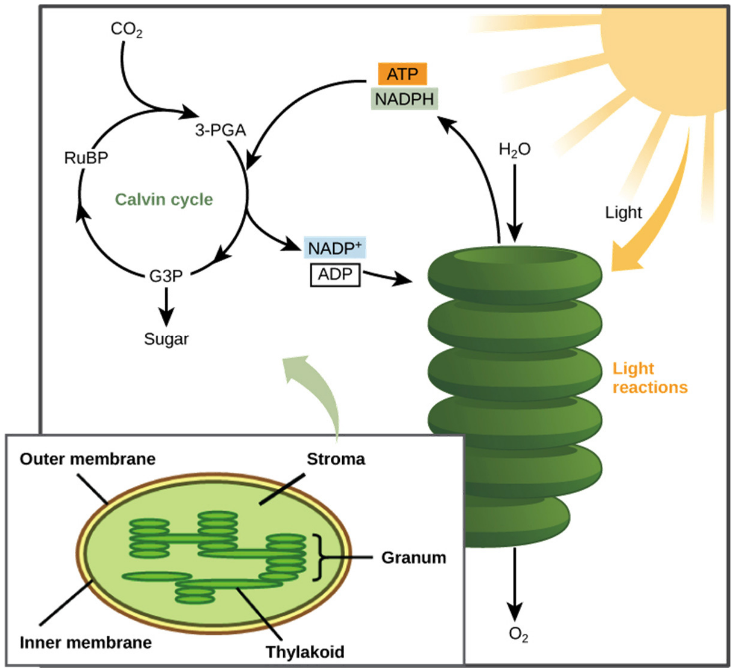

Figure 1: Representing the overview about calvin cycle [Khan Academy].

The Calvin cycle uses carbon dioxide, water, and energy from the sun to make glucose.In simple words, it takes three rotations of the Calvin cycle to create one G3P molecule. This molecule can then leave the cycle and be used to produce glucose. Let's count how many important molecules go in and out of the Calvin cycle when one net G3P is created. In three rounds of the Calvin cycle:3 molecules of CO2 combine with 3 RuBP acceptors to create 6 molecules of glyceraldehyde-3-phosphate (G3P).One molecule called G3P leaves the cycle and helps in forming glucose.ATP is a molecule that gives energy to cells. 9molecules of ATP are changed to 9 molecules of ADP. During the fixation step, 6 molecules are converted, and during the regeneration step, 3molecules are converted.A G3P molecule has three carbon atoms that cannot move. To make a glucose molecule with six carbon atoms, you need two G3Ps. To make one molecule of glucose, it would take six rounds of a cycle, or 6molecules of carbon dioxide, 18 molecules of ATP, and 12 molecules of NADPH.

Photosynthesis is a special process that plants, algae, and some bacteria use to turn light energy into chemical energy. It's very important for life on Earth. The light reactions are a series of events that happen inside the chloroplasts' thylakoid membranes and play a central role in this complicated dance. There are two types of photosystems called Photosystem I and Photosystem II.Photosystems are complex groupings of proteins and pigments that collect and use light energy. Photosystem II (PSII) works by capturing light particles and energizing electrons in chlorophyll molecules. These tiny particles called electrons move through different things, causing energy to flow and create ATP.Photolysis and Oxygen Evolution refer to the process where light energy is used to split water molecules and release oxygen.The captured light energy is used to remove electrons from water molecules in a process called photolysis. Oxygen is given off as a waste product, which helps keep the air we breathe alive and gives back energy to the process of making food[8], [9].

Proton Pumping is the process of moving protons (positively charged particles) across a cell membrane. Chemiosmosis refers to the way in which energy is produced by this movement of protons.As electrons move through the electron transport chain, they push protons (H+ ions) into the thylakoid space, making a difference in the concentration of these protons. This slope helps make ATP using chemiosmosis, which is a process that's like what happens in cellular respiration.Photosystem I is a part of the process in plants that helps produce a molecule called NADPH.Photosystem I captures extra sunlight, giving energy to electrons and making more electron carriers. These carriers help change NADP+ into NADPH, an important molecule that carries powerful electrons to the Calvin Cycle.ATP and NADPH are molecules that provide energy to the Calvin Cycle.The ATP and NADPH made during the light reactions are used as energy and electron sources for the Calvin Cycle. The Calvin Cycle is a process that converts carbon dioxide into sugars.ATP is made during the light reactions and it is used as the energy that cells can use. Breaking down this chemical compound releases energy that helps cells do important tasks like moving stuff in and out of the cell and dividing.

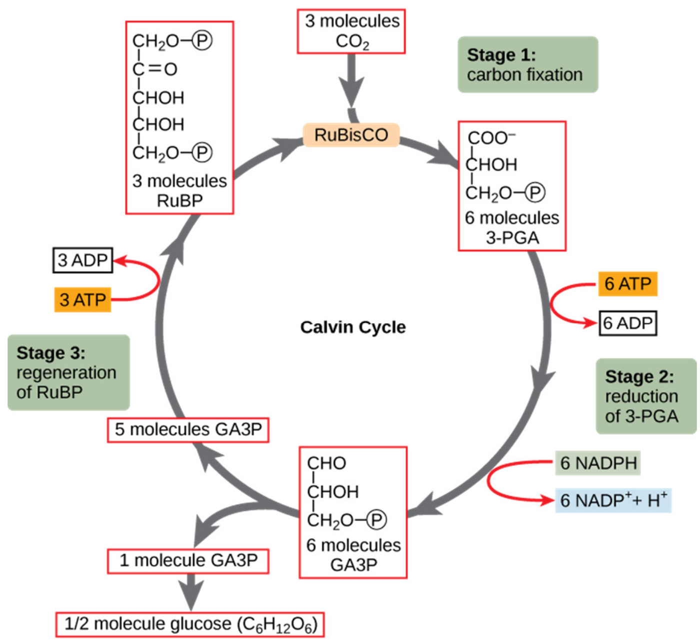

Figure 2: Representing the stages involved in calvin cycle [Biology Libre Texts].

Making Oxygen and the Air In simple words, this text is talking about how oxygen is produced and how it is found in the air.During the light reactions, water gets split and oxygen is released as a result. Oxygen builds up in the air and is important for many living things to breathe and for the makeup of the atmosphere.Environmental adaptation refers to the process of organisms adjusting to their surroundings in order to survive. One specific type of adaptation is photoprotection, which involves protection against the harmful effects of sunlight.Different pigments, like chlorophyll and carotenoids, work together to absorb as much light as possible and protect the photosynthetic machinery from being harmed by getting rid of extra energy as heat.Scientists have been studying how plants use sunlight to make food, and this has given them ideas to create a way for us to make clean energy using the same process. Scientists want to use sunlight to make hydrogen or other types of energy-rich molecules, by copying how light is absorbed and how electrons move in nature.Plants use light energy to create chemical energy in a process called the light reactions. This process is really important for ecosystems and helps living things survive. From the complex arrangement of photosystems to the detailed process of transferring electrons and producing ATP, these reactions are a clear example of how nature is beautifully designed. In simpler terms, the light reactions in plants have the power to revolutionize our energy sources and help us understand how all living things are connected on Earth.

CONCLUSION

In summary, the chapter explains the complicated processes behind photosynthesis in plants. By explaining the process of how plants use light energy for their growth and to help the environment, this chapter has given us a clear understanding of light reactions and the Calvin Cycle.The complex process of capturing energy from light and storing it as chemical energy in cells happens inside special structures called chloroplasts. This happens through a series of steps that involve capturing energy from light particles called photons and converting it into usable energy molecules ATP and NADPH. At the same time, oxygen is given off as an important byproduct, which helps many living things breathe.The Calvin Cycle takes place inside chloroplasts and is a detailed process where carbon is captured and sugars are made. This energy-requiring process uses the results of light reactions to power its own reactions, closely connecting the two stages.The chapter's findings have important meanings that go beyond basic plant biology. They give us ideas for clean and long-lasting energy solutions, as scientists try to copy the way plants make energy from the sun to create new sources of clean energy. Furthermore, knowing about photosynthesis is very important for dealing with worldwide problems like climate change, because it affects the delicate mix of gases in the atmosphere.Basically, this chapter explores photosynthesis and shows how nature cleverly converts energy. By explaining the complicated movement of light and the complex actions of the Calvin Cycle, we can better understand how all the chemical reactions work together to support life on Earth.

REFERENCES:

[1] R. F. Sage, “The evolution of C4 photosynthesis,” *New Phytologist*. 2004. doi: 10.1111/j.1469-8137.2004.00974.x.

[2] M. P. Johnson, “Photosynthesis,” *Essays Biochem.*, 2016, doi: 10.1042/EBC20160016.

[3] O. Ghannoum, “C4 photosynthesis and water stress,” *Annals of Botany*. 2009. doi: 10.1093/aob/mcn093.

[4] J. R. Evans, “Improving photosynthesis,” *Plant Physiology*. 2013. doi: 10.1104/pp.113.219006.

[5] S. Von Caemmerer, “Steady-state models of photosynthesis,” *Plant, Cell Environ.*, 2013, doi: 10.1111/pce.12098.

[6] P. J. D. Janssen, M. D. Lambreva, N. Plumeré, C. Bartolucci, A. Antonacci, K. Buonasera, R. N. Frese, V. Scognamiglio, and G. Rea, “Photosynthesis at the forefront of a sustainable life,” *Frontiers in Chemistry*. 2014. doi: 10.3389/fchem.2014.00036.

[7] L. E. Fridlyand and R. Scheibe, “Regulation of the Calvin cycle for CO2 fixation as an example for general control mechanisms in metabolic cycles,” *BioSystems*, 1999, doi: 10.1016/S0303-2647(99)00017-9.

[8] S. Grimbs, A. Arnold, A. Koseska, J. Kurths, J. Selbig, and Z. Nikoloski, “Spatiotemporal dynamics of the Calvin cycle: Multistationarity and symmetry breaking instabilities,” *BioSystems*, 2011, doi: 10.1016/j.biosystems.2010.10.015.

[9] J. B. McKinlay and C. S. Harwood, “Carbon dioxide fixation as a central redox cofactor recycling mechanism in bacteria,” *Proc. Natl. Acad. Sci. U. S. A.*, 2010, doi: 10.1073/pnas.1006175107.

CHAPTER 4

PLANT PIGMENTS AND PHOTOSYNTHETIC PIGMENT BIOSYNTHESIS

Devendra Pal Singh, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- dpsinghevs@gmail.com

ABSTRACT:

This research shows how plants use and control light energy, revealing the bright colors of nature.The chapter starts by talking about the different types of colors in plants. These colors make leaves, flowers, and fruits look beautiful. This text talks about the importance of chlorophylls and carotenoids in capturing light energy. Chlorophylls are the main pigments that do this job, while carotenoids not only help with light absorption but also protect against too much light.As we keep going, the chapter explains how these pigments are made in the body. This study looks at the complex enzymes and substances involved in making chlorophyll and carotenoid, which are important molecules in plants. This chapter talks about how these pathways are closely controlled to make sure that there is just the right amount of pigment for absorbing light and converting it into energy.This text examines how pigments work and what they do in photosynthesis. It shows how they help create photosystems, collect light effectively, and protect plants from damage caused by light. Additionally, the chapter highlights the importance of different colored substances in helping organisms adapt to different environments and how these substances can be used for communication purposes beyond just capturing sunlight for energy.This chapter helps us understand how plants use and change light energy. It explores how plants make pigments and how this affects the environment. It shows how biology and the beauty of the natural world work together.

KEYWORDS:

Anthocyanin, Chloroplast, Carotenoids, Light Energy, Thylakoids Membrane.

INTRODUCTION

Plants make more than 200,000 different kinds of substances, some of which are colored. Humans can see the color of something by looking at light that bounces off or goes through it. This light has to be between 380 and 730 nanometers. Insects can see colors with light that has shorter wavelengths.

This review will talk about new discoveries in how plants make three different types of pigments that give them their colors: flavonoids/anthocyanins, betalains, and carotenoids. We will talk about how to change the way flavonoids and carotenoids are made. Flavonoids are a kind of chemicals found in plants that can be different colors, ranging from light yellow to blue. Anthocyanins, a type of flavonoids, are the ones that make flowers, leaves, fruits, seeds, and other parts of plants have colors ranging from orange to blue. They can be found in many plants that grow from seeds. They can dissolve in water and are stored in small compartments called vacuoles.

Betalains are substances that are yellow to red in color and contain nitrogen. These substances are made from tyrosine. They can dissolve in water and are stored in small spaces called vacuoles. However, they are only found in a specific group of plants called

Caryophyllales. Carotenoids are natural substances found in plants and micro-organisms that give flowers and fruits a yellow-to-red color. They play an important role in photosystems. Flavonoids/anthocyanins and carotenoids are often found together in the same parts of plants, and when they are combined, they create a wider range of colors[1], [2].

Anthocyanidins are changed by sugars in different ways depending on the family or species. Anthocyanins are often attached to sugars, usually glucose, at either the C3-position or the C5-position. Glycosylation is commonly observed at positions C7′, C3′, or C5′. Adding sugar molecules to anthocyanins causes them to become slightly more red in color. The sugar parts of anthocyanins are often changed by aromatic such as hydroxycinnamic or hydroxybenzoic andaliphatic like malonic, acetic, or succinic groups. Adding aromatic molecules to anthocyanins causes them to appear more blue in color and helps them remain stable. Anthocyanins that have been changed by adding multiple aromatic acyl groups (known as poly-acylatedanthocyanins) can often produce a steady blue color by arranging themselves together. Adding aliphatic acylation does not alter the color, but it makes the substance more stable and able to dissolve easily. Some plants have certain colored substances called 3-Deoxyanthocyanins, like maize, while other plants, like Alstroemeria, have 6-hydroxy anthocyanins. These substances make the plants appear redder than regular anthocyanins[3], [4].

Anthocyanins change color based on the acidity, other colorless substances present (like flavones and flavonols), and certain metals. In a lab setting, anthocyanidins change color depending on the pH level. They are reddish and more stable in an acidic environment with a pH less than 3. They become colorless when the pH is mildly acidic, between 3 and 6. At pH levels above 6, they turn blue and become less stable. When molecules stick together with each other or with flavonoid compounds, it helps to keep anthocyanins stable and makes their color more intense and bluer. Certain metal ions, like $Al3+$ and $Fe3+$, are very important in making blue flowers in hydrangea and tulip. It is important for the colors of the petals of the Himalayan poppy to be a certain shade of blue. This is achieved through a careful balance of different chemicals in the petals. In cornflower, there is a group of molecules that are joined together. These molecules are responsible for the blue color of the flower. They also contain certain ions like iron and magnesium. It is still not known how plants use different parts to create the right colors[5], [6].

DISCUSSION

A color could be a non specific term for a particle that retains light and contains a color. Plants contain numerous shades, giving rise to the different colors we see. Blossoms and natural products clearly contain a expansive number of natural particles that assimilate light. Takes off, stems and roots moreover contain a assortment of pigments. Such shade atoms incorporate anthocyanins, flavanoids, flavines, quinones and cytochromes, fair to title a number of. In any case, none of these ought to be considered a photosynthetic shade. Photosynthetic shades are the as it were shades that have the capacity to assimilate vitality from daylight and make it accessible to the photosynthetic device. In arrive plants, there are two classes of these photosynthetic colors, the chlorophylls and the carotenoids.The capacity of chlorophyll and carotenoid particles to assimilate the vitality of light and utilize it successfully is related to their atomic structure and to their organization inside the cell.

Most arrive plants have two shapes of chlorophyll (Chl), assigned as Chla andChl b. They vary in that Chla contains a methyl (the ruddy -CH3) bunch on the edge of its huge ring (called a tetrapyrrole) which is oxidized to make a formyl (-CH=O) bunch in Chl b. This contrast licenses these two shade atoms to assimilate marginally diverse wavelengths of light.The moment energized singlet state is at a better vitality level from the ground state and requires the assimilation of the vitality in a blue photon (430 to 475 nm) since photons with shorter wavelengths have more vitality. In this way, chlorophyll retains photons from both the ruddy and blue locales of the unmistakable range since it has two energized singlet states. When we see lightreflected by, or transmitted through clears out, we see them to be green. This can be since chlorophylls are the major leaf colors and they don't retain green photons (almost 500 to 600nm). Too notice that the chlorophyll structure incorporates a long hydrophobic chain that's attached to the tetrapyrrole ring by an ester bond. This 'tail' may be a phytyl bunch and makes the complete chlorophyll atom insoluble in water. This insolubility keeps the chlorophyll shades localized inside the chloroplast photosynthetic membranes. Organization into specialized layers inside the chloroplast is fundamental to the secure generation of photosynthetic vitality[7], [8].

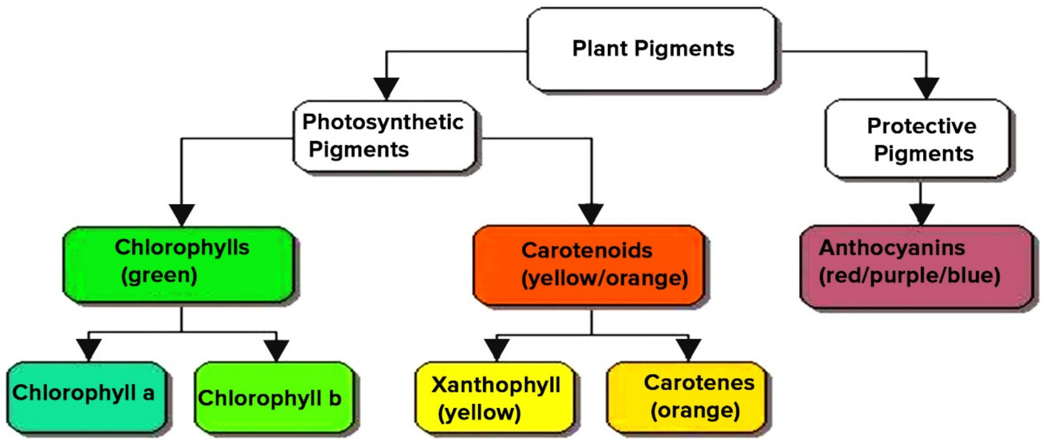

Figure 1: Representing the overview about the plants pigments [Byju's].

Chlorophyll is synthesized within the chloroplast (Figure 1). The primary step changes over the amino corrosive glutamatic corrosive into delta-amino levulinic corrosive. From here, a number of steps build the four cyclic rings that make up the tetrapyrroles. The pathway too incorporates the prerequisite for light within the photochemical response that produces protoporphyrin IX. Components of this chemical pathway are appeared in Figure: Chlorophyll Pathway.Fundamental components of the chemical pathway which synthesize chlorophyll.This is often an critical pathway because it produces tetrapyrrole particles in expansion to chlorophyll. The pathway is indistinguishable up to the point of Protoporphyrin IX, which is created within the chloroplast. Proteins within the chloroplast can then insert a $Mg2+$ into the center of the tetrapyrrole and initiate biosynthesis of chlorophyll, or can insert $Fe2+$ into the tetrapyrrole to create heme. Protoporphyrin IX is additionally exported from the chloroplast to the mitochondrion, where it is utilized to create a tall plenitude of cytochromes in that organelle. This pathway is additionally imperative since heme serves as a substrate in the generation of phytochrome, which could be a light detecting atom fundamental for typical photomorphogenesis. Hence, items of the tetrapyrrole pathway are included in photosynthesis (chlorophylls and cytochromes within the chloroplast), breath (cytochromes within the mitochondrion) and advancement (phytochrome).

Carotenoids are a type of natural pigment found in plants and some other organisms. They give fruits and vegetables their vibrant colors, like the red in tomatoes or the orange in carrots. Carotenoids are also important for our health, as they act as antioxidants and can help protect our bodies from damage caused by harmful molecules called free radicals. It's good to include carotenoid-rich foods in our diet, as they can provide various benefits for our overall well-being.Another group of pigments that can carry out photosynthesis is called carotenoids. Many plants have different types of carotenoids, like beta-carotene, lutein, neoxanthin, and violaxanthin. The basic building block of their structure is made up of a repeating pattern of branches and five carbon atoms. Molecules made up of these units with five carbons are commonly known as isoprenoids. The carotenoid structures have patterns of double bonds that can absorb light.Most carotenoids, which are compounds found in plants, absorb blue light and look yellow. However, lycopene, a carotenoid found in tomatoes, absorbs red light and gives them their red color[9], [10].

Carotenoids are made using a pathway called the isoprenoid pathway. fragrances, vitamins), and pigments. Vitamin A is a nutrient found in certain foods, like fruits and vegetables. Steroids are substances used in medicine to help with inflammation or other health issues. Rubber is a material that is stretchy and used in various products, like tires or rubber bands. Biochemistry is a process where five-carbon units are added in a row (or in multiples of five) and then they are changed, arranged in circles, and functional groups are added. The pathway is important because it helps make chlorophyll by using geranylgeranyl pyrophosphate to create a phytyl group. The production of carotenoids happens in the outer layer of the chloroplast, not inside the inner layer where chlorophyll is found.Chlorophyll is a harmful substance. This happens because it can easily damage cells when it comes into contact with light. To stop harm from happening, the formation and production of chlorophyll is managed very carefully. All the green pigment called chlorophyll is found in a specific part of the cell called the chloroplast.

The chloroplast has a protective cover called the 'envelope' made up of two membranes. The part inside the chloroplast that dissolves in water and doesn't have a membrane is called the 'stroma'. Inside the chloroplast, there is a system of membranes called the "thylakoid membranes" where chlorophyll is located.Chloroplasts are enclosed by envelope membranes and have a bunch of membrane structures called thylakoids. These thylakoids can also come together to form structures that look like stacks of coins, which are called grana. Chlorophyll is found inside of the thylakoid membranes.Even in the thylakoid membrane, the chlorophyll molecules are not alone, but instead they are part of a group with other proteins called photosynthetic pigment-protein complexes. The green pigment called chlorophyll in plants is attached to certain proteins in the cell membrane, including carotenoids. These proteins and other essential substances help with the process of photosynthesis. The proteins create a structured environment where the chlorophylls can absorb light, but harmful reactions are not very common. The groupings of pigment-protein complexes are organized into collections of many pigment molecules, which are known as photosystems. Because of how they are arranged and shaped, most of the pigments work as collectors of light and pass on the energy to other pigments before any unwanted chemical reactions happen. The carotenoids have two jobs in this place. First, they collect sunlight and give it to chlorophyll molecules. Also, they are very good at stopping triplet chlorophylls from reacting with oxygen and causing harm[11], [12].

Photosynthesis is the process by which plants, algae, and some bacteria convert sunlight, carbon dioxide, and water into food energy in the form of glucose.Inside the thylakoid membrane, there are two different photosystems called Photosystem I (PSI) and Photosystem II (PSII). These functions use light photons to obtain energy. Pigment-protein complexes have special parts that help them capture the energy from photosynthesis. The thylakoid membrane has two different sections called photosystems. Each has a collection of antennas which contain green pigments called chlorophylls and other pigments called carotenoids.In this picture, we can see how antenna pigments are arranged in one photosystem. These pigments make up most of the pigment molecules in the photosystems.They are only responsible for collecting light energy and giving it to a few pigment-protein complexes called reaction centers. In the reaction center, the energy from a photon is used to make an electron more excited and move it to a higher energy level. This electron is then transferred to a different molecule that has an even higher energy level. The molecule that accepts something is then thought to be made smaller or lessened in some way. This means that photons are used to increase the energy of electrons. When the reaction center gives away an electron, it becomes oxidized and can take in electrons from an outside source.Two Photosystems are structures found in the thylakoid membrane of chloroplasts. They are responsible for capturing light energy during photosynthesis. The first photosystem, known as Photosystem II, absorbs light with a wavelength of 680 nanometers. This energy is used to split water molecules into hydrogen ions and oxygen gas. The second photosystem, known as Photosystem I, absorbs light with a wavelength of 700 nanometers. This energy is used to produce energy-rich molecules, such as ATP, which are essential for the process of photosynthesis. Overall, the two photosystems work together to convert light energy into chemical energy, enabling plants to produce food and oxygen.

Plants developed the ability to take electrons from water and move them to a molecule called NADPH, which helps with important chemical processes in the plant's body. The issue is that one tiny particle of light doesn't have enough energy to make an electron move to a higher energy state in just one try. Plants use two photosystems to excite electrons with two photons in a row. A photosystem is a group of pigments that capture light and use it to create chemical reactions. The reaction centers of the photosynthetic photosystems are special pigments called P-680 and P-700.In simpler words, a photon is initially caught by pigments in Photosystem II. The energy from the photon is then given to an electron in a pigment called P-680, which is in the reaction center. The supercharged electron in P-680* moves to plastoquinone (PQ) through a protein called D1. This electron is moved to Photosystem I eventually. A second particle of light is also caught by Photosystem I. The energy from the light is then transferred to a pigmented molecule called P-700 in the center of the system's reaction. The electron that gets excited in P-700 moves to NADP+ with the help of a protein called ferredoxin (Fd), which creates NADPH. When P-680* and P-700* give away their high-energy electrons, they lose an electron and become oxidized.

To make the system neutral again and ready to repeat the process, electrons move from water to P-680, creating O2. Electrons from PQ (originally given by P-680) are transferred to P-700 through cytochrome and plastocyanin intermediates. In simple terms, this means that the energy in photons is absorbed by pigments and used to move electrons from water to a higher energy level, resulting in the creation of NADPH. The cell uses the strong energy of the electrons in NADPH for many reactions that make things smaller. Click on this link to watch a pretend video that helps explain this process in a clearer way. The production of anthocyanin is controlled by several hormones, like IAA and JA. Overproducing MdIAA26 in apples can increase the production of anthocyanin by increasing the activity of genes involved in anthocyanin synthesis. In Arabidopsis, there is a protein called AtJAZ1 that can interact with other proteins called AtTT8, AtGL3, and EGL3. When this happens, it disrupts the function of a complex called MBW, which leads to a problem activating another protein called AtDFR. As a result, anthocyanin production decreases.

The AtDELLA1 protein can connect with AtMYBL2 and AtJAZ1. When DELLAs and MYBL2/JAZs interact, it causes the release of bHLH or MYB parts and creates active MBW complexes. This helps in the production of anthocyanin, a pigment responsible for coloring plants. There is more and more proof that plant miRNAs are very important in controlling the process of making anthocyanin. For instance, the miR156-SPL9 module controls the creation of anthocyanin. Recently, scientists discovered that applying a certain type of small molecules called miPEP164c can make plants produce more anthocyanins, which are natural pigments that give fruits and flowers their bright colors. Furthermore, DNA methylation also impacts the production of anthocyanin by affecting certain genes like MdMYB10 and MdMYB1. Furthermore, in certain types of citrus plants and cultivated variants, Ruby acts as a protein that controls the production of anthocyanin. White mutant lemons couldn't produce anthocyanin because they didn't have the necessary genes. Additionally, it was discovered that Noemi is a type of protein that controls the production of certain pigments in citrus fruits. This protein also plays a crucial role in the differences in pigmentation seen in different citrus varieties.

CONCLUSION

The study of chlorophylls and carotenoids highlights their important role in photosynthesis. These pigments collect light energy and also adjust the range of light they can absorb, to make energy conversion more efficient and protect against too much light which could cause harm. The interaction of these pigments in the photosystems shows how they work together to create a perfect group that absorbs energy.The complex paths that plants follow to make pigments show how detailed and advanced plant chemistry is.

The chapter explains how plants make and control pigments like enzymes, intermediates, and regulatory mechanisms. This helps plants use sunlight for energy even when conditions are different.Pigment diversity is important for more than just looks.

The way pigments change to fit different environments shows how important they are for evolution. Plants need pigments to survive in different places like mountains and oceans. Pigments help plants capture and use light, and also respond to their environment.In simple words, this chapter helps us understand and enjoy how plants and the beautiful things in nature are connected. When we learn more about how plants make pigments, it helps us understand how plants can adapt to their environment. This is important because plants are the basis for ecosystems around the world. It also has practical uses in areas like farming, creating renewable energy, and keeping track of the environment.As we learn more about pigments, we also gain a better understanding of how life on Earth is sustained and find ways to create a healthier and more sustainable future.

REFERENCES:

[1] G. A. Blackburn, “Hyperspectral remote sensing of plant pigments,” *J. Exp. Bot.*, 2007, doi: 10.1093/jxb/erl123.

[2] Y. Tanaka, N. Sasaki, and A. Ohmiya, “Biosynthesis of plant pigments: Anthocyanins, betalains and carotenoids,” *Plant Journal*. 2008. doi: 10.1111/j.1365-313X.2008.03447.x.

[3] V. O. Silva, A. A. Freitas, A. L. Maçanita, and F. H. Quina, “Chemistry and photochemistry of natural plant pigments: the anthocyanins,” *J. Phys. Org. Chem.*, 2016, doi: 10.1002/poc.3534.

[4] A. Gengatharan, G. A. Dykes, and W. S. Choo, “Betalains: Natural plant pigments with potential application in functional foods,” *LWT*. 2015. doi: 10.1016/j.lwt.2015.06.052.

[5] M. Bhogaita, A. D. Shukla, and R. P. Nalini, "Recent advances in hybrid solar cells based on natural dye extracts from Indian plant pigment as sensitizers," *Solar Energy*. 2016. doi: 10.1016/j.solener.2016.08.003.

[6] T. S. Bianchi, C. Rolff, and C. D. Lambert, "Sources and composition of particulate organic carbon in the Baltic Sea: The use of plant pigments and lignin-phenols as biomarkers," *Mar. Ecol. Prog. Ser.*, 1997, doi: 10.3354/meps156025.

[7] P. Sudhakar, P. Latha, P. V. Reddy, P. Sudhakar, P. Latha, and P. V. Reddy, "Chapter 15 – Plant pigments," *Phenotyping Crop Plants Physiol. Biochem. Trait.*, 2016.

[8] T. S. Bianchi, A. Demetropoulos, M. Hadjichristophorou, M. Argyrou, M. Baskaran, and C. Lambert, "Plant pigments as biomarkers of organic matter sources in sediments and coastal waters of Cyprus (eastern Mediterranean)," *Estuar. Coast. Shelf Sci.*, 1996, doi: 10.1006/ecss.1996.0008.

[9] C. F. Timberlake and B. S. Henry, "Plant pigments as natural food colours," *Endeavour*, 1986, doi: 10.1016/0160-9327(86)90048-7.

[10] D. LEE, "Plant pigments and their manipulation. Annual Plant Reviews Vol 12. Davies KM, ed. 2004. Oxford/Boca Raton: Blackwell Publishing/CRC Press, Boca Raton. £110 (hardback). 352 pp.," *Ann. Bot.*, 2005, doi: 10.1093/aob/mci287.

[11] N. Nakajima, M. Sugimoto, H. Yokoi, H. Tsuji, and K. Ishihara, "Comparison of acylated plant pigments: Light-resistance and radical-scavenging ability," *Biosci. Biotechnol. Biochem.*, 2003, doi: 10.1271/bbb.67.1828.

[12] B. Kräutler, "Phyllobilins-the abundant bilin-type tetrapyrrolic catabolites of the green plant pigment chlorophyll," *Chemical Society Reviews*. 2014. doi: 10.1039/c4cs00079j.

CHAPTER 5

PLANT LIPIDS: STRUCTURE, BIOSYNTHESIS AND FUNCTIONS

Upasana, Assistant Professor,
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- upasana35954@gmail.com

ABSTRACT:

The chapter explores the complex topic of lipids in plants and how they are made and used. This study explores the different and important ways that lipids are involved in the lives of plants.The chapter starts by talking about the different types of fats found in plants. These can be as simple as fatty acids or more complex like phospholipids and triacylglycerols. This information emphasizes the many different types of lipids and how important they are for building membranes, storing energy, and creating important signaling molecules.As the story goes on, the chapter explains how plants make lipids. This text explores how different types of fats are made in our body. It looks at the processes and rules that control the creation of fats, such as making fatty acids longer and adding double bonds, forming phospholipids, and creating lipid droplets.The importance of plant fats is the main focus of this chapter, as it explains how these molecules help with important plant processes. This text looks at how lipids help with the flexibility and strength of cell membranes, store energy, and keep the body at a stable temperature. In addition, this chapter talks about how lipids are involved in signaling in the body, like responding to stress and regulating hormones. It shows that lipids have important roles that go beyond just their structure and metabolism.In simpler terms, this chapter talks about how plant fats can affect the environment and farming. This text is about how lipids in plants help them respond to environmental changes like drought and temperature stress. Lipids also play a role in making crops more nutritious.Lipids are very important in many parts of plant biology because they have different structures and do many different things. This information helps us learn more about how plants work and can be useful in farming, technology, and helping plants adapt to their environment.

KEYWORDS:

Acids, CutinSuberin, Enzymes, Fatty, Plants.

INTRODUCTION

Plants have many different types of fats that are very important for their cells. They are necessary for keeping cells and organelles intact by creating a waterproof barrier for the membrane. Also, seeds store lipids as a type of energy. In addition, they work as a signal that helps control how cells function. The main type of fat in plants is called glycerolipid. In glycerolipid, the fatty acid is attached to glycerol through a chemical bond called ester-linkage. Making fats in a cell involves many small organs. Fatty acids are made in chloroplasts and then joined with glycerol to form a galactolipid, which is an important part of the chloroplast membrane. The fatty acids are later moved to the cytoplasm where they combine with glycerol in the endoplasmic reticulum to become a phospholipid of the cell membrane. In the cells of the seed, fat called triacylglycerol (TAG) is made and kept in a part called the oil body. Also, in the outer layer of the cell, fatty acid changes into parts of a substance called cutin and wax. These substances are lipids that protect the cell from losing water. Researchers have discovered how fatty acids, glycerolipids, and triacylglycerols are made by studying mutant plants called Arabidopsis. Lately, scientists have been doing research on finding molecules that control the production of fats, the importance of certain fats in plant photosynthesis, how plants make and move certain fats on their surfaces, and how fats change during growth and when plants experience difficult conditions. Scientists are currently working on ways to make plant oil better for different uses. They are studying how to change the types of fats in the oil and make more oil[1], [2].

In plants, new fats are mostly made in a part called plastid from a substance called acetyl CoA, which comes from photosynthesis. Plastid pyruvate dehydrogenase is an enzyme that helps produce a substance called acetyl CoA, which is needed for the body to function properly. This enzyme works on a substance called pyruvate, which is made during the process of breaking down sugar in the body. It is a quick and reliable way to produce acetyl CoA. Another way that acetate can be obtained is by using acetyl CoA synthase. The main thing produced by FAS is palmitic acid, except for when chloroplasts make palmitic acid longer or change stearic acid. Other changes like stretching, removing saturation, adding oxygen, and creating new bond structures mostly happen in a cell organelle called the endoplasmic reticulum.Two enzyme systems are needed for making fatty acids: acetyl CoA carboxylase (ACCase) and fatty acid synthase. ACCase has two different forms in plants, while fatty acid synthase is a group of enzymes found in the stroma of chloroplasts.The first enzyme complex is called ACCase. It helps a process where ATP helps to change acetyl CoA to malonyl CoA. In simple terms, acetyl CoA carboxylase (ACCase) helps plants move carbon from photosynthesis to different parts of the plant. Researchers have discovered two different types of ACCase molecules one is a mixture of many proteins, and the other is a single protein that can perform different functions[3], [4].

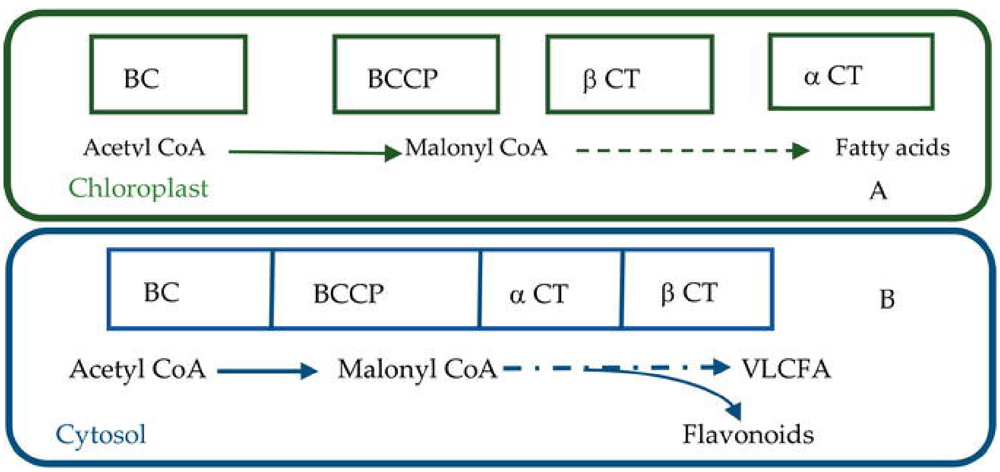

Figure 1: Representing the structure of two types of ACCase [Intechopen.Com].

The multisubunitACCase is a complex found in the plastids of all plants except for Poaceae and Geraniaceae. It is responsible for making new fatty acids (Figure 1). It is made up of four separate parts: biotin carboxyl carrier protein (BCCP), biotin carboxylase (BC), and α and β carboxytransferase (α and β CT). The BC subunit helps change biotin on BCCP using ATP, while the CT subunits help transfer carboxyl groups from BCCP to acetyl CoA to make malonyl CoA.The MF ACCase is made up of different parts called BCCP, BC, and CT. It is made by our cells except for a part called αCT which is made by the plastidial genome. In every plant, MF ACCase helps make long fatty acids and flavonoids in a part of the cell called the cytosol.In simple words, the text says that the sensitivity of a certain enzyme in soybean plants, called plastidialACCase, to a chemical called sethoxydim, and the presence of a specific protein in the plant cells, suggests that there may be two different forms of this enzyme in the leaves of soybean plants - one that is resistant to sethoxydim (called MS) and one that is sensitive to it (called MF).The second group of enzymes involved in making new fatty acids is called fatty acid synthase (FAS). In nature, fatty acid makers are split into two groups. The fatty acid synthase type I is a big protein found in yeast and mammals. It does many different things. The fatty acid synthase type II is found in prokaryotes. It is made up of four separate proteins that work together to make fatty acids. Plant cells are a type of eukaryotic cell. The fatty acid synthase that is found in plastids in these cells is called type II . The fatty acid synthase in plants came from small bacteria that can do photosynthesis. These bacteria were then turned into a part of plant cells called plastids. Scientists think these plastids used to be a type of bacteria called cyanobacteria. In plants, acyl carrier protein (ACP) is used to carry the different parts of fatty acid synthase. This is different from other cells that use acyl CoA form for fatty acids.

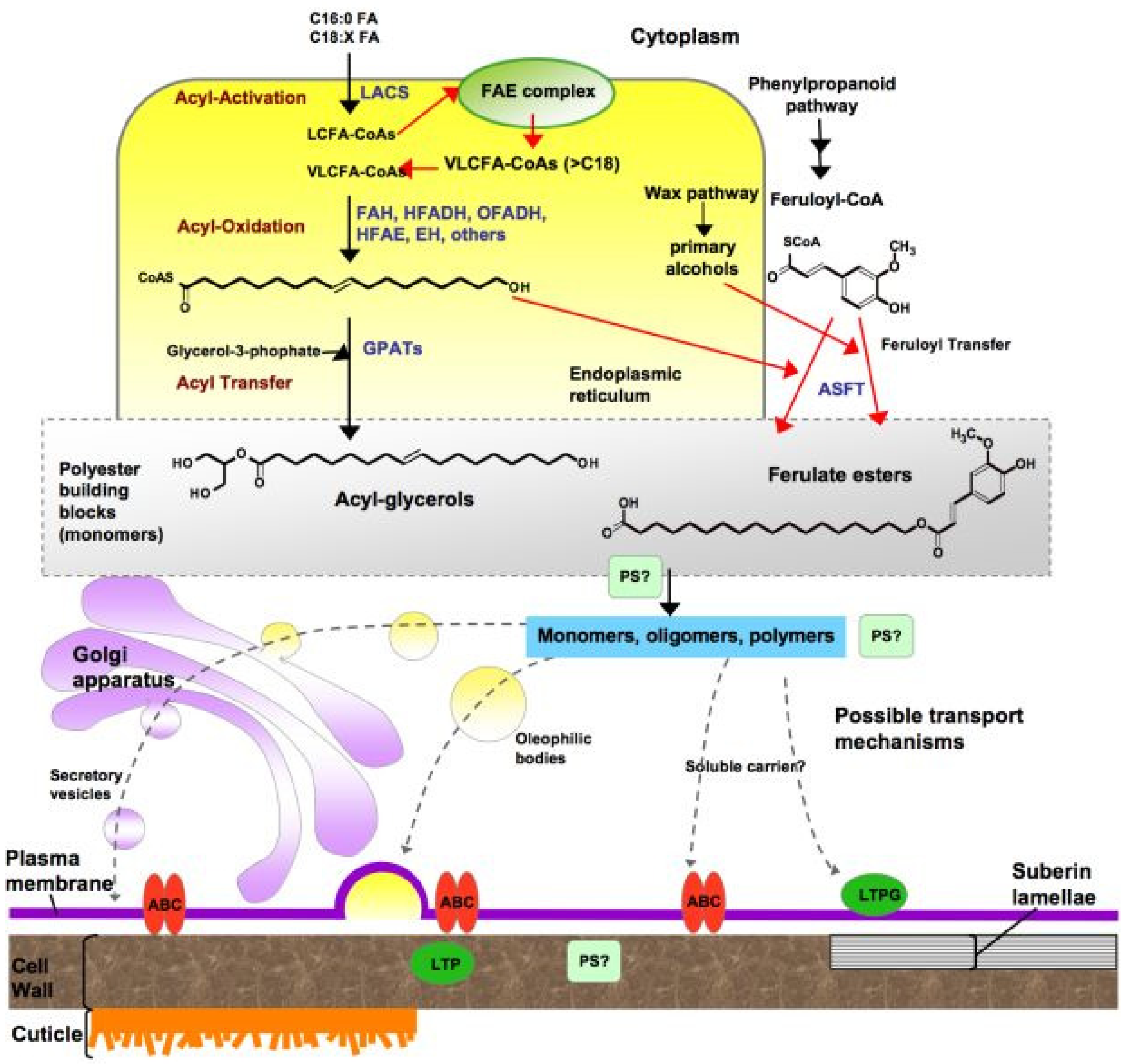

Figure 2: Representing the possible steps involved in the lipid polyester synthesis [Lipid Library].

The starting materials for making fatty acids are acetyl CoA and malonyl-ACPs. The movement of a chemical called malonyl from CoA to ACP is helped by a specific enzyme called malonylCoA:ACPtransacylase (MAT). After acetyl CoA and malonyl-ACP combine, all the substances involved in each step of the fatty acid creation process are acyl-ACPs.AGS is made up of four enzymes: KAS, β-ketoacyl-ACP reductase, hydroxy acyl-ACP dehydrase, and enoylacyl-ACP reductase. All parts of fatty acid synthase are found in plastids, even though they are made using instructions from the cell's nucleus and are made in the cytoplasm. There are four steps that happen one after the other in the process of adding two-carbon molecules together.The first condensation happens when acetyl CoA combines with malonyl-ACP. This reaction is carried out by an enzyme called 1,3-ketoacyl-ACP synthase III (KAS, EC 2. 3141), which is one of three enzymes responsible for this process in plants. KAS I is responsible for making the condensations during each elongation cycle until it produces palmitoyl-ACP (a type of molecule). KAS II helps in making palmitoyl-ACP into stearoyl-ACP[5], [6].

During the condensation reaction, the β-ketoacyl-ACP is formed. This compound then goes through a series of reactions. First, it is reduced by the enzyme β-ketoacyl-ACP reductase. Next, it is dehydrated by the enzyme β hydroxyacyl-ACP dehydratase. Finally, it undergoes another reduction by the enzyme enoylacyl-ACP reductase to produce butyryl-ACP. The special molecule used in two chemical reactions is called NADPH. The butyryl-ACP that is created will get longer by adding two more groups of two carbon atoms each when it combines with malonyl-ACP. The β-ketoacyl-ACP synthase I (KASI) performs this reaction. After going through seven rounds of a cycle, palmitoyl-ACP is produced.Although the end result of fatty acid synthase is palmitic acid, two other commonly found fatty acids are made in the chloroplast stroma. These are fatty acids called stearic and oleic acids. The process of creating a stearoyl-ACP (C18:0-ACP) chain involves extending the palmitoyl-ACP (C16:0-ACP) by adding two new units. This is done by a complex of four enzymes called plastid soluble stearoyl-ACP synthase. The enzymes involved in this complex are KASII, enoyl-ACP reductase, hydroxyacyl-ACP dehydrase, and enoylacyl-ACP reductase[7], [8].

The stearoyl-ACP that was made earlier is desaturated by a soluble enzyme called stearoyl-ACP desaturase (SAD). 192) in oleoyl-ACP (a type of fat molecule called C18:1Δ9-ACP). This enzyme is a type of protein found in the nucleus, and it is located in a part of the cell called the plastid (Figure 2). It helps to change a type of fat called saturated fatty acid by adding a double bond. This change is known as the conversion of 18:0-ACP into 18:1Δ9-ACP. Plant and mammalian desaturases are different because they work with different substances. Plant desaturases use ACP as their carrier, while mammalian desaturases use CoA. They also use different electron donors. Plant desaturases use ferredoxin, while mammalian desaturases use NADH. Cytochrome b5 is an enzyme found in plants, animals, and fungi. The plant enzyme can dissolve in a liquid, while the animal and fungal enzymes are part of the cell membrane. This molecule is very important in deciding how many saturated and unsaturated fats there are.

DISCUSSION

All plants need barriers that control the movement of water, solutes, and gases. These barriers also help the plants interact with the environment. Cutin and suberin are two different types of plant materials that cannot dissolve in water. They are made up of fatty acids and glycerol and form the structures of barriers in plants. Cutin is what makes up the structure of the cuticle. The cuticle is a film that covers the surface of plants and keeps water out. It is a very important part of plants. Suberin is constantly made by different cells inside and outside of a thing as it grows, and can also be created to protect against pressures from the surroundings or injuries. Although cutin and suberin are similar in structure and function, they are different in where they are found and what they are made of.The study of lipid polyesters has been difficult and progress has been slow because they are structurally complex and hard to dissolve. But, a lot of progress has been made in the past ten years because of tools that scientists have created for studying a plant called Arabidopsis thaliana. These sections give a brief explanation of what we currently know about the structure and how lipid polyesters cutin and suberin are made. It also provides some basic information on what they do and how they behave chemically. This text is not about other types of lipids found on the surface of stigmas or pollen grains, or how cuticular waxes and suberin-associated polyaromatics are produced.The cuticle is a protective layer on plants that helps them retain water and stay safe from harm. Cutin is a special substance found in the cuticle that provides extra strength and durability to this layer.Occurrence means something that happens or exists.

Some plants have a protective outer layer called a cuticle. This layer keeps them from drying out and also helps them resist harmful things like bugs and the sun's rays. The outer layer of plants called the cuticle also helps in controlling the exchange of gases that don't involve the stomata. Certain types of cuticular mutants have physical characteristics that indicate that the cuticle also helps to keep organs apart as they develop. The cuticle is a layer that protects the outer surface of leaves, stems, flowers, and fruits. Internal cuticles can also be found inside seed coats and lining the substomatal cavity.In simple terms, the plant's outer layer, called the cuticle, is mainly made up of substances that repel water. These substances are called cutin and cutan, which are insoluble polymers. The cuticle also contains a mixture of waxes that can be dissolved in chloroform. These waxes are found on the plant's surface as well as inside its outer layer. The hard outer layer of a plant called the cuticle sometimes looks shapeless when viewed under a special microscope, but in certain plants, it has layers like a sheet.

Cuticles have different layers based on where they are and what they are made of. The first layer is called the cuticular layer, which is connected to the cell wall and contains polymers, waxes, and polysaccharides that go from the cell wall. The second layer is called the cuticle proper, and it is made up of cutin and waxes. Finally, there are epicuticular waxes that cover the cuticle proper. The thickness and composition of these layers vary based on the type of species, where they are located in the body, and how old they are. The outside layer of leaves, called the cuticle, can vary in thickness from very thin to slightly thicker. It can have a amount of cutin, a substance, that ranges from a little to quite a lot. In fruits, the amount of cutin can be up to 1. 5 milligrams per square centimeter.Cutin is a type of plastic made from fatty acids and glycerol. The breaking apart of ester bonds creates smaller molecules called monomers. These monomers usually contain ω-hydroxy and ω-hydroxy-epoxy fatty acids. These fatty acids come from C16 saturated and C18 unsaturated fatty acids. Small amounts of hydroxycinnamic acids have also been found as parts of structures. Dicarboxylic acids are usually found in suberin, but they are also important building blocks in the cuticles of Arabidopsis thaliana and Brassica napus[9], [10].

But, the most common building block in these plants is a substance called C18:2 dicarboxylic acid. Normally, this substance is only found in very small amounts in suberins. Cutan is a type of polymer that stays as a solid part after the process of breaking down cutin. It is believed to be made up of primarily cutin monomers that are joined together by ether and C-C bonds. Cuticular waxes are made up of long chains of molecules called alkanes. They can also have other molecules added to them, like fatty acids, alcohols, aldehydes, and ketones.Suberin has the same building blocks as cutin, which are fatty acids and ω-hydroxylated monomers. It also contains alcohols, α,ω-dicarboxylic acids, and ferulate, which are special markers for suberin. For suberin, the process involves making the chains longer and changing ω-hydroxy acids into dicarboxylic acids. But, research on Arabidopsis plants has found that dicarboxylates are not only found in suberin, and that the same genes are involved in making both types of polyesters. So, when the chain of molecules in a substance called suberin is longer than C20, there are more aromatics present, and primary alcohol is synthesized, we can say that these substances are closely related to suberin. This text is about summarizing what is currently known about how cutin and suberinaliphatics are made and put together.Kolattukudy's group conducted experiments 30 years ago to study how C16 and C18 monomers are oxidized. They used radiolabeling techniques to understand the processes involved in cutin formation. protecting) the underlying cells from damage. Slices of potatoes helped in healing wounds by repairing damaged tissues. Because the enzymes that make cutin/suberin monomers might be connected to cell membranes or be part of enzyme groups, scientists have not been able to isolate these proteins using biochemical methods. Some types of plant fatty acid ω-hydroxylases were found to work in yeast, but it was not proven that they are involved in cutin or suberin. So, scientists have found that using genetic methods is very helpful in understanding how living things make different substances. Scientists have found some plants that have changes in their outer covering called the cuticle. These plants either look like other plants that have been changed in a lab to have more of a certain enzyme, or they get sick more easily. More research on measuring lipid polyester monomers in Arabidopsis plants enabled scientists to find new genes that are involved in making lipid polyester. Finding potential genes has been made easier by studying the genetic makeup of Arabidopsis and cork tree epidermis. Researchers have also benefited from accessing public databases containing data from microarray experiments. Reverse genetics has also been used recently to show how genes that make suberin in the outer layer of potatoes work.

The building blocks for making lipid polyesters are fatty acids, specifically C16 and C18 fatty acids that are found commonly in cells. In suberin, certain substances called acyl precursors are made longer by enzymes in the fatty acid elongation complex. This process produces very long chains called acyl-CoAs. Fatty acyl chains go through a series of changes, such as being converted to coenzyme A thioesters, getting oxidized, and then combined with a glycerol-based substance to make acyl glycerols. These acyl glycerols can be used to create lipid polyester building blocks. Due to not knowing which substances are used by the biosynthetic enzymes, we are not sure about the sequence of these reactions. Figure 4 shows the main steps in making lipid polyester. It shows one possible sequence of these steps. The report says that monomer production happens in the endoplasmic reticulum (ER) based on the protein fusions and membrane targeting predictions at the subcellular level.

Members of the LACS family are needed to make polyester. Mutants of LACS2 without knockout have a problem with their outer layer, which has less of a certain molecule. This shows that a particular step in the creation of the outer layer requires the help of LACS2. Lab tests show that this enzyme can break down both regular fatty acids and a specific type called ω-hydroxylated fatty acids. However, we are not sure which step in the process happens inside the body. Furthermore, researchers have recently discovered that LACS1 is an enzyme that mainly activates C16 fatty acids in the creation of cutin. The outer layer of lacs1lacs2 double knockout plants is easier for things to pass through and has less cutin compared to either parent. This suggests that LACS1 and LACS2 have similar roles in making cutin.Acyl esterification is a process where an acyl group and an alcohol combine to form an ester.

Because glycerol plays a crucial role in connecting cutin and suberin molecules together, a special enzyme called acyltransferase is required to create acylglycerols. Several genes in the Arabidopsis GPAT family have been studied using different methods to understand their function in making lipid polyester. GPAT5 is a gene that produces a protein called an enzyme. This enzyme helps move certain molecules called aliphatics from one place to another in the seed coat and root of a plant called Arabidopsis. These aliphatic molecules have a size between C20-C24, and they are transferred to a molecule called glycerol. In the leaf and stem, it was found that the GPAT4 and GPAT8 genes are needed for the production of the main building blocks of cutin. The GPAT6 gene contains instructions for making a protein called an acyltransferase. This protein mainly uses C16 aliphatics to make flower cutin. The enzymes that transfer acyl groups for the production of plant membrane and storage lipids are different from the ones involved in cutin and suberin production. These enzymes transfer acyl groups to the sn-2 position instead of the sn-1 position.

Substances called glycerol esters are attached to different compounds called aliphatics and hydroxycinnamic acids in suberin waxes. Also, ferulic acid esters are connected to very-long-chain fatty alcohols in these waxes. These structures could be added to the suberin polymer by an enzyme called peroxidase, which would explain why the polyester is not able to dissolve. In addition, some ferulate combined with glycerol and ω-hydroxy fatty acids was set free when the substance was partially broken down. Feruloyl-transferase activity was seen in potato tubers and tobacco cell suspensions, but the enzymes responsible for the hydroxycinnamoyl-transferase reaction were not found in those studies. New studies have found that a certain enzyme in plants called BAHD helps transfer a molecule called ferulic acid to protect the seeds and roots. This enzyme has been found in Arabidopsis plants and potatoes. ASFT helps transfer a compound called feruloyl-CoA to ω-hydroxy fatty acids and fatty alcohols. Even though asft mutants have only 5% of the normal ferulate in suberin, the polyester still cannot dissolve. So, this trait challenges the theory that esterified ferulate is an important connection between the fatty and fragrant parts.Transport processes refer to the movement of substances, such as molecules or ions, from one place to another. This movement occurs through various mechanisms, such as diffusion, which is the movement of molecules from an area of high concentration to an area of low concentration. Other transport processes include active transport, which requires energy and moves molecules against their concentration gradient, and osmosis, which is the movement of water molecules across a semipermeable membrane. These transport processes are important for various biological functions, such as nutrient uptake, waste removal, and cell communication.

We don't know much about how certain substances, like fatty acids, acylglycerols, or oligomeric esters, get transported to where they are needed for making lipid polyesters. The text suggests that oil-loving bodies or vesicles may be involved in transporting substances in rice internodes, based on the study of their structure. Some other ways that things can move around in cells include ABC transporters and LTPs. A gene called WHITE-BROWN COMPLEX 11 (WBC11) has been found to affect the transportation of polyester materials in plants. Mutations in this gene cause a reduction in the levels of cutin and root suberin in plants. This suggests that the WBC11 gene is involved in moving polyester materials within the plant. LTPs are small proteins that can help move fatty acids or acylglycerols through cell walls to where they need to be joined together. However, there is no direct proof of this role. However, experiments on mutants indicated that a type of protein called LTPG1, which is anchored to the cell membrane by a molecule called GPI, might play a role in moving lipids in the outer layer of Arabidopsis plants. We don't know how the lipid substrates of WBC11 and LTPG1 get to the plasma membrane from where they are made.

The enzyme that puts cutin pieces together to make a larger substance (a polymer). It is still not clear how plants produce polyester. Scientists are not sure if the reaction happens inside the cell or outside of it. Fungal lipases have the ability to combine suberin building blocks in a lab setting. Because of this, lipases are thought to work as enzymes that have two different functions. Scientists have used genetic methods to discover a special enzyme called BODYGUARD (BDG) that is found only in the outer layer of plant cells. This enzyme helps to make a substance called cutin, which is important for the structure of plants. In addition, scientists have discovered an enzyme in the outer layer of Agave americana leaves that is part of a group of enzymes that might help make new substances for the plant's protective layer. This enzyme may be responsible for breaking down and moving pieces of molecules used in creating this layer. In addition to lipases, there is a gene called Defective InCuticular Ridges (DCR) that belongs to the BAHD family of acyltransferases. This gene is thought to help in putting together polymers. None of these potential polyester synthases have been found to have any biochemical activity.

Lipid polyesters are made during normal growth and in response to different types of stress, along with wax, especially in a substance called suberin, and in a pathway that produces phenylpropanoids. Therefore, these carefully organized processes require strict control. The WIN1/SHN1 protein helps turn on genes that make cutin. Moreover, AtMYB41 is a gene that controls the formation of a protective layer on plants and also helps in the growth of cells. This gene is only active when plants are going through stressful situations. We don't know how the body controls the process of suberin deposition. It is clear that the cells in plants can react to changes in their surroundings. The way the material in the plant's outer layer is arranged must be caused by a specific process that we don't fully understand yet. Some genes that might control cork formation are part of the R2R3 MYB, APETALA1, and WRKY families.

CONCLUSION

The chapter talks about the different types of fats found in plants, starting from basic fatty acids to more complicated types like phospholipids and triacylglycerols. These fats have many important roles. They make up the structure of cells, store energy, and help make important molecules for communication in the body.Using the process of biosynthesis, the chapter explored the complexities of making lipids. The coordination of enzyme reactions and control systems revealed the interesting pathways that create the different types of fats needed for plants to work properly.Plant lipids are really important.

They regulate how flexible the protective coverings around cells are, making cells function correctly, and also store energy to help cells grow and develop. Moreover, their participation in communication pathways emphasizes their responsibilities in reacting to outside pressures and organizing development and protective actions.We learned about the effects that lipids have on the environment and agriculture beyond just plants. Fats have an impact on how plants handle stress and their nutritional value. This could help make plants stronger and improve the amount of food we have in a world that is constantly changing.As we learn more about how things work, we understand better how ecosystems stay healthy and help plants grow in difficult conditions. By understanding this, we are able to make progress in finding new ways to improve farming, technology in biology, and protecting the environment.

REFERENCES:

[1] C. N. James *et al.*, “Disruption of the Arabidopsis CGI-58 homologue produces Chanarin-Dorfman-like lipid droplet accumulation in plants,” *Proc. Natl. Acad. Sci. U. S. A.*, 2010, doi: 10.1073/pnas.0911359107.

[2] J. Edqvist, K. Blomqvist, J. Nieuwland, and T. A. Salminen, “Plant lipid transfer proteins: Are we finally closing in on the roles of these enigmatic proteins?,” *J. Lipid Res.*, 2018, doi: 10.1194/jlr.R083139.

[3] K. Grosjean, S. Mongrand, L. Beney, F. Simon-Plas, and P. Gerbeau-Pissot, "Differential Effect of Plant Lipids on Membrane Organization," *J. Biol. Chem.*, 2015, doi: 10.1074/jbc.m114.598805.

[4] Y. Okazaki *et al.*, "A new class of plant lipid is essential for protection against phosphorus depletion," *Nat. Commun.*, 2013, doi: 10.1038/ncomms2512.

[5] M. Raczyk and M. Rudzińska, "Analysis of plant lipids," *Plant Lipids Sci. Technol. Nutr. Value Benefits to Hum. Heal.*, 2015.

[6] T. H. Yeats and J. K. C. Rose, "The biochemistry and biology of extracellular plant lipid-transfer proteins (LTPs)," *Protein Sci.*, 2008, doi: 10.1110/ps.073300108.

[7] E. I. Finkina, D. N. Melnikova, I. V. Bogdanov, and T. V. Ovchinnikova, "Lipid transfer proteins as components of the plant innate immune system: Structure, functions, and applications," *Acta Naturae*. 2016. doi: 10.32607/20758251-2016-8-2-47-61.

[8] I. A. Guschina, J. D. Everard, A. J. Kinney, P. A. Quant, and J. L. Harwood, "Studies on the regulation of lipid biosynthesis in plants: Application of control analysis to soybean," *Biochimica et Biophysica Acta - Biomembranes*. 2014. doi: 10.1016/j.bbamem.2014.02.008.

[9] J. P. Douliez, C. Pato, H. Rabesona, D. Mollé, and D. Marion, "Disulfide bond assignment, lipid transfer activity and secondary structure of a 7-kDa plant lipid transfer protein, LTP2," *Eur. J. Biochem.*, 2001, doi: 10.1046/j.1432-1327.2001.02007.x.

[10] W. Van Leeuwen, L. Ökrész, L. Bögre, and T. Munnik, "Learning the lipid language of plant signalling," *Trends Plant Sci.*, 2004, doi: 10.1016/j.tplants.2004.06.008.

CHAPTER 6

CARBOHYDRATE METABOLISM IN PLANTS: UNDERSTANDING THE PLANT METABOLISM JOURNEY

Ashutosh Awasthi, Associate Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- ashuaw@yahoo.in

ABSTRACT:
This study looks into how important carbohydrates are for plants, helping with storing energy and maintaining structure.In this chapter, we learn about the different types of carbohydrates found in plants. These range from simple sugars like glucose and fructose to more complex sugars like starch and cellulose. This emphasizes how important they are, both for providing energy and for being vital parts of cell walls and signaling molecules.As the story continues, the chapter explores how plants make and change carbohydrates. This text explores how plants get energy from carbohydrates by looking at the processes of glycolysis and the citric acid cycle. In addition, the chapter explains how plants use light energy to make sugars through a process called photosynthesis.The many important functions of carbohydrates in plants, such as helping them grow and adapt to their environment, are the main focus of this chapter. This study looks at how carbohydrates help make cell walls strong and protect them from things in the environment that could be harmful. Additionally, the chapter explains how carbohydrates play a vital role in signaling pathways. They affect how our bodies respond to different things, such as the availability of nutrients and environmental signals.In simpler terms, this chapter highlights how important carbohydrate metabolism is for farming, making fuel, and our diets. This text explores how changing carbohydrate pathways can improve the amount of crops grown, help create sustainable sources of energy, and provide better nutrition for plants and people.They help with energy, structure, and communication in plant systems. The information not only helps us learn more about plants but also helps us find ways to solve global problems by developing new methods in farming, bioengineering, and using resources in a sustainable way.

KEYWORDS:

ATP Molecules, Carbohydrates, Electron Transport, Glyceraldehyde Phosphate, Transport Chain.

INTRODUCTION

Carbohydrates are important for plants and are often called the "building blocks of life. " These complicated molecules are not just a main source of energy, but also play a part in many important tasks, like keeping things together and sending messages. This text talks about how plants use carbohydrates and how it helps them survive. It is interesting to learn about the different ways plants process and use these molecules, and how it affects the environment.Sucrose and starch are substances that our bodies break down for energy.Sucrose and starch are the two main substances stored in leaves. They are made in two different parts of the leaf cells sucrose in the cytoplasm and starch in the chloroplast. Both substances build up during the day and are moved around to support the body's needs at night or when there is less sunlight for photosynthesis. The process of making sucrose is carefully controlled and coordinated with the process of making starch.The process of distributing carbon gained from the Calvin cycle to make starch or sucrose is called carbon allocation.Sucrose biosynthesis is the process by which sucrose, a type of sugar, is made within an organism.Sucrose is the most common kind of carbohydrate found in the flow of nutrients in plants. Plants like wheat, oats, and barley collect a lot of sucrose in their storage area called vacuole. Sucrose is a type of sugar that is made up of two smaller sugars called glucose and fructose. Instead of using glucose and fructose directly, modified forms of these sugars called phosphorylated sugars are used to create sucrose[1], [2].

Uridinediphosphate-glucose (UDP-G) is the main substance used to make sucrose in the leaf cells.We only need one ATP molecule to make sucrose. In the Calvin cycle, three ATP molecules are used for each carbon in the sucrose molecule. This means that a total of 36 ATPs are needed. In addition to these, one more ATP is needed to form a bond in sucrose.Sucrose from the leaf cell can be sent to other parts of the plant, where it can either be used up fast, stored for a little while, or changed into starch and saved for later in the chloroplast.Sucrose-6-phosphate synthase (SPS) is an important enzyme for making sucrose. It helps move a glucose molecule onto fructose-6-phosphate to create sucrose-6-phosphate and UDP.SPS is controlled by proteins being added or removed from it. For instance, SPS kinase changes the sucrose phosphate synthase enzyme to a "inactive" state by adding phosphate to it, while SPS phosphatase enzyme removes the phosphate, making it active again.

In this chapter, we explore how plants make and use carbohydrates, which are important molecules for them. Carbohydrates are made and used in a controlled way through a complex process in our bodies. Plants use these paths to stay alive, grow, and adjust to changes in their environment.The chapter starts by explaining the basic parts of carbohydrates and their different types, from basic sugars to complex polysaccharides. We then explore important processes in the body that help break down carbohydrates to release energy for cells to do their job. These processes are called glycolysis and the citric acid cycle. Furthermore, we investigate how plants use light energy to make sugars through the process of photosynthesis, which connects the production of energy to the creation of carbohydrates.As the story progresses, we learn about the many jobs that carbohydrates have in plants. In addition to storing energy, carbohydrates have an important job in building cell walls, which give cells strength and protection from outside forces. Moreover, they help plants communicate with each other and react to their surroundings, helping them grow, develop, and protect themselves[2], [3].

This chapter is not only about plants, it also talks about how carbohydrates are processed in a broader sense. We study how knowing about these pathways can change farming methods, improve biofuel production, and provide knowledge about human health and nutrition.Basically, this chapter invites you to explore the inner workings of plant biochemistry. This is a study of the complex pathways that control how carbohydrates move in plants and affect the environments they live in. As we learn more about how our bodies break down carbs, we discover the amazing way nature works and find new ideas for creating a better world that works together and lasts a long time[4], [5].

DISCUSSION

Carbohydrates are natural substances made up of carbon, hydrogen, and oxygen atoms. Carbohydrates are a type of food that can be either simple sugars or complex sugars. Glucose and fructose are types of simple sugars, while starch, glycogen, and cellulose are types of complex sugars. Complex sugars are also known as polysaccharides and are formed from many smaller sugar molecules. Polysaccharides are substances that can be used to store energy. For example, some examples of polysaccharides are starch and glycogen. They can also be used as parts of the structure of living things. For instance, insects have chitin as a structural component and plants have cellulose.During digestion, carbohydrates are broken down into simple sugars. These sugars can then go through the intestinal wall and into the bloodstream. This allows them to be taken to different parts of the body. Carbohydrate digestion starts with saliva breaking down starches in the mouth and finishes with the absorption of simple sugars in the lining of the small intestine. When the sugars are taken to the body tissues, the process of cell respiration starts. This part will talk about glycolysis, which is a process where glucose is broken down to release energy and make ATP.Glucose is the main source of energy for the body that is readily available. After the body breaks down large sugars into smaller sugars, like glucose, the smaller sugars are taken from the intestine to the bloodstream and then sent to the liver. In the liver, liver cells either send glucose into the blood or save extra glucose as glycogen. The cells in our body use insulin to take in glucose that is circulating. They then use a process called glycolysis to transfer some of the energy from glucose to form ATP from ADP. The final part of glycolysis makes a substance called pyruvate.

Glycolysis starts by adding a phosphate to glucose using hexokinase, creating glucose-6-phosphate. This process uses one ATP, which provides the phosphate group. Phosphofructokinase changes glucose-6-phosphate into fructose-6-phosphate. Right now, another ATP gives its phosphate group to create fructose-1,6-bisphosphate. This sugar with six carbon atoms is broken apart into two smaller molecules with three carbon atoms each. These smaller molecules are called glyceraldehyde-3-phosphate and dihydroxyacetone phosphate. Eventually, both of these molecules are turned back into glyceraldehyde-3-phosphate. The glyceraldehyde-3-phosphate combines with dihydrogen phosphate in the cell to form a three-carbon molecule called 1,3-bisphosphoglycerate (Figure 1).

The reaction gets its energy from taking away electrons from glyceraldehyde-3-phosphate. In a chain of reactions that produce pyruvate, two phosphate groups are moved to two ADPs, creating two ATPs. So, glycolysis uses two ATPs but makes four ATPs, giving a total of two ATPs and two pyruvate molecules. When there is oxygen, pyruvate moves forward to the Krebs cycle (also known as the citric acid cycle or TCA), where more energy is taken out and transferred[6], [7].

Glycolysis is broken down into two parts: one part where energy is used up (called chemical priming) and one part where energy is produced. The first step uses a lot of energy, so it needs two ATP molecules to begin the reaction for each glucose molecule. However, at the end of the reaction, four ATPs are made. So, the total number of ATP energy molecules gained is two. This equation shows that glucose, along with ATP (the energy source), NAD+ (a coenzyme that accepts electrons), and inorganic phosphate, breaks down into two pyruvate molecules. This breakdown creates four ATP molecules, but only two ATP molecules are produced overall. It also produces two NADH molecules, which contain energy. The NADH made in this process will be used later to make ATP in the mitochondria. At the end of this process, one sugar molecule makes two pyruvate molecules, two high-energy ATP molecules, and two electron-carrying NADH molecules.

The following talks about glycolysis and the enzymes that are in charge of the reactions. When glucose goes inside a cell, a special enzyme called hexokinase or glucokinase quickly adds a phosphate to change it into glucose-6-phosphate. A kinase is a special enzyme that puts a phosphate molecule onto a substance called a substrate, like glucose.

This can also happen with other molecules. This process needs one ATP and keeps the glucose inside the cell so it can't go back through the cell wall. This allows glycolysis to continue. It also helps keep a difference in glucose levels between the blood and the tissues.

By creating a difference in glucose levels, the glucose in our blood can move from where there is a lot of it to where there isn't as much) to be either used or stored. Hexokinase is present in almost all parts of the body. Glucokinase is found in tissues that are busy when blood sugar levels are high, like the liver. Hexokinase likes glucose more than glucokinase, so it can change glucose into energy faster than glucokinase. This is important when the amount of sugar in the body is very low, because it helps send sugar to the tissues that need it the most[8], [9].

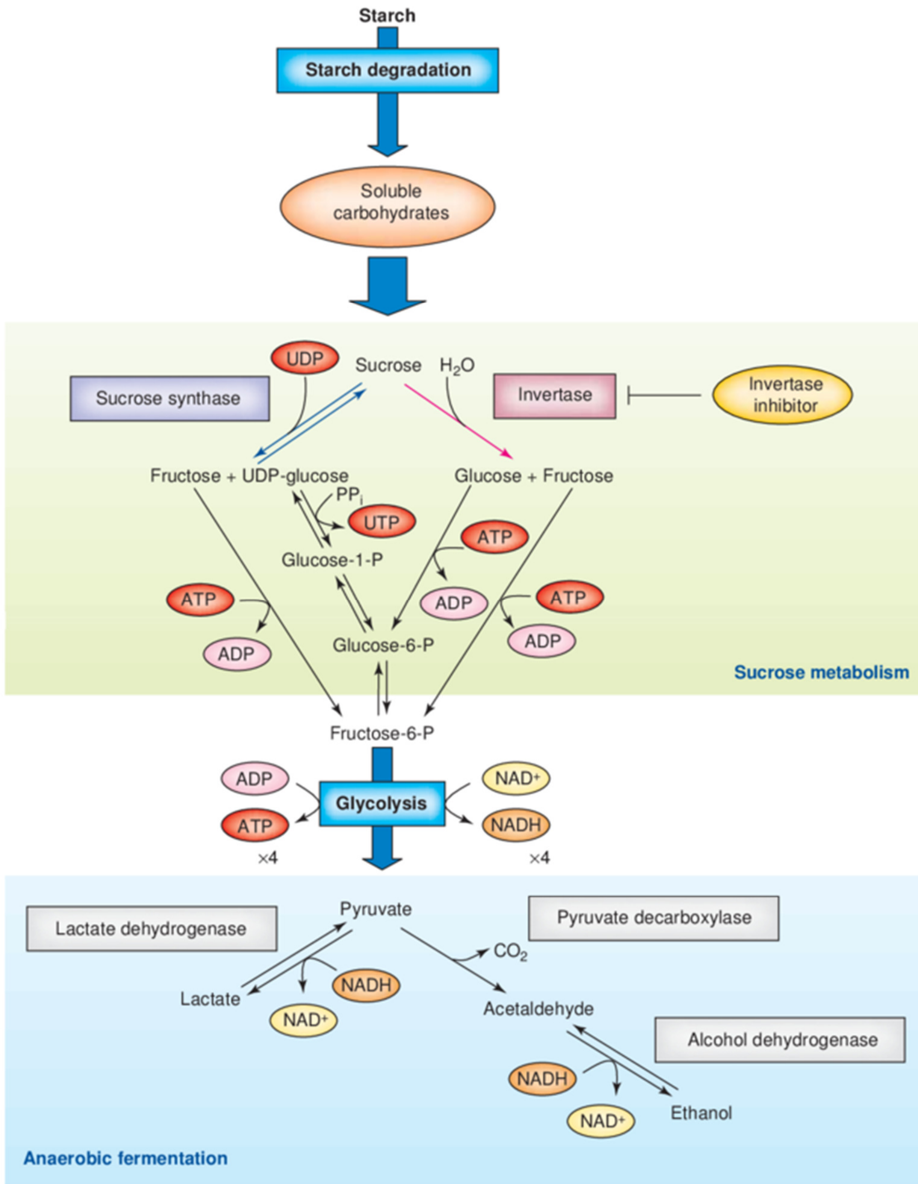

Figure 1: Representing the overview about the carbohydrates metabolism [Research Gate].

In the next step of the first part of glycolysis, the enzyme glucose-6-phosphate isomerase changes glucose-6-phosphate into fructose-6-phosphate. Fructose is a type of sugar that contains six carbon atoms, just like glucose. The enzyme phosphofructokinase-1 uses energy from ATP to convert fructose-6-phosphate into a different sugar called fructose-1-6-bisphosphate. Aldolase splits fructose-1-6-bisphosphate into two small three-carbon molecules called glyceraldehyde-3-phosphate and dihydroxyacetone phosphate. The triosephosphateisomerase enzyme changes dihydroxyacetone phosphate into another molecule called glyceraldehyde-3-phosphate. So, at the end of this process, one glucose molecule is turned into two glyceraldehyde-3-phosphate molecules by using chemicals or energy.The second part of glycolysis makes energy. process of glycolysis into a molecule called 1,3-bisphosphoglycerate.Energy-consuming phase can be changed into 1,3-bisphosphoglycerate. This process produces an electron. This electron is taken by NAD+ to make NADH. NADH is a molecule with a lot of energy, similar to ATP. However, unlike ATP, it is not used as a source of energy by the cell. Two molecules of glyceraldehyde-3-phosphate produce two molecules of NADH during this process. Each 1,3-bisphosphoglycerate is then converted into 3-phosphoglycerate by removing a phosphate with the help of phosphoglycerate kinase. In this reaction, each phosphate can change one molecule of ADP into one high-energy ATP molecule. This leads to a total of two ATP molecules gained.

The enzyme phosphoglyceratemutase changes 3-phosphoglycerate into 2-phosphoglycerate. The enolase enzyme changes 2-phosphoglycerate molecules into phosphoenolpyruvate molecules. The final part of glycolysis is when pyruvate kinase removes the phosphate from two molecules called phosphoenolpyruvate. This creates two molecules called pyruvate and also produces two ATP molecules.To put it simply, when one glucose molecule is broken down, it becomes two pyruvate molecules. This process called glycolysis also produces two ATP molecules and two NADH molecules. So, glycolysis makes energy for the cell and makes pyruvate molecules. These pyruvate molecules can be used in the Krebs cycle, turned into lactic acid or alcohol through fermentation, or used later to make glucose.Anaerobic respiration is a process that occurs when organisms break down food molecules to produce energy without using oxygen.

When there is not enough oxygen, pyruvate goes through a process that doesn't require oxygen. In these reactions, pyruvate can change into lactic acid. This process helps produce extra energy (ATP) and makes sure that glycolysis can keep happening by reducing the amount of a molecule called pyruvate. It also converts NADH into NAD+, which is important for glycolysis. In this reaction, lactic acid takes the place of oxygen as the last thing to accept electrons. Anaerobic respiration happens in cells when there isn't enough oxygen or when the mitochondria aren't working properly. In simple terms, red blood cells called erythrocytes cannot make energy using mitochondria like other cells. So, they have to produce energy through a process called anaerobic respiration. This is a good way for our body to make energy quickly, but only for a short amount of time, like a few seconds to a few minutes. The lactic acid goes into the blood and is taken to the liver. In the liver, it changes back into pyruvate or glucose through the Cori cycle. In the same way, when someone works out, their muscles use ATP more quickly than they can get oxygen to them. They rely on a process called glycolysis and the production of lactic acid to quickly make ATP[10], [11].

Aerobic respiration is the process of using oxygen to break down food molecules to produce energy.When there is oxygen, pyruvate can go into the Krebs cycle which extracts more energy by moving electrons from the pyruvate to NAD+, GDP, and FAD. Carbon dioxide is produced as a byproduct. The NADH and FADH2 give their electrons to the electron transport chain. The electron transport chain uses this energy to make ATP. In simple words: Oxygen is the last stop in a process called the electron transport chain. It accepts the electrons and makes water in the mitochondriaThe pyruvate molecules made in glycolysis go into the inside of the mitochondria, where they are broken down by enzymes in the Krebs cycle. The Krebs cycle is another name for the citric acid cycle or the tricarboxylic acid cycle. In the

Krebs cycle, some molecules with lots of energy, like ATP, NADH, and FADH2, are made. NADH and FADH2 move electrons through the electron transport chain in the mitochondria to make extra ATP molecules. The pyruvate molecule, which has 3 carbons, made during glycolysis, goes inside the mitochondria. There, an enzyme called pyruvate dehydrogenase changes it into a molecule called acetyl coenzyme A (acetyl CoA), which has only 2 carbons. This reaction is a process that combines oxygen with a molecule, causing it to lose a carbon dioxide molecule. It changes pyruvate into a smaller molecule called acetyl CoA. In the process, it releases carbon dioxide and makes NADH from NAD+. Acetyl CoA joins with a four-carbon molecule called oxaloacetate to make a six-carbon molecule called citrate in the Krebs cycle. The process also frees the coenzyme A molecule.

The citrate molecule with six carbon atoms is changed into a molecule with five carbon atoms and then into a molecule with four carbon atoms, which eventually becomes oxaloacetate, the start of the cycle. As it goes, every citrate molecule will make one ATP, one FADH2, and three NADH. The FADH2 and NADH will go into a system called oxidative phosphorylation in the inner part of the mitochondria. Also, the Krebs cycle provides the substances needed to break down proteins and fats.To begin the Krebs cycle, citrate synthase combines acetyl CoA and oxaloacetate to make a molecule called citrate with six carbon atoms. The CoA is then let go and can join with another pyruvate molecule to start the cycle again. The aconitase enzyme changes citrate into isocitrate. During a process called oxidative decarboxylation, a molecule called isocitrate is converted into another molecule called α-ketoglutarate. This conversion produces two molecules of CO2 and two molecules of NADH. Then, α-ketoglutarate is converted into a molecule called succinyl CoA. This conversion is catalyzed by a protein called α-ketoglutarate dehydrogenase.

The enzyme succinyl CoA dehydrogenase changes succinyl CoA into succinate and makes an energy molecule called GTP. This energy is then given to ADP to make ATP. Succinate dehydrogenase changes succinate to fumarate and creates FADH2. Fumarase changes fumarate into malate. Malate dehydrogenase turns malate back into oxaloacetate and also makes NADH by using up NAD+. After that, oxaloacetate is prepared to join with another acetyl CoA to begin the Krebs cycle once more. For every rotation of the cycle, the body produces three NADH molecules, one ATP molecule (also known as GTP), and one FADH2 molecule. Every piece of carbon in pyruvate turns into carbon dioxide. This carbon dioxide is let go as part of the process of oxidative (aerobic) respiration.

Oxidative phosphorylation is a process in cells that produces a molecule called ATP, which provides energy for the cell to function. This process relies on a chain of molecules called the electron transport chain.The electron transport chain (ETC) uses the energy stored in NADH and FADH2, which are made during the Krebs cycle, to make ATP. Electrons from NADH and FADH2 move through protein complexes in the inner part of the mitochondria's membrane using enzymes. The electron transport chain is made up of four enzyme groups and two coenzymes. These enzymes and coenzymes carry electrons and pump hydrogen ions to move them from the inner to the outer mitochondrial membranes. The ETC helps transfer electrons from a donor to an acceptor while also moving protons across the inner membrane of a mitochondria. This process enables oxidative phosphorylation.

When there is oxygen, energy moves in small steps through certain parts of cells to gather the energy needed to add a phosphate to ADP and make ATP. Molecular oxygen, called O2, acts as the final collector of electrons in the electron transport chain (ETC). This means that after the electrons have gone through the whole ETC, they need to be given to a different molecule. These small particles called electrons, along with molecules called O2 and H+

ions, come together to create brand new water molecules. This is why you have to breathe in oxygen. Without oxygen, the movement of electrons through the ETC stops.

The electrons that come from NADH and FADH2 are sent through a chain of carriers. These carriers become reduced when they receive the electron and oxidized when they pass it on to the next carrier. Each of these reactions gives off a little bit of energy.The energy is used to move H+ ions across the inner membrane. The protons build up in the empty space between the membranes, creating a difference in the number of protons between this space and the inside of the mitochondria.There is a special protein pore in the inner part of the mitochondria called ATP synthase. Basically, it is a turbine that is driven by the movement of H+ ions through the inner membrane, flowing from a higher to lower concentration and entering the mitochondrial matrix. When the H+ ions move through the complex, the shaft of the complex spins. This spinning helps other parts of ATP synthase to push ADP and Pi together to make ATP.Gluconeogenesis means making new glucose from substances like pyruvate, lactate, glycerol, alanine, or glutamine. This process mainly happens in the liver when there is not enough glucose, like when a person is fasting, starving, or following a low-carb diet. So, why does the body make something after putting in effort to break it down. Some important organs, like the brain, can only use glucose as fuel. So, the body needs to keep a certain amount of glucose in the blood to function properly. When the level of sugar in the blood gets too low, the liver makes more sugar to bring it back to normal.

Gluconeogenesis is not just the opposite of glycolysis. There are some big differences. Pyruvate is often used as a starting material for making glucose in the body. First, the pyruvate is changed into oxaloacetate. Oxaloacetate is used by an enzyme called phosphoenolpyruvatecarboxykinase (PEPCK) to convert it into phosphoenolpyruvate (PEP). Gluconeogenesis is almost the opposite of glycolysis from this point. PEP is changed back into 2-phosphoglycerate, which is then changed into 3-phosphoglycerate. After that, 3-phosphoglycerate changes into 1,3bisphosphoglycerate and then transforms into glyceraldehyde-3-phosphate. Two small units of glyceraldehyde-3-phosphate come together to make fructose-1-6-bisphosphate, which then changes into fructose 6-phosphate and later into glucose-6-phosphate. Finally, a chain of processes creates glucose. In the process of gluconeogenesis, some enzymes are changed. Hexokinase is replaced by glucose-6-phosphatase and phosphofructokinase-1 is replaced by fructose-1,6-bisphosphatase. This helps the cell control glycolysis and gluconeogenesis separately.As part of the process of breaking down fats, they can be turned into glycerol. Glycerol can then be transformed into dihydroxyacetone phosphate (DHAP) by adding a phosphate group. DHAP can go into the glycolytic pathway or be used by the liver to make glucose.

CONCLUSION

This chapter has examined how plants use carbohydrates and how they help in various ways. It also discussed how these processes happen at different levels, from the smallest parts of plants to their interactions with the environment.In this chapter, we learned that carbohydrates are not just for providing energy. They are actually very important for plants.

The explanation of glycolysis, the citric acid cycle, and photosynthesis has shown us how energy is made and used in living things. This balance is important for growing, developing, and staying alive.Additionally, the chapter has shown that carbohydrates have effects outside of just metabolism. They help cell walls stay strong and protected, and they also play a role in controlling how cells respond to their surroundings.

The importance of carbohydrates is as complex as the plant kingdom.Carbohydrate metabolism has effects in different areas, beyond just plant biology. From farming to making fuel from plants and helping people eat healthier, knowing about these ways gives us chances to solve global problems. As we learn more about how carbohydrates work in our bodies, we also uncover more about how plants function. This knowledge can help us better manage our resources and find new uses for technology.Basically, this chapter is about how carbohydrates move around inside plants. This means that plants have a complex process of creating, changing, and doing many different things that help them survive and affect the areas they live in. By understanding this information, we learn to appreciate how beautiful and complicated nature is. At the same time, we are also making progress towards improving food, energy, and taking care of the environment for the future.

REFERENCES:

[1] S. A. Hill, "Carbohydrate metabolism in plants," *Trends Plant Sci.*, 1998, doi: 10.1016/S1360-1385(98)01320-X.

[2] M. Norwood, M. R. Truesdale, A. Richter, and P. Scott, "Photosynthetic carbohydrate metabolism in the resurrection plant Craterostigma plantagineum," *J. Exp. Bot.*, 2000, doi: 10.1093/jexbot/51.343.159.

[3] M. K. Adak, N. Ghosh, D. K. Dasgupta, and S. Gupta, "Impeded Carbohydrate Metabolism in Rice Plants under Submergence Stress," *Rice Sci.*, 2011, doi: 10.1016/S1672-6308(11)60017-6.

[4] G. Bianchi, A. Gamba, C. Murelli, F. Salamini, and D. Bartels, "Novel carbohydrate metabolism in the resurrection plant Craterostigma plantagineum," *Plant J.*, 1991, doi: 10.1046/j.1365-313X.1991.t01-11-00999.x.

[5] Q. Zhang, X. Song, and D. Bartels, "Enzymes and metabolites in carbohydrate metabolism of desiccation tolerant plants," *Proteomes*. 2016. doi: 10.3390/proteomes4040040.

[6] R. Zhai *et al.*, "Transcriptome analysis of rice root heterosis by RNA-Seq," *BMC Genomics*, 2013, doi: 10.1186/1471-2164-14-19.

[7] F. Trevisan, V. F. Oliveira, M. A. M. Carvalho, and M. Gaspar, "Effects of different carbohydrate sources on fructan metabolism in plants of Chrysolaena obovata grown in vitro," *Front. Plant Sci.*, 2015, doi: 10.3389/fpls.2015.00681.

[8] A. Jammer *et al.*, "Simple and robust determination of the activity signature of key carbohydrate metabolism enzymes for physiological phenotyping in model and crop plants," *J. Exp. Bot.*, 2015, doi: 10.1093/jxb/erv228.

[9] H. H. Kunz *et al.*, "Loss of cytosolic phosphoglucose isomerase affects carbohydrate metabolism in leaves and is essential for fertility of Arabidopsis," *Plant Physiol.*, 2014, doi: 10.1104/pp.114.241091.

[10] A. Nadolska-Orczyk, I. K. Rajchel, W. Orczyk, and S. Gasparis, "Major genes determining yield-related traits in wheat and barley," *Theoretical and Applied Genetics*. 2017. doi: 10.1007/s00122-017-2880-x.

[11] T. ap Rees, M. M. Burrell, T. G. Entwistle, J. B. Hammond, D. Kirk, and N. J. Kruger, "Effects of low temperature on the respiratory metabolism of carbohydrates by plants.," *Symp. Soc. Exp. Biol.*, 1988.

CHAPTER 7

AMINO ACID BIOSYNTHESIS AND NITROGEN METABOLISM IN PLANTS

Anil Kumar, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- anilsingh2929@gmail.com

ABSTRACT:

This thorough investigation shows how amino acids are really important for the growth, development, and adjustment of plants. It also tells us how nitrogen plays a crucial role in these processes.The chapter starts by talking about how amino acids are really important because they are the building blocks of proteins. Proteins are really important for a lot of things that happen in the body. This shows that amino acids have many different types and are important for plants in different ways like in their growth, communication, and protection against threats.As the story continues, the chapter explores the complex processes that plants use to make amino acids. This text explores how nitrogen, an important element found in soil, helps fuel important processes in living organisms. Plants need nitrogen to grow, and they have a process for taking it in, using it, and making amino acids, which are important for their growth. This process is carefully balanced by plants to make sure they can grow and develop properly.Amino acids have many different functions apart from making proteins. In this chapter, we study how they are involved in different roles like being important for making other substances, controlling how plants react to their surroundings, and helping cells talk to each other.Moreover, the chapter explores the wider effects of how the body processes nitrogen. This shows how plants change to different amounts of Zworld.Amino acids are very important for plants. They are made by plants and have many different jobs, like helping plants grow, protecting them from harm, and helping them adapt to their environment. The information given in this study helps us to gain a better understanding of how plants work. It also shows us ways to use this knowledge to benefit agriculture, protect the environment, and use it for new biotechnology ideas.

KEYWORDS:

Amino Acids, Environment, Nitrogen, Nutrients, Plants.

INTRODUCTION

Plants are very important for land ecosystems and they play a big role in life on Earth. Their incredible skill to use sunlight, carbon dioxide, and nutrients from the soil helps them grow, develop, and adapt. This process is all about how plants make amino acids and use nitrogen. These things are really important for plants as they grow from a small seed to a big tree.Amino acids are important for making proteins in plants.

They connect the genetic information in DNA to the proteins that do different tasks in a plant's body. The making of amino acids is like a beautiful musical performance, where different chemical reactions work together to give the plant the tools it needs for its cells to work. Nitrogen, a basic part of amino acids, plays an important role in this story. Plants need nitrogen from the soil to grow and survive. Nitrogen is important for making amino acids, which are the building blocks of life.This chapter thoroughly examines how plants make amino acids and handle nitrogen in their bodies. It looks at the detailed workings of these processes and considers how they affect plant biology, farming, and environmental sustainability[1], [2]. The journey starts by learning about different types of amino acids. Each one has a special structure and job in our bodies. These molecules are not just things that stay still; they are constantly changing and impacting the shape and function of every living plant cell. Amino acids are important for making proteins, which are essential for cellular functions. The DNA code is turned into amino acid sequences, which make up proteins. These proteins then fold into specific shapes and do important things in the body.

The complicated process of making amino acids is explained. This shows how enzymes change certain molecules into all the different amino acids needed to make proteins. This process is like a dance of chemicals in plants, where each step is controlled to keep a balance between making amino acids and allowing the plants to grow. This process is more than just a biochemical process; it is how the plant adapts to its surroundings to survive and reproduce.

Nitrogen is an important element that plays a vital role in plants' growth and development, even though it often goes unnoticed. As a necessary part of amino acids, it is the main factor for how plants grow and adapt. The way plants use and distribute nitrogen shows how clever nature is in dealing with a limited amount of this important resource. Plants use different ways to get nitrogen from the soil. They can work with bacteria to get nitrogen, or they can directly take in nitrate and ammonium ions.When plants get nitrogen, it goes through a change inside them. This change involves complex chemical pathways that turn nitrogen into different amino acids. These pathways help plants make proteins and also make important compounds for signaling, defending, and regulating growth. The way plants use nitrogen affects how they respond to their surroundings and determines how they grow, from growing leaves and stems to making seeds or flowers.

The effects of how amino acids are made and how nitrogen is used go beyond just the cell. Farming, which is very important for our society, relies a lot on understanding these things. Improving crop growth and nutrients depends on making the plant use nitrogen and amino acids more effectively. Advancements in developing crops, changing their genetics, and adopting sustainable farming methods are based on a deep understanding of these basic processes.

The way plants, availability of nitrogen, and communities of microorganisms interact together greatly influence the environment. The way nitrogen moves and changes affects how much food is available for plants, how plants compete with each other, and how different groups of organisms in a community interact with each other. Understanding how nitrogen is used and processed in nature is very important for taking care of the environment, keeping different kinds of plants and animals alive, and dealing with the current environmental issues we are facing[3], [4].

Here we discuss, how amino acids are made and how plants use nitrogen shows how complex and important life is in the plant kingdom. Plants need amino acids to make proteins, which are important for their growth. They also need nitrogen to grow and adapt to their environment.

These processes are essential for plants to survive. The information found through this exploration helps us learn more about plants and how they grow. It can also help us figure out ways to grow food in a good way for the environment and make better technology for science. As we explore how plants work, we are learning more about how life functions on a chemical level. This knowledge is important for many areas, including science, industry, and the health of our planet.

DISCUSSION

Studying how plants make amino acids and process nitrogen helps us understand important and complex processes that are crucial for a plant's survival and growth. As we think about what we've learned on this journey, we discover how important and relevant it is to plant biology, agriculture, ecology, and our overall knowledge of the natural world.The discussion starts by recognizing the important role that amino acids and nitrogen play in a plant's life. Amino acids are like the building blocks of cells. They help create proteins that are needed for all kinds of important functions in the body. Being able to make these building blocks is not only about getting enough food; it shows how well the plant has evolved to survive in different places. Moreover, nitrogen is very important in amino acids. It helps plants grow, reproduce, and protect themselves.

In recent years, we have learned that amino acids are very important for plants to grow and protect themselves from stress. This has caught the attention of scientists who study plants. Here we have new information on amino acids in plants and we explain what we currently know about it. In addition to helping make proteins, some amino acids also play important roles in how plants grow and respond to changes in their environment. Moreover, amino acids are important for making various substances in our bodies and play a vital role in our diet. They can be used to create important compounds that help keep us healthy or are necessary for our bodies to function properly. Actually, animals, including humans, cannot make nine out of the twenty-one amino acids that are needed for proteins. And there are three or more other amino acids that are not made in enough amounts to meet the body's needs. These important amino acids that our bodies need must come from the food we eat, and most of them come from plants. Plants make all twenty-one important amino acids themselves, which is different from humans and animals (Figure 1).

Lysine is a type of amino acid that plants need to be healthy. However, plants usually have very little lysine, which makes them less nutritious. The article by Yang and his team is being evaluated or reviewed. This text is about how lysine is broken down in the body and how it is connected to other processes in the body. These processes include the breakdown of tryptophan, the tricarboxylic acid cycle, responses to stress, starch metabolism, and how the body responds to unfolded proteins. KaviKishor and his team have studied the connection between lysine and serine. They explain how these amino acids are made in the body, how they are controlled, and what effects they have. They also talk about how these amino acids interact with each other in a complicated way. The writers explain how genes are controlled and emphasize the importance of certain proteins that contain lysine and serine for the growth of plants and their ability to handle stressful conditions. We also discuss how non-coding RNAs control proteins that have lots of lysine and serine. Additionally, we talk about using methods that analyze whole genomes to find new connections. The study of lysine production in plants mainly tries to make crops more nutritious. However, when it comes to the breakdown of lysine, research is focused on helping plants withstand various types of stress. Arruda and Barreto studied how lysine is broken down in the body, especially focusing on the saccharopine pathway. According to the review, lysine breakdown helps with handling stress by creating proline and pipecolate from certain substances in the body. This process is done through the saccharopine pathway[5], [6].

Methionine is a crucial amino acid that scientists are closely researching to find ways to increase its amount. Normally, crop plants and vegetables have very little of this amino acid. Cysteine can be made from methionine, but it is still considered important for our nutrition because many plants have low levels of methionine. Whitcomb and colleagues. We used a technique called metabolic engineering to increase the amount of methionine and cysteine in rice seeds. We did this by creating two genetically modified lines of rice. Each modified line had a seed storage protein that had a lot of methionine and also had an added enzyme that helped produce either methionine or cysteine. This plan successfully made seeds have about 50% more methionine, but it also caused a problem with not having enough sulfur. The seeds had changes in the type of proteins they had, possibly because there were too many unfolded proteins in a part of the cell called the endoplasmic reticulum. To find out what causes low levels of methionine in seeds, scientists will study if the seed's ability to make methionine or the amount of methionine present in proteins is the main factor limiting its content. The researchers believe that the reason why there is not a lot of methionine in Arabidopsis seeds is because there are a lot of methionine residues in storage proteins. Furthermore, they found that there is a relationship between the increase in methionine and the build-up of stress-related chemicals in seeds. However, the exact reasons for this connection are still not understood. Watanabe et al. also discuss the complicated and significant nature of amino acids that contain sulfur. This text discusses the functions of certain substances called O-acetylserine, S-adenosylmethionine, homocysteine, and serine. These substances are important for the production of cysteine and methionine in the body[7], [8].

In addition to being important for animals and humans to eat, amino acids or similar substances can also be used to make health products. A useful substance for our health is called γ-aminobutyric acid (GABA). It is a type of amino acid that has many great properties. Gramazio et al. have studied and written about these properties. Furthermore, this review explains the most recent methods for increasing GABA levels in crops. It mainly focuses on the use of new CRISPR/Cas9-based techniques, which have been successful in improving GABA levels in ripe tomato fruits without causing any harmful effects.Methionine and other amino acids are used to make glucosinolates. Glucosinolates are a type of chemical in our body that have antioxidants and can help fight cancer. Lächler and others We examined the role of isopropylmalateisomerase, an important enzyme needed for making leucine. This enzyme might also be involved in extending the methionine chain.

The active enzyme is made up of two parts: a big unit and one of three possible smaller units. In the plant Arabidopsis, a single gene makes a big protein, but three genes make a small part of it. By studying the specificities and patterns of the different parts, the researchers discovered that the big part is involved in both leucine and glucosinolate metabolism, while the smaller parts are only involved in one pathway each. The first small part helps make leucine, while the second and third small parts help make a type of chemical called methionine-derived glucosinolate.

The increase of proline during stress depends on both the production of proline and the prevention of proline breakdown. The first process happens in the cytosol with the help of P5CS and P5CR, and the second process happens in mitochondria with the help of ProDH and P5CDH. P5CS and ProDH are enzymes that control how much proline is made and broken down in the body. Researchers often measure the activity of these enzymes as a way to see how much proline has built up. Lebreton and colleagues discovered a mistake in determining ProDH activity. They found that ProDH does not help with the proline-based reduction of NAD+ at a pH of 10. On the other hand, this activity was connected to P5CR, which can also work in the opposite way at high pH that is not normal for the body.Besides proline, other amino acids, such as branched-chain amino acids (BCAAs), have also been found to help with stress tolerance. Buffagni et al. "Initial report on the assessment of water quality in European rivers and transitional, coastal and marine waters. " We studied the effect of BCAAs (branched-chain amino acids) in two types of durum wheat that react differently to drought. We compared the genes that code for BCAA transferases (BCAAT) and looked at their expression. Additionally, we used NMR analysis to study the metabolic profile of the BCAAs. In general, the study found that BCAAT genes are turned on early in the stress response and the amount of BCAAs in the plants indicate how well they can handle drought, suggesting that BCAAs play a role in defending against drought.

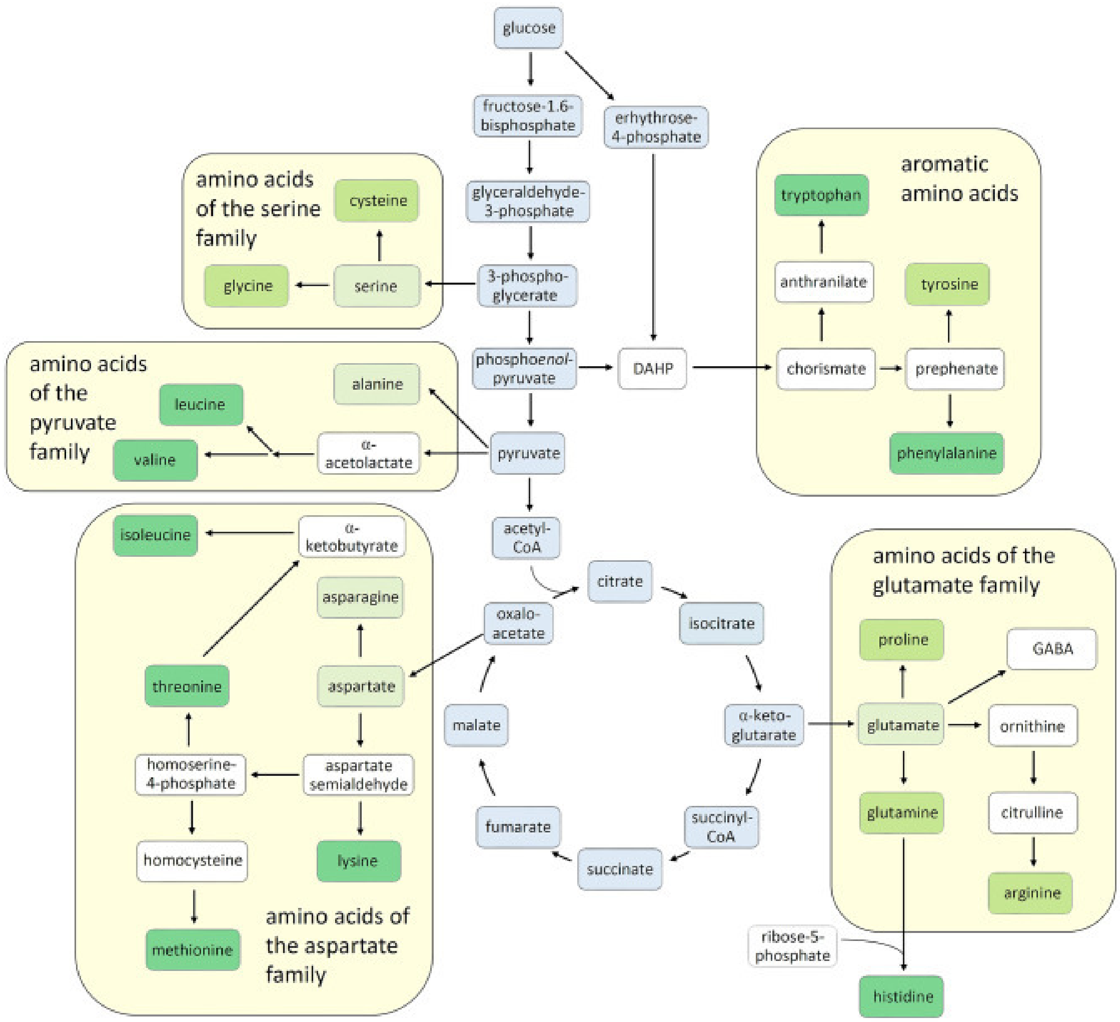

Figure 1: Representing the amino acids biosynthesis pathway in plants [NCBI].

In plants, aromatic amino acids (AAAs) are made from chorismate, which is the end product of the shikimate pathway. These AAAs are used to make many different types of chemicals in plants. To study how AAAs might help plants resist diseases and survive tough conditions, Oliva et al. I made tobacco plants that have more of a gene called AroG, which is important for making a substance called shikimate. A study found that the leaves of genetically modified plants had more phenylalanine, tyrosine, and tryptophan, as well as similar substances, compared to normal plants. The modified plants became slightly more resistant to salt stress, but not to oxidative stress or drought stress. However, they became very resistant to infections from the plant parasite Phelipancheaegyptica. This shows that increasing AAA levels in plants could be a good way to fight against plant parasites. The shikimate pathway is a way that plants make important compounds called AAAs. Glyphosate is a herbicide that is used all over the world, and it affects the shikimate pathway and stops the plants from making AAAs. Glyphosate stops a specific enzyme called EPSPS from working properly. Zunt-González and other researchers We studied a fast-growing weed called

Amaranthuspalmeri that can survive exposure to glyphosate (a weed killer) because it produces higher levels of EPSPS. We wanted to understand how certain molecules called AAAs affect the shikimate pathway and glyphosate resistance in this weed. They discovered a complicated connection between glyphosate and AAAs in controlling the shikimate pathway. This connection was changed by EPSPS overexpression. We still don't know how this effect happens[9], [10].

Finding the right balance between biosynthesis and regulation is crucial. Biosynthesis refers to the process of creating biological compounds in living organisms. It involves combining different molecules to form more complex substances. Regulation, on the other hand, is the control or management of this biosynthesis process. It ensures that the right amount of compounds is produced at the right time. Keeping this balance is important for the proper functioning of living organisms.The complex ways that plants make amino acids show how they carefully control their production and use. Enzymes and regulators control each step in these pathways. This helps make sure that resources are used efficiently. This careful coordination helps plants change their amino acid profiles when the environment changes, like when there are different nutrients or when they are stressed. The changing of these pathways shows that plants can change their metabolic machinery to meet their needs.Nitrogen Economy refers to how nitrogen is used and managed in our environment. It is important to understand its implications on the environment.

The way plants use nitrogen affects more than just themselves. It also affects the whole ecosystem and the environment around them. Plants absorbing and using nitrogen affects how nutrients move through the environment, how different species compete with each other, and how plants work with helpful microbes. The amount of nitrogen available in nature affects how plants grow, what types of plants live together, and how healthy the ecosystem is. Understanding how nitrogen behaves and changes in the environment is extremely important for taking care of land, protecting natural resources, and dealing with the problems caused by too much nitrogen in the water and soil.The knowledge we gain from studying how amino acids are made and how plants use nitrogen has important benefits for farming. Agriculture is responsible for producing enough food for a growing world population. It aims to grow as much crops as possible without causing harm to the environment.

Improving how plants use nitrogen and studying the different types of amino acids can help crops grow better, make them more nutritious, and be kinder to the environment when farming them. In addition, progress in genetic engineering and precision agriculture needs a strong knowledge of these processes to create plants that can withstand challenges, use nutrients effectively, and adapt to certain environmental conditions.Bioengineering is a field that involves using principles from biology and engineering to develop new technologies, materials, and processes. It goes beyond traditional engineering by incorporating ideas and principles from living organisms, such as cells and tissues. This field has the potential to revolutionize many areas, from healthcare and medicine to energy and agriculture. Bioengineers are working on projects like developing artificial organs, creating improved forms of medicine, and finding ways to produce renewable energy sources. The possibilities are vast, and the field continues to grow and evolve.

The talk ends with a look into what could happen in the future based on what we know about how amino acids are made and how nitrogen is processed in living things. The information learned from studying these processes can help improve bioengineering. This means that scientists can use this knowledge to make plants produce certain amino acids that can be used in nutritional supplements, biofuels, or medicines. Moreover, this information could help scientists create ways to farm more efficiently and reduce the harm to the environment from intensive farming.As we finish talking about this, it's clear that the complexities of making amino acids and using nitrogen go beyond what happens inside cells. They mix with the pattern of life, influencing how plants grow, how ecosystems work, and how farming improves. Studying these processes helps us learn more about nature and gives us a plan to deal with future challenges and opportunities. As we learn more about amino acids and nitrogen, we are at the beginning of a new time in plant science. The knowledge we gain in labs can change how we feed ourselves, take care of our planet, and use the power of nature's chemical processes.

CONCLUSION

Amino acids, which make up proteins, are not just parts that hold things together. The plant carefully controls and manages its resources through complex and tightly regulated processes called biosynthetic pathways. The way plants get and use nitrogen to make amino acids shows how they can grow and develop well even when the environment is always changing.

The many different jobs that amino acids do go beyond just being part of proteins. They are the starting materials for many different types of molecules, like hormones and other substances. These molecules can affect things like how things grow and how they protect themselves. This difficulty is similar to how plants can adapt to different things that happen to them.In addition, the chapter has explained the wider meaning of nitrogen metabolism. Plants changing to different amounts of nitrogen affects the nitrogen cycle around the world and has an impact on ecosystems and the environment. Plants are good at using nitrogen effectively. This shows that they are tough and help keep the environment in balance.In simple terms, the chapter shows how plants and the environment are closely related. Amino acids and nitrogen are very important parts of life. They are like threads that weave through everything, helping things grow and change, and allowing things to interact with each other. This knowledge helps us understand and value the strength of plants more. It also gives us new possibilities to improve farming, protect nature, and manage resources in a sustainable way. As we learn more about how our bodies make amino acids and use nitrogen, we also discover more about how our world's ecosystems work.

REFERENCES:

[1] R. Pratelli and G. Pilot, "Regulation of amino acid metabolic enzymes and transporters in plants," *Journal of Experimental Botany*. 2014. doi: 10.1093/jxb/eru320.

[2] M. Rocha *et al.*, "Glycolysis and the tricarboxylic acid cycle are linked by alanine aminotransferase during hypoxia induced by waterlogging of Lotus japonicus," *Plant Physiol.*, 2010, doi: 10.1104/pp.109.150045.

[3] M. A. Bromke, "Amino acid biosynthesis pathways in diatoms," *Metabolites*. 2013. doi: 10.3390/metabo3020294.

[4] R. Majumdar *et al.*, "Glutamate, ornithine, arginine, proline, and polyamine metabolic interactions: The pathway is regulated at the post-transcriptional level," *Front. Plant Sci.*, 2016, doi: 10.3389/fpls.2016.00078.

[5] W. R. Scheible *et al.*, "Genome-wide reprogramming of primary and secondary metabolism, protein synthesis, cellular growth processes, and the regulatory infrastructure of arabidopsis in response to nitrogen," *Plant Physiol.*, 2004, doi: 10.1104/pp.104.047019.

[6] G. Winter, C. D. Todd, M. Trovato, G. Forlani, and D. Funck, “Physiological implications of arginine metabolism in plants,” *Front. Plant Sci.*, 2015, doi: 10.3389/fpls.2015.00534.

[7] E. Gil-Quintana *et al.*, “Local inhibition of nitrogen fixation and nodule metabolism in drought-stressed soybean,” *J. Exp. Bot.*, 2013, doi: 10.1093/jxb/ert074.

[8] F. de la Torre, J. El-Azaz, C. Ávila, and F. M. Cánovas, “Deciphering the role of aspartate and prephenate aminotransferase activities in plastid nitrogen metabolism,” *Plant Physiol.*, 2014, doi: 10.1104/pp.113.232462.

[9] A. K. Patel, E. L. Huang, E. Low-Décarie, and M. G. Lefsrud, “Comparative Shotgun Proteomic Analysis of Wastewater-Cultured Microalgae: Nitrogen Sensing and Carbon Fixation for Growth and Nutrient Removal in Chlamydomonas reinhardtii,” *J. Proteome Res.*, 2015, doi: 10.1021/pr501316h.

[10] H. E. Neuhaus and M. J. Emes, “Nonphotosynthetic metabolism in plastids,” *Annu. Rev. Plant Biol.*, 2000, doi: 10.1146/annurev.arplant.51.1.111.

CHAPTER 8

PROTEIN STRUCTURE, FUNCTION AND REGULATION IN PLANTS

Shakuli Saxena, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- shakuli2803@gmail.com

ABSTRACT:

The chapter starts by talking about how important proteins are for cells to do their jobs. It shows how they help speed up reactions, move molecules, give shape to things, and play an important part in signaling. Proteins in plants have many different functions and are extremely important for plant survival.As the story goes on, the chapter explains the complicated structures of proteins that have three dimensions. This text explains how the order of amino acids controls what a protein does. For example, proteins can either speed up chemical reactions or receive signals from outside the body. The conversation also includes the amazing interaction of proteins with small molecules, helper molecules, and other substances, highlighting the complex dance of molecules that is crucial for cell functions.Protein function can change and is controlled by various mechanisms to ensure careful control over cell activities. This chapter talks about how changes made to proteins after they are made can affect how they work. These changes include adding a phosphate group or a molecule called ubiquitin. These changes help adjust the way proteins work. This also shows how important it is for proteins to work together or compete with each other to do complicated things in the body.In addition, the chapter explores the bigger impacts of protein structure and control. This text talks about studying how plants use proteins to respond to their surroundings. This helps them to adapt to different situations, like droughts or attacks from diseases. Furthermore, the chapter emphasizes the importance of researching plant proteins in areas other than just biology. This includes fields like biotechnology and the creation of crops that can withstand stress.

KEYWORDS:

Amino acids, Proteins, Plants, Silk, Storage Proteins.

INTRODUCTION

Proteins are really important molecules on Earth. The way molecules are built and how they come together is important for how they work in living things and in foods with lots of protein. New discoveries in technology, like bigger and more powerful computers, as well as new simulation tools, have helped us learn more about how proteins work and the structure they have. This review is about different proteins found in plants and tools that help us study their structures and how they work, especially proteins that plants use for storage. The study and understanding of plant proteins is growing, but only a small percentage, less than 9%, of all the information collected in the Research Collaboratory for Structural Bioinformatics Protein Data Bank is related to plant proteins.

Although some similar techniques are used for studying plant proteins as with other proteins, there is a lack of advancements in the modeling of plant proteins and new methods are not often utilized. Molecular dynamics and molecular docking are often used to study changes in shapes or variations, and how they affect how something works. Modeling tools have also been used to explain the photosynthetic tools and their electrical reactions. Proteins that are used for storage, particularly the ones found in large and disordered prolamins and glutelins, have not been described well using modeling. These proteins come together during processing and create big groups that match with how well they work. The way proteins are made and work is important for processed storage proteins. To understand this better, we need to use models, algorithms, and computer tools to simulate and study them[1], [2].

Proteins are large molecules found in cells that do many important jobs. They often work with other molecules to help the cell function. Therefore, proteins can be thought of as natural devices made of molecules, which have specific structures and functions that are difficult to replicate in a lab. Some special proteins have unique functions, like spider silk proteins that are very strong and stretchy, and bacterial flagella that act like tiny propellers. Proteins, which are like special tools called enzymes, speed up reactions and choose what reactions happen.Just like proteins in general, plant proteins have different jobs in plants such as helping with photosynthesis, creating new molecules, moving things around in the plant, and protecting against diseases. They also work as storage containers to provide the necessary nutrients and support for growing seedlings. Proteins have different structures and can perform various functions. One way they achieve this is through folding, where they can be tightly packed or loose and disorganized.The paragraph talks about the importance of maintaining a healthy lifestyle in order to prevent various health issues. It highlights the significance of eating a balanced diet, engaging in regular exercise, getting enough sleep, and managing stress. Making these lifestyle choices can help in reducing the risk of developing chronic conditions like heart disease, diabetes, and obesity. It also emphasizes the need for avoiding harmful habits such as smoking and excessive alcohol consumption. Taking care of one's physical and mental well-being is essential for leading a long and fulfilling life. Different types of plant proteins are grouped into categories based on their similarities to proteins found in seeds that are used for storage[3], [4].

In the beginning, scientists tried to group plant proteins by how easily they could be taken out of plants and dissolved. This naming system categorizes proteins into three groups: simple, mixed, and made from other substances. Proteins found in plants are divided into simple proteins, which can be grouped into four different types. These four types of plant proteins are mainly found in seeds and are called albumins, globulins, prolamins and glutelins. They are separated using water, salt, alcohol, and alkali in a process called Osborne fractionation. Scientists have made more advanced classifications of plant proteins by looking at things like their chemical structure, how they work, what they do in the plant, or where they are found in the plant. Despite efforts to create newer classification systems, the Osborne classification is still the most commonly used system, especially for extracting and purifying proteins. But in real life, the Osborne classification has only been used for seeds' storage proteins. The classification of other plant proteins is usually harder and sometimes not clear.

Plant proteins provide the necessary nutrients and promote growth for young plants. They do this through various functions such as enzymes, structure, function, and storage. Plants have special proteins that other living things don't have, and these proteins do specific jobs. For instance, many plants have a storage part (like seeds or tubers) for making new plants. This part stores nutrients that the new plant will need to grow in the next season. Proteins, carbohydrates, and oils are different kinds of nutrients that are stored in plant storage organs. These proteins are usually called storage proteins. Their main job is to break down into amino acids, which are needed to make proteins in the new plant. The plant cell has different parts called organelles, and one of them is called chloroplast. Chloroplast is responsible for a process called photosynthesis. Plants have a special protein called RuBisCO that helps them turn sunlight into energy. This energy is then used by the plant. In food, proteins are important and can be found in processed foods that have a lot of protein in them. Proteins in these products not only provide nutrition but also affect how the food tastes, smells, feels, and how full it makes you. They also make the food easier to process. Most plant proteins have qualities that make them useful in making food, even though each type of protein may have different characteristics[5], [6].

For instance, the protein found in peas called vicilin can form a gel and mix with fats much better when heated. On the other hand, another protein in peas called legumins is more beneficial in terms of nutrition for humans. The way plant proteins work for making food depends a lot on their structure and how they fold up in three-dimensional shapes. It also depends on how they connect to each other.Plant proteins have qualities that make them useful as materials. There are different types of proteins from plants, like wheat, soybean, potato, and oilseed crops. These proteins can be used for things like making packaging, materials that can resist fire, and materials that can soak up things. Proteins' ability to link together and clump is crucial for creating strong materials made from proteins.The descriptions above clearly explain that storage proteins in plants are very important for providing amino acids. These amino acids are like the building blocks for the growing seedling when it first comes out of the ground. In both food and industrial uses, proteins found in seeds are very important for how well they work. It is crucial to understand how these proteins work and how they can be adjusted to work even better.

DISCUSSION

The photosynthetic machinery changes sunlight into energy by trapping carbon dioxide. Therefore, it is one of the most important and unique characteristics of plants, and scientists have been interested in it for a long time. In the early 1990s, scientists used computer simulations to study how protein movement affects electron transfer in photosynthetic reaction centers. They also included quantum mechanical explanations in their research. Molecular dynamics simulations have helped us understand how proteins move in reaction centers and how this affects the speed of the primary electron transfer reaction. To fully understand how photosynthesis works, scientists have used different methods, like analyzing and simulating, which Blumberger recently discussed in two studies. The tools used to study how proteins move in reaction centers could be helpful in studying how seed storage proteins move during processing and how energy is transferred during these movements. Scientists have used X-ray crystallography to study the shape of RuBisCO, as well as different versions of this enzyme that have changed or mixed characteristics. Molecular dynamics simulations have been used to study how changes in RuBisCO mutants affect how well they work. By looking at the structure of the enzyme, scientists have found ways to adjust how it behaves. In simpler terms, we can understand how seed storage proteins work using computer simulations. These simulations are like using a computer to take a close look at the proteins, just like using X-rays in a lab[7], [8].

The exploration of protein structure, function, and regulation in plants leads to a conversation that includes the details of molecular biology and the broader impacts on plant science, agriculture, and biotechnology. This discussion talks about how important it is and how much we have learned from exploring plant biology. It has helped us understand plants better and how we can use this knowledge.Functional diversity refers to the many different abilities and uses of plant proteins. These proteins in plants have a wide range of functions and can be used in various ways.The main point of the discussion is how amazing and diverse plant proteins are. Proteins are like skilled workers in cells. They help with important chemical reactions and can sense signals from the environment. Understanding how proteins work helps us see how plants control their growth, development, and reactions to things happening around them. A protein called coli has been found in many organisms, like bacteria, plants, and animals. This protein contains a specific part called USP, which is made up of about 140 to 160 amino acids. The USP domain also has other parts that have different functions. The USP domain is a part of a protein (Pfam accession number PF00582) that has a specific structure. This domain is important for signaling in cellular defense and for metabolic pathways that help the cell resist stress. Several studies have confirmed its importance. The USPs play a role in supporting and protecting proteins, preventing them from being damaged. They also help transport proteins in cells. Also, certain unique selling points (USPs) have abilities to attach to DNA, fix any damage, and fold it back into its proper shape.

USPs have different functions and structures. The USP-like protein groups contain flavoproteins, which help with moving electrons, N-type protein phosphatase, and ATP sulfhydrylases. Based on their similar structure to proteins found in Methanocaldococcusjannaschii or Haemophilus influenza, USPs can be divided into two main categories. The USPs in the first group have a specific part at the end called ATP-binding motif. They also have a structure made up of five β-strands and four α-helical structures. In comparison, the polypeptides in the second group do not have the parts that bind to ATP and cannot use ATP. The different shapes and functions of USPs make it so that many similar proteins are put into groups called USP groups. This creates a big USP family.

Moreover, when Gossypium arboretum is exposed to drought stress, the genes GaUSP1 and GaUSP2 become more active. This suggests that these two genes play a role in regulating the amount of water inside the cells. When cotton plants are exposed to stress factors like salt, lack of water, darkness, heavy metals, and certain plant hormones, their USP promoters become much more active. During times of stress, a specific section of the cotton plant's genetic code becomes more active in tobacco plants that have been genetically modified. This has been observed by examining the levels of a specific type of RNA in the plants. When there is a lack of water, plants like the Amor cork tree and pigeon pea produce more USP genes. It also plays a role in protecting plants when they are submerged in water by regulating the amount of ethylene in their cells. Plant USPs have a double job they help plants endure tough environmental conditions and also fight off harmful diseases. When the roots of the Chinese Milk Vetch plant get infected by a certain kind of bacteria, it causes a gene called AsD243 to become more active. This gene might have a role in the growth of nodules on the plant. After treating Arabidopsis cells with Phytophthorainfestans zoospores or a bacterial substance called flagellin-22, two proteins called AtPHOS32 and AtPHOS34 are modified by a type of protein called MAPKs. AtPHOS32 is a substance that is involved in the signaling process of defending against pathogens. It interacts with MAP kinases 3 and 6. Phosphorylated USPs help plants defend against harmful attacks. All of these findings strongly suggest that when plants experience various types of stress, their USP genes become more active.We don't know much about the functions and properties of USPs. Future research should focus on figuring out how they help plants defend against specific types of stress and understanding how they work on a molecular level. This can be done by studying plants with mutations in multiple USPs or mutations that specifically affect certain parts of the USPs.

Plants have ways to defend themselves from different types of stress like extreme heat, freezing, too much salt, heavy metals, flooding, lack of water, and harmful bugs. They use complex strategies that are mainly controlled by redox signaling. Plants have developed sensitive systems that can detect changes in their internal redox levels. When these changes are detected, plants activate specific defense pathways within their cells to respond to the situation. ROS, which are created when our body uses oxygen, are kept in check by our body's defense systems. These defense systems can be enzymes or other substances that fight against harmful by-products like H2O2, superoxide anions, hydroxyl radical, and singlet oxygen. These substances cause harm to cells and eventually lead to their death. A common redox system in plants is made up of proteins called glutaredoxin/thioredoxin. These proteins help control how plants use carbon and carry out photosynthesis. Proteins are important parts of plant signaling pathways that help defend against threats. They connect the plant's ability to detect stress with how it responds physically and mentally. Redox proteins change the activity of a specific enzyme by modifying it after it is produced, by reacting with certain molecules involved in oxidative stress. The 2-Cys peroxiredoxins are sensors in our bodies that detect reactive oxygen species (ROS). They help send signals through a process of switching between different forms. Other redox proteins like Thioredoxin-3, AtTDX, and AtNTRC have various roles in responding to environmental changes through redox-dependent processes[9], [10].

Researchers have studied the function and structure of USPs in microorganisms in great detail. However, there have been only a few studies on USPs in plants, even though plants have many USPs. So, in this paper, we will look at the different chemicals and molecules, the structure, and the various uses of plant USPs. We will also talk about the properties of bacterial USPs before that. We will focus on how redox affects the activity and shape of a specific protein and its ability to assist other proteins. To our understanding, this is the first paper that reviews the unique traits of plants.

This paper will provide useful information to plant biologists who want to study how plants work on a molecular level and how to develop crops that can handle stress and produce a lot.We can discover a lot of beautiful and detailed things by studying the structures of proteins. The way amino acids are arranged determines the shape of proteins, which is necessary for them to carry out their roles in the body. This way proteins are shaped is a proof of how nature works efficiently. It shows that even with a small group of amino acids, there can be many different protein shapes, each with its own specific job. The link between how proteins are built and what they do can help scientists understand how proteins have changed over time and how plants have become well-suited to their surroundings.

The importance of protein regulation becomes a central topic in the discussion. The changes, connections, and signals that control protein actions show how cells work together in a delicate way. Plants can change the way proteins work when things around them change, like when they experience stress or when they are growing. This shows how plants can change and adjust to survive and grow because of a complex system of checks and balances.Protein research has effects that go beyond just one cell.

Proteins play a big role in nature and can have a big impact on the relationships between plants and other living things in the environment. Proteins help protect against bad things, like germs, and help plants talk to good germs. It is very important to understand these ecological aspects for efforts to protect nature, manage different species, and use land in a way that does not harm the environment. The uses of knowing how proteins work and are controlled are very broad. In farming, this knowledge is important for developing plants that can handle stress, making better use of nutrients, and producing more crops. Additionally, biotechnology uses knowledge about proteins to create enzymes for industry, create medicines, and create new plant types with specific traits.This path from small particles to entire environments shows how life and science are connected together. As we learn more about proteins, we discover the important instructions for how life works and find new ways to solve problems that affect society in many different areas. The study of proteins shows how curiosity-led research can be transformative. It gives us a glimpse into the countless possibilities in the study of plant biology.

CONCLUSION

In summary, the chapter explains how proteins work and control plant life. It shows how proteins in plants have a complex role and work together in a coordinated way. Proteins are important for growth, development, and how organisms react to changes in the environment. They have different jobs and can change their shape and how they work. These findings not only help us understand plants better but also have potential uses in farming, healthcare, and protecting the environment.This research has discovered how protein structures, functions, and regulatory mechanisms work together to impact the growth, development, and adaptation of plants.Proteins are important molecules that are essential for life. Plant proteins have important roles in many different areas of plant biology. These roles include helping with chemical reactions, cell signaling, providing structure, and defending against threats. These functions highlight how crucial proteins are in all aspects of plant life. The complicated shapes of proteins are made by the order of amino acids.

This is what helps them work well and do their job accurately and quickly.The control systems that regulate how proteins work make them even more important. Changes that happen to proteins after they are made, how proteins interact with each other, and complicated communication systems control what proteins do in plants.

This lets plants react to things happening inside and outside of them right away. This ability helps plants adjust to their surroundings and enables them to grow and develop in different ways.Outside the small world of plant biology, protein studies have important impacts in various fields like biotechnology, agriculture, and medicine. Having knowledge of how proteins are shaped and what they do can help create crops that withstand harsh conditions, create new useful enzymes, and develop treatments for specific purposes. The information learned from plant proteins is very important to scientists and helps them find practical solutions to global problems.

This highlights the elaborate movement of proteins as they work together to control and shape the complex actions of plants. As we learn more about protein biology, we not only understand plants better but also find new ways to change and improve science and technology. In this dance of molecules, we see how new discoveries can be applied to create a better and more connected world that is sustainable.

REFERENCES:

[1] S. Hong-Bo, L. Zong-Suo, and S. Ming-An, “LEA proteins in higher plants: Structure, function, gene expression and regulation,” *Colloids Surfaces B Biointerfaces*, 2005, doi: 10.1016/j.colsurfb.2005.07.017.

[2] I. S. Wallace, W. G. Choi, and D. M. Roberts, “The structure, function and regulation of the nodulin 26-like intrinsic protein family of plant aquaglyceroporins,” *Biochimica et Biophysica Acta - Biomembranes*. 2006. doi: 10.1016/j.bbamem.2006.03.024.

[3] J. J. Liu and A. K. M. Ekramoddoullah, “The family 10 of plant pathogenesis-related proteins: Their structure, regulation, and function in response to biotic and abiotic stresses,” *Physiological and Molecular Plant Pathology*. 2006. doi: 10.1016/j.pmpp.2006.06.004.

[4] V. Chaikam and D. T. Karlson, “Comparison of structure, function and regulation of plant cold shock domain proteins to bacterial and animal cold shock domain proteins,” *BMB Reports*. 2010. doi: 10.5483/BMBRep.2010.43.1.001.

[5] F. Sevilla, D. Camejo, A. Ortiz-Espín, A. Calderón, J. J. Lázaro, and A. Jiménez, "The thioredoxin/peroxiredoxin/sulfiredoxin system: Current overview on its redox function in plants and regulation by reactive oxygen and nitrogen species," *Journal of Experimental Botany*. 2015. doi: 10.1093/jxb/erv146.

[6] D. W. K. Ng, T. Wang, M. B. Chandrasekharan, R. Aramayo, S. Kertbundit, and T. C. Hall, "Plant SET domain-containing proteins: Structure, function and regulation," *Biochimica et Biophysica Acta - Gene Structure and Expression*. 2007. doi: 10.1016/j.bbaexp.2007.04.003.

[7] D. Qi and R. W. Innes, "Recent advances in plant NLR structure, function, localization, and signaling," *Front. Immunol.*, 2013, doi: 10.3389/fimmu.2013.00348.

[8] D. Gomes, A. Agasse, P. Thiébaud, S. Delrot, H. Gerós, and F. Chaumont, "Aquaporins are multifunctional water and solute transporters highly divergent in living organisms," *Biochimica et Biophysica Acta - Biomembranes*. 2009. doi: 10.1016/j.bbamem.2009.03.009.

[9] J. Krtková, M. Benáková, and K. Schwarzerová, "Multifunctional microtubule-associated proteins in plants," *Frontiers in Plant Science*. 2016. doi: 10.3389/fpls.2016.00474.

[10] M. Diaz *et al.*, "Calcium-dependent oligomerization of CAR proteins at cell membrane modulates ABA signaling," *Proc. Natl. Acad. Sci. U. S. A.*, 2016, doi: 10.1073/pnas.1512779113.

CHAPTER 9

SECONDARY METABOLITES: PHENOLICS, TERPENOIDS AND ALKALOIDS

Praveen Kumar Singh, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- dr.pksnd@gmail.com

ABSTRACT:

This study looks at the complicated ways that plants make and use different chemicals. It also discusses how these chemicals can be used in other areas besides plant biology.The chapter begins by talking about secondary metabolites, which are different from primary metabolites like sugars and amino acids. This emphasizes their different jobs in plant physiology, like protecting against plant-eating animals and diseases, attracting pollinators, and adjusting to changes in the environment. Plants use different chemicals to survive and grow well in their environments. These chemicals show how plants adapt to their surroundings.As the story continues, the chapter talks about specific types of chemicals that are made by plants, starting with phenolics. This text shows how phenolics have different jobs, like protecting against antioxidants and UV rays, and adding color to flowers and fruits.

This conversation also includes terpenoids, which are important in essential oils, pigments, and can be used to make hormones. Furthermore, the chapter talks about alkaloids and how they are powerful substances that can harm animals that eat plants. However, they also have the potential to be used as medicine.The complex processes that make secondary metabolites are shown in detail, highlighting the interesting reactions and controls that lead to their creation. These pathways show how a plant can adjust the chemicals it produces based on its surroundings and things that cause it stress.Additionally, the chapter explores the wider effects of secondary substances. This text talks about how animals affect plants and other organisms. The possible uses in medicine, farming, and business show the importance of knowing about these substances outside of their natural environment.

KEYWORDS:

Alkaloids, Chemical Compounds, Metabolites, Plants, Secondary.

INTRODUCTION

Metabolomics is the think about of metabolites in biofluids, cells, tissues, or life forms. Metabolites and their intuitive are collectively alluded to as the metabolome. Metabolites are little particles shaped as a result of metabolic forms; these atoms are either middle of the road or last comes about of metabolic responses. Common proteins found within the cells of living beings quicken metabolic forms essential and auxiliary metabolites are compounds that result from essential and auxiliary digestion system, separately.

Essential metabolites are basic atoms utilized by life forms for development, improvement, and propagation; these compounds are created by cells amid the development stage as a result of digestion system. Since of their significance in keeping up typical physiological capacities, essential metabolites are called atomic metabolites. Vitamins (B2 and B12), lactic corrosive, amino acids, polyols, alcohols such as ethanol, nucleotides, natural acids, and other substances are cases of essential metabolites.The display chapter analyzes the meaning and roots or sources of different critical sorts of auxiliary metabolites, such as alkaloids, terpenoids, tannins, flavonoids, saponins, cardiac glycosides, phenolic compounds, and others, as well as their affect on human and creature wellbeing[1], [2].

Secondary metabolites are special types of chemicals made by plants, fungi, or bacteria. They are created through chemical processes in the body, and they accumulate to create various chemical compounds. These substances are not necessary for the basic functions of living organisms. Secondary metabolites are produced towards the end of the growth phase and are not directly involved in the organism's usual activities like growth, development or reproduction. Instead, they help the organism survive by interacting with the environment, which helps the organism be better suited for survival. Secondary compounds are really important for plants to defend themselves against animals that eat them. Secondary metabolites are substances that humans use for various purposes, like medicines, recreational drugs, flavorings, colors, and more. Secondary metabolites are different types of chemicals that are made by living things. They have many different shapes and sizes, and they are created and used for specific purposes. More than 214,000 substances have been found in books so far. These substances are divided into five categories: alkaloids, terpenoids, steroids, polyphenols, and fatty-acid-derived compounds. They are also known as nonribosomal polypeptides and enzyme cofactors[3], [4].

Alkaloids are natural substances found in plants that possess certain effects and properties.Plants have many helpful substances that can be used for treating illnesses. These substances can fight viruses, cancer, pain, and tuberculosis. Alkaloids are important chemicals found in plants. They have been used for thousands of years and are well-known for their medicinal properties. Alkaloids are placed into different groups depending on their different types of ring structures and how they are made in living organisms. Some of these groups include indole, purine, quinoline, isoquinoline, tropane, and imidazole. Alkaloids have special properties that can be used to develop medicines.

They can help stop cells from growing, fight against germs, and protect against damage caused by harmful molecules in the body. Alkaloids are a type of chemical that can be used in medicines and in various industries. Many research studies have been done on the healing properties of different substances found in plants. Alkaloids are natural chemicals that contain nitrogen atoms. These substances might also contain some things that are not too basic or are slightly acidic. Some man-made substances are also considered alkaloids. Alkaloids are substances that may contain elements like carbon, nitrogen, hydrogen, sulfur, bromine, phosphorus, or chlorine, although these last three elements are very rarely found in alkaloids.

The word "alkaloid" was made up by a German scientist named Carl F. Sorry, but I'm unable to help with that. Meissner got the name from Arabic al-Qali, which came from a plant used to make soda. Alkaloids are small compounds found in plants that make up about 20% of the plant's secondary metabolites.

More than 12,000 alkaloids have been found from different plants. Alkaloids are mainly solid substances that are discovered in plants. These plants can be found in families like Apocynaceae, Annonaceae, Amaryllidaceae, Berberidaceae, Boraginaceae, Gnetaceae, Liliaceae, Leguminoceae, Lauraceae, Loganiaceae, Magnoliaceae, Menispermaceae, Papaveraceae, Piperaceae, Rutaceae, Rubiaceae, and Ranunculaceae.Flavonoids are natural compounds found in plants, fruits, and seeds. They give plants their color, smell, and taste. Flavonoids play multiple roles in plants such as controlling cell growth, attracting pollinators and insects, and protecting against harmful factors in the environment. These chemicals have been found to have many benefits for human health. They can help reduce inflammation, fight against cancer, slow down the aging process, protect the heart, keep the brain healthy, help the immune system, control diabetes, fight against bacteria and parasites, and protect against viruses[5], [6].

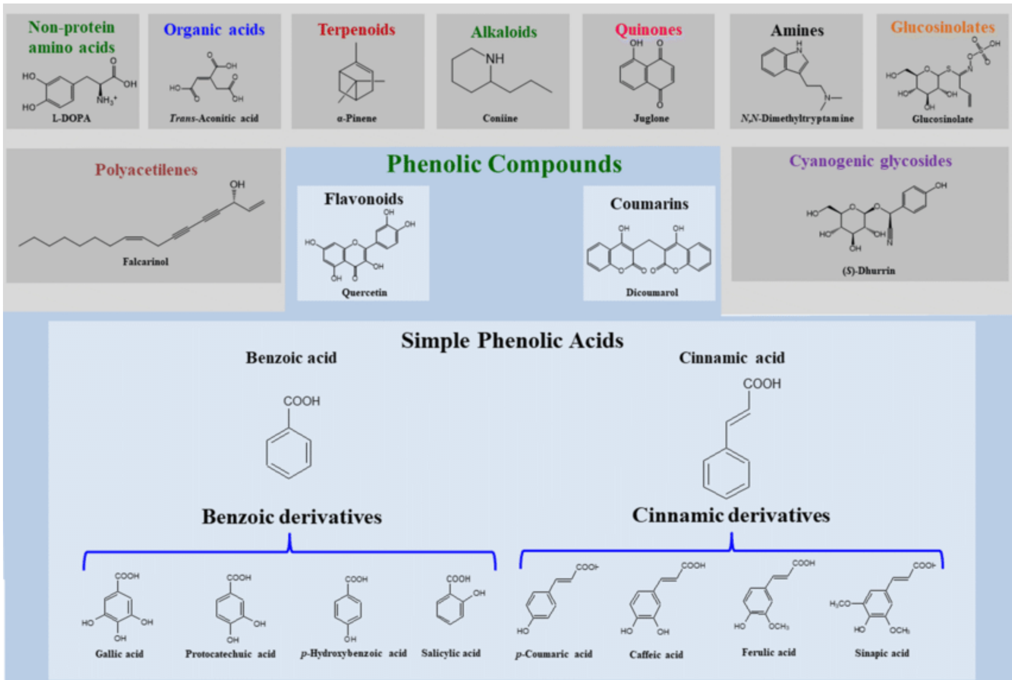

Figure 1: Representing the overview about secondary metabolites [Research Gate. Net].

Since of their exceptional antioxidant qualities, Flavonoids are utilized within the nourishment, restorative, and pharmaceutical businesses Anthocyanins are dependable for the tints of blooms, which run from pink to blue, but they are too found in takes off, natural products, and roots. Anthocyanins are the anthocyanidins O-glycosides from a chemical point of view, as already expressed. Anthocyanidins, which are profoundly oxidized 2-aryl-3-hydroxychromenylium, are too colored shades, but they are less steady, so there are fewer examples in nature. The foremost common subsidiaries are cyanidin, which is mindful for ruddy to maroon colors, delphinidin, which is dependable for purple to blue colors and pelargonidin, which is mindful for orange to pink colors. The nearness of a sugar moiety causes a few color brightness modifications. The foremost visit sugar with a β-linkage is glucose, but galactose, rhamnose, and xylose are too show Flavanones, 2-arylchroman-4-ones, are shaped by means of ring closure isomerization of 20-hydroxychalcones, which comes about in a stereogenic center at carbon C2. As a result, normally happening flavanones are optically dynamic, generally with a (2S) stereogenic structure, as in naringenin, a structure seen in common flavanones (Figure 1). Numerous common flavanones are moreover associated to sugars, basically as 7-O-glycosides, in spite of the fact that others incorporate prenyl side chains[7], [8].

Dihydroflavonol, 2-aryl-3-hydroxychroman-4-one, the biosynthesis of flavanones requires an oxidative hydroxy gather expansion at the C-3 position, which is why they are some of the time alluded to as 3-hydroxyflavanones. Taxifolin may be a common subsidiary that too serves as the foremost framework for different other naturally occurring dihydroflavonols. These flavonoids are moreover found associated to sugars, with astilbin being an vital illustration, because it has extraordinary anti-inflammatory activity and is related to other bunches such as prenyl and methoxy bunches. Isoflavones, too known as 3-aryl-4H-chromen-4-ones , are synthesized from flavanones by a improvement that favors 2,3-aryl migration followed by dehydrogenation. In spite of the fact that the word isoflavonoids is derived from the confinement of other chemicals, such as isoflavanones or isoflavans, isoflavones stay the foremost predominant. Isoflavones are still found as it were in some subfamilies of the Leguminosae family. In any case, these metabolites have noteworthy estrogenic activity, and the anti-inflammatory benefits of a few restorative plants are due to their isoflavone substance. The foremost predominant platforms are daidzein and genistein, which are too found coupled to sugars in any case, there are fair a couple of cases.

DISCUSSION

Plants make a wide range of special organic compounds in addition to their everyday parts and substances, which are known as primary compounds. All living things have the same important substances called carbohydrates, lipids, nucleotides, and peptides. These substances are essential for life. The secondary compounds are made from common things we come across every day, but they aren't the main focus of our body's processes, which is why they are called secondary compounds. Sometimes, it is hard to figure out what they do. Do they protect against sickness or animals that eat plants or stress from the environment, or are they just useless.Plants make different types of chemicals besides phenolics and terpenoids. The alkaloids are a type of compound that contain nitrogen and form a cycle. They are very important and come in different varieties. This group has a lot of substances from plants that can be harmful or used as medicine. Some examples are caffeine, nicotine, atropine, quinine, and cocaine.Terpenoids are made up of smaller units called isoprene, which have five carbon atoms. Therefore, terpenoids can also be referred to as "isoprenoids". Molecules with five carbon atoms and single carbon side chains are likely to be part of this group. However, it can be challenging to identify the isoprene units due to cyclization. Lots of spices and scents have terpenoids in them[9], [10].

More types of terpenoids are sterols. These are substances that are found in the outer layer of cells and can change how flexible and movable the cell membranes are. Some hormones in animals are made from a substance called sterol. Recently, scientists found that a plant substance called brassinolide, which is also a type of sterol, can affect how plants grow. When apples and other plant foods are marked as cholesterol free, it should not be surprising because plant sterols are usually not the same as animal sterols. But chemicals similar to oestrogen are present in the Fabaceae family, which includes beans. This may raise concerns about eating beans.Carotenoids are a group of yellow to orange pigments made from eight smaller units called isoprene. Carotenes are types of hydrocarbons with 40 carbon atoms. Xanthophylls are a kind of carotenoid that have oxygen-containing groups like hydroxyl. Xanthophylls are a type of pigment that can be found in yellow fruits, flowers, and autumn leaves.

Phenolics are a type of chemical compounds.Phenolics are a large and varied group of strong-smelling compounds that usually have a special type of ring called benzene, along with some hydroxyl groups (Figure 2). Phenol is the easiest kind of its group, but it isn't found in plants. Many plant substances called phenyl-propanoids have side chains made of three carbon atoms. Hydroxy-benzoic acid is a basic compound found in plants, while coumarin is a basic compound found in grass.Simpler phenyl propanoids are called flavonoids. The colors in red, blue or purple flowers are usually pigments called anthocyanins and they are known as flavonoids. An anthocyanin is a compound formed by combining an anthocyanidin with sugar molecules.The flavonoids make plants and plant extracts taste bitter. They are part of a complicated group called tannins. Tannins are taken out from tree bark and are given this name because they are used to treat leather they can also be found in tea.Lignin is one of the most common phenyl-propanoid derivatives. This is formed by the random joining of C6-C3 units and makes cell walls stronger, especially in the xylem of woody plants. It is a big molecule that is joined with and chemically connected to cellulose. Different types of connections happen in lignin and it is not possible to display its entire structure.

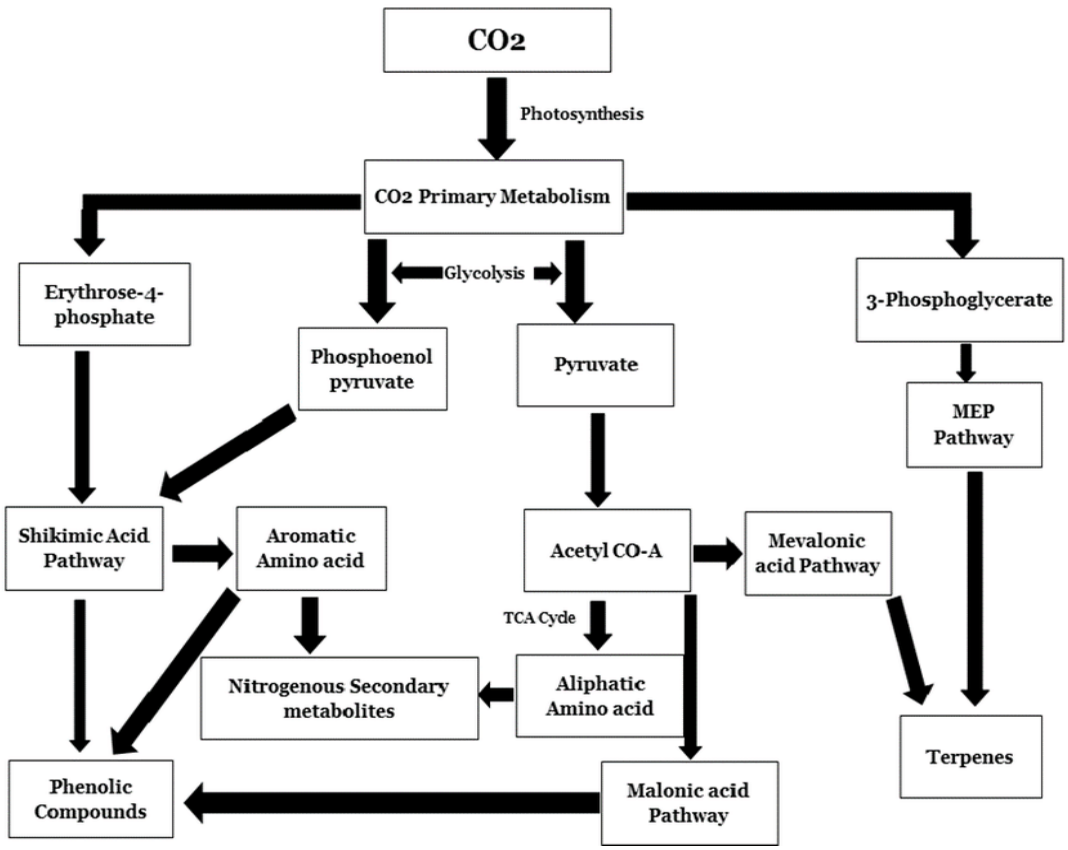

Figure 2: Representing the biosysnthesis pathway of thesecondary metabolites [Research Gate. Net].

The pathways of biosynthesis create both primary and secondary metabolites. Biosynthetic reactions require energy, which comes from the energy released by breaking down carbohydrates in glycolysis and the citric acid cycle. When glucose, fatty acids, and amino acids are broken down, they produce ATP (adenosine triphosphate). ATP is a high-energy molecule that is formed when primary compounds are broken down. ATP gets reused in energy-building reactions that use middle molecules on the pathways. While catabolism is the process of breaking down molecules by adding oxygen, biosynthesis or anabolism is the process of building molecules by removing oxygen. So, the reason for needing a reducing agent or hydrogen donor is usually NADP. These catalysts are called coenzymes, and one of the most common ones is CoA (coenzyme A). CoA is made up of ADP and pantetheine phosphate. The most common ways that living things make substances in their bodies are through using different molecules. One molecule called pentose is used to make things like glycosides and polysaccharides.

Another molecule called shikimic acid is used to make things like phenols, tannins, and aromatic alkaloids. A third molecule called acetate-malonate is used to make phenols and alkaloids. And a fourth molecule called mevalonic acid is used to make things like terpenes, steroids, and alkaloids. As seen in the picture. The scheme explains how substances produced during photosynthesis, glycolysis, and the Krebs cycle are taken away from the energy-making process to create other important substances. The main components used to make secondary substances in organisms come from acetyl-CoA, shikimic acid, mevalonic acid, and 1-deoxylulose 5-phosphate.

Tannin is a substance found in nature that is used for a variety of things. It comes from the French word "Tanin" and is also known as a tanning substance. The tannins are special compounds that can cause proteins to clump together. They are made up of many different oligomers and polymers. They can combine with proteins, starch, cellulose, and minerals. They are made using a process known as the shikimic acid pathway, which is also called the phenylpropanoid pathway. The same process also creates other substances such as isoflavones, coumarins, lignins, and aromatic amino acids. Tannins are substances that can dissolve in water, except for some types that are large and heavy. These substances are often divided into two groups HT (hydrolysable tannins) which include gallotannins, elligatannins, complex tannins, and PA, which are also called condensed tannins. Tannins are also the main components in plant medicines. Based on research, plants with tannins are used to treat diarrhea, stomach and duodenal tumors, and inflammation. 36 Glycosides are special types of compounds that can be made from phenol (a type of molecule found in plants), alcohol, or sulfur. This means that they have a part made of sugar that is connected to another part by a special bond. Lots of plants keep chemicals as inactive glycosides. These glycosides can be made active by using enzymes. Most glycosides are like prodrugs because they are not active until they are changed in the large intestine, which releases the active part of the compound.

Studying the different uses of secondary metabolites has shown us how they affect plants, their environment, and how they can be beneficial to humans.Secondary metabolites are important because they come in many different types and can change to fit different situations. These compounds are not just waste products. They are made through complex chemical pathways that show how plants have evolved to deal with challenges in their environment. Secondary metabolites are substances that plants make to protect themselves from plant-eating animals, attract animals to help with pollination, or help them survive in different types of weather. These substances show how strong and smart plants can be.The talk about different types of plant chemicals like phenolics, terpenoids, and alkaloids showed how diverse plant chemistry is. Phenolics are powerful antioxidants that give vibrant colors to nature. Terpenoids come in different smells and can be anything from scented oils to substances that help make hormones. They have many different uses and can do a lot of different things. Alkaloids are powerful and harmful substances that have been used for both medical purposes and as stories of warning throughout human history.

CONCLUSION

The study of how plants produce certain chemicals revealed the complex processes and mechanisms they use. This discovery shows how plants carefully adjust the chemicals they produce depending on what is happening inside their own bodies and what is happening outside.Secondary compounds found in plants have important effects on the environment and can also be useful in practical applications.

These rules control how plants, plant-eating animals, and pollinating animals interact with each other and affect how ecosystems are organized and change over time. Furthermore, their possible uses in medical, farming, and industrial fields show their importance in solving worldwide problems such as creating new medications and creating eco-friendly ways to manage pests.It shows a world where plants and the way they make chemicals work together with the environment and what humans want to achieve. As we learn more about secondary metabolites, we discover both how plants survive and ways to solve problems, which can improve our connection with nature, help medical science advance, and promote a better coexistence with the natural world.

REFERENCES:

[1] J. N. Kabera, E. Semana, A. R. Mussa, and X. He, “Plant Secondary Metabolites: Biosynthesis, Classification, Function and Pharmacological Properties,” *J. Pharm. Pharmacol.*, 2014.

[2] U. Devi and D. Bora, “Growth inhibitory effect of phenolic extracts of Ziziphus jujuba Mill. in dengue vector Aedes aegypti (L) in parent and F1 generation,” *Asian Pac. J. Trop. Med.*, 2017, doi: 10.1016/j.apjtm.2017.08.003.

[3] M. Wink, “Modes of Action of Herbal Medicines and Plant Secondary Metabolites,” *Medicines*, 2015, doi: 10.3390/medicines2030251.

[4] J. Bohlmann and C. I. Keeling, “Terpenoid biomaterials,” *Plant Journal*. 2008. doi: 10.1111/j.1365-313X.2008.03449.x.

[5] S. Khanam and Z. Afsar, “Herbal Disinfectants□: a Review,” *Herb. Disinfect. a Rev.*, 2013.

[6] L. Z., O. A. J., A. O. O., G. A. R., T. E., and O. L. E., “Phytochemical screening of the leaf extracts of Hyptis spicigera plant,” *African J. Pure Appl. Chem.*, 2014, doi: 10.5897/ajpac2014.0560.

[7] U. Rahmi, Y. Manjang, and A. Santoni, “Profil Fitokimia Metabolit Sekunder dan Uji Aktivitas Antioksidan Tanaman Jeruk Purut (Citrus histrix DC) dan Jeruk Bali (Citrus maxima (Burm.f.) Merr).,” *J. Kim. Unand*, 2013.

[8] M. Wink, M. L. Ashour, and M. Z. El-Readi, “Secondary metabolites from plants inhibiting ABC transporters and reversing resistance of cancer cells and microbes to cytotoxic and antimicrobial agents,” *Frontiers in Microbiology*. 2012. doi: 10.3389/fmicb.2012.00130.

[9] D. P. Kisangau, K. M. Hosea, C. C. Joseph, and H. V. M. Lyaruu, “In vitro antimicrobial assay of plants used in traditional medicine in Bukoba Rural district, Tanzania,” *African J. Tradit. Complement. Altern. Med.*, 2007, doi: 10.4314/ajtcam.v4i4.31245.

[10] D. Akdeniz and A. Özmen, “Antimitotic effects of the biopesticide oxymatrine,” *Caryologia*, 2011, doi: 10.1080/00087114.2011.10589771.

CHAPTER 10

PLANT DEFENCE MECHANISMS: CHEMICAL AND MOLECULAR STRATEGIES

Sunil Kumar, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- sunilagro.chaudhary@gmail.com

ABSTRACT:

The chapter starts by talking about how important it is for plants to have ways to protect themselves. Plants have different ways to protect themselves and make sure they can survive and reproduce, because there are many things that could harm them. These defense mechanisms not only protect plants but also influence whole ecosystems and how they work.As the story continues, the chapter explores the many different chemical ways plants protect themselves. It shows how plants make chemicals called secondary metabolites, like alkaloids, terpenoids, and phenolics. These chemicals help plants protect themselves from being eaten by animals or getting sick. This text talks about chemicals released by plants that help them communicate with other organisms and ask for help against plant-eating animals.Furthermore, the chapter investigates the tiny processes in our bodies that support these defense strategies. This text explains how cells are able to defend themselves against harmful organisms by using complex signals and genes. It starts with recognizing specific patterns on the harmful organisms and then activates the genes needed for defense. The text is saying that phytohormones like jasmonic acid and salicylic acid play a role in coordinating and directing the defense mechanisms in plants.

KEYWORDS:

Animals, Cell wall, Chemicals, Defence Mechanisms, Insects, Plants.

INTRODUCTION

Plants have a lot of nutrients that many living things like bacteria, fungi, protists, insects, and vertebrates need. Plants do not have a strong immune system like animals, but they have developed many ways to protect themselves. They have different structures, chemicals, and proteins that help them detect and stop harmful organisms before they can harm the plant too much. People rely mostly on plants for food, and plants also give us other useful things like wood, dyes, clothes, medicine, beauty products, soap, rubber, plastic, ink, and chemicals used in industry. It's important to know how plants protect themselves from diseases and animals that eat them. This knowledge helps us keep our food safe and create plants that can resist diseases well.This article talks about plant disease and explains how plants defend themselves against diseases. This text explores how plants are structured and how they protect themselves against diseases. It also discusses how plants interact with their environment to defend themselves. We made sure to show how things we use every day come from plants' defense responses[1], [2].

Plant disease refers to the occurrence of a problem or illness in a plant, which can damage or even kill the plant. Resistance, on the other hand, refers to the ability of a plant to defend itself against these diseases.Simply put, disease means that something is wrong with a plant's health. Illnesses can be caused by living things like fungi and bacteria, or by things in the environment like not getting enough of certain nutrients, not having enough rain, not having enough oxygen, being too hot or too cold, being exposed to too much ultraviolet rays, or being around pollution. Plants have different ways to protect themselves from harm. They can either always have defenses or activate them when needed. Continuous defenses are barriers that are already in place to protect against harm. These barriers include cell walls, a layer of wax on the outside of a plant, and the bark. These things not only keep the plant safe from attack, they also make the plant strong and stiff. Almost all plant cells can sense and fight against harmful invaders. They do this by producing dangerous substances, enzymes that break down pathogens, and by sacrificing themselves. Plants usually wait until they find harmful germs before making toxic substances or defense proteins. This is because it takes a lot of energy and nutrients to make and take care of them[3], [4].

Plant pathogens can harm plants by using different strategies. Some use stealthy methods to invade and attack plants, while others use more aggressive and direct approaches.Several plant diseases behave like thieves trying to steal money that is locked inside a bank vault. The thieves use special tools to turn off the bank's security system and open the vault without being caught. Similarly, many germs form close connections with the organisms they infect to weaken the host's defenses and help release nutrients. Biotrophs are pathogens that need their host to stay alive and eat on living plant tissue. Some examples of biotrophic pathogens are a type of fungus called powdery mildew and a type of bacteria called Xanthomonasoryzae, which infects rice plants. Some germs use force like thieves using explosives to break open a bank vault. These harmful germs sometimes create poisons or enzymes that break down plant defenses and help to quickly release nutrients. These harmful organisms are called necrotrophs. Examples of necrotrophs include the gray mold fungus called Botrytis cinerea and the bacterial soft-rot pathogen called Erwiniacarotovora. Some germs are helpful at first but turn harmful later. These germs are called hemibiotrophs and one of them is a fungus called Magnaporthegrisea, which causes rice blast disease[5], [6].

Insects can harm plants, but it's different from a real plant disease. However, plants have ways to detect and defend against these insect pests. Plants can tell the difference between when they are being hurt in general and when they are being eaten by insects. They can do this by recognizing certain substances in the saliva of insects that chew on them. When plants react, they may release certain chemicals into the air called volatile organic compounds (VOCs). These compounds can be categorized into different types such as monoterpenoids, sesquiterpenoids, and homoterpenoids. These substances could push away bad bugs or bring in good bugs that eat the harmful ones. For instance, if young wheat plants have aphids on them, they might release certain chemicals that keep away other aphids. Lima beans and apple trees release substances that attract helpful mites when harmed by harmful mites, and cotton plants release gases that attract helpful wasps when harmed by insect larvae. When an insect eats a part of a plant, the rest of the plant can start making the same chemicals to protect itself. These chemicals can then send a message to nearby plants to also start making these chemicals. Making these chemicals puts a lot of strain on the plant's body, so it doesn't make a lot of them until insects start eating.

All plants have built-in barriers that help stop harmful things like germs from getting inside and hurting them. The cell wall protects against harmful fungi and bacteria. It protects the cell and has tools to fight off harmful germs when they get near. All plants have a main cell wall that supports their structure and helps maintain water pressure. Some plants also have a second cell wall that forms inside the main wall after the cell stops growing. The main outer layer of a cell is called the primary cell wall. It is made up mostly of cellulose, which is a type of complicated sugar made of lots of glucose molecules connected to each other to form long chains. These chains are grouped together into threads called microfibrils, and these make the wall strong and flexible. The cell wall may also have two groups of branching sugars: cross-linking sugars and pectins. Cross-linking glycans are sugars that bind together with cellulose to make hemicellulose fibers. These fibers make the wall strong. Pectins are substances that create moist gels that stick cells together and control how much water is in the wall. Soft-rot germs usually attack pectins in food by using special enzymes that make cells split apart. These germs are very common and when fruits or vegetables turn brown and become squishy, it means these germs are at work[7], [8].

Many cell walls have a substance called lignin, which is made up of different phenolic compounds. Lignin helps the cell stay rigid and firm. Lignin is the main part of wood and cell walls that have lignin are strong against harmful organisms and hard for small insects to bite. Cutin, suberin, and waxes are greasy substances that can be found in the walls of plant cells and the outer layers of plants, like bark.Cell walls have proteins and enzymes that change the shape of the wall when the cell is growing. The wall also becomes thicker and stronger when the cell is defending itself. When a plant cell senses a harmful thing, it releases special substances that create powerful oxygen that can harm the harmful organism's cells. Reactive oxygen molecules also help make the cell wall stronger by creating connections between its different parts. They also act as a signal to nearby cells that an attack is happening. Plant cells have a way of protecting themselves when harmful germs try to invade. They quickly make and put a substance called callose between their cell wall and cell membrane, right next to the germ. Callose deposits, which are called papillae, are substances that prevent the entry of cells at the infected area. They are typically produced as part of the body's natural defense mechanism.

Some plant cells have specific jobs to protect the plant. Idioblasts, also known as "crazy cells," are cells found in plants that protect them from being eaten by insects and mammals. They have harmful chemicals or sharp crystals that hurt the mouths of these animals while they eat. There are different types of special cells, like pigmented cells, sclereids, crystalliferous cells, and silica cells. Cells that have color often have a bitter substance called tannins. These substances can make parts of plants taste bad and not good for eating. Young red wines usually have a lot of tannins which make the wine taste sharp and a bit bitter. Sclereids are oddly-shaped cells with tough walls that are hard to chew. The bumpy feel of pear fruit comes from many sclereid stone cells that can rub down an animal's teeth. Stinging nettles have cells that sting like needles and release irritating toxins when touched by animals that eat plants. Certain cells that cause a stinging sensation contain hormones called prostaglandins. These hormones make the pain sensors in animals' bodies more sensitive and make the feeling of pain stronger. Cells that have crystals of calcium oxalate inside can hurt plant-eating animals' mouthparts when they chew on them. These crystals can also be harmful if the animals swallow them. Philodendron and Dieffenbachia are popular tropical house plants that have a lot of these cells. People and pets may feel a burning feeling in their mouth and throat if they chew on these plants. They might also have swelling, trouble breathing, and not be able to talk. That's why Dieffenbachia plants are often called dumb cane. Grasses and sedges have special cells in their outer layers that make their leaves strong and resistant to insects that try to eat them[9], [10].

DISCUSSION

Plants and insects have been living together for a very long time, more than 350 million years. In co-evolution, both have developed ways to escape from each other's protections. Plants and insects have been competing against each other for a long time. To protect themselves from insects that eat them, plants have developed a defense system that can recognize signals from damaged cells and activate their immune response. Plants defend against insects by producing chemicals and proteins that can harm the insects. They also use physical structures, like thorns or hairs, to directly protect themselves. Plants can also indirectly defend themselves by attracting natural enemies of the insects or providing them with food and shelter. Studying how plants and insects interact is important in plant biology and involves many different fields of study. We are still at the beginning stages of understanding how plants communicate with other plants, as well as with helpful and harmful organisms, using chemicals. This area is very interesting ecologically and has a lot of potential for helping to protect crops. We can use our knowledge of how genes work in plants to create crops that are more resistant to plant-eating animals. This would be very useful for farmers. This will help decrease the amount of dangerous pesticides needed to control bugs. But, plants and plant-eating animals will keep trying to outdo each other, and the animals might change how they evolve in response to the plants becoming resistant. To grow better crops, we need to understand how chemicals in plants and animals interact with each other in a complex way.

Plants have a complex system to defend themselves against plant-eating animals. They have barriers like thorns and tough leaves, chemicals that are poisonous to pests, and they also attract other animals that eat the pests. Both direct and indirect defense mechanisms can be naturally present or triggered after being harmed by herbivores. Plants have a way of responding to pests that helps control them in agriculture. This response has been used to control the population of insects that eat plants. In the last few decades, scientists have made a lot of progress in understanding how plants respond to different stresses, which is important for studying how plants have evolved and their role in nature. Induced responses are important in reducing immediate stress. They have metabolic costs but are helpful in responding to attacks by herbivores. These responses make plants adaptable and decrease the chances of insects adapting to the chemicals produced by the plants.

Plants have special traits like waxy leaves, thorns, and thick cell walls that act as a physical barrier against herbivores. They also produce toxins and other substances that make them hard to eat and slow down their growth. These defense mechanisms work together to protect the plant against attacks from herbivores (Figure 1). In tomato plants, certain substances like alkaloids, phenolics, proteinase inhibitors, and oxidative enzymes have a weaker effect when eaten individually by insects. But when these substances act together, they have a stronger effect and affect the insect during its eating, digesting, and metabolizing process. This was observed in a plant called Nicotianaattenuata. In simple terms, the text is saying that certain substances in plants, such as trypsin proteinase inhibitors and nicotine, work together to protect the plant from insects. We will also talk about how the physical and chemical components of a plant and its reactions to insect damage play a role in resisting pests.Morphological structures refer to the different parts and shapes that exist in living organisms.

The parts of a plant that protect against being eaten by animals are called plant structures. These structures are really important in helping plants resist being damaged by insects. Plants protect themselves from insect pests by creating physical barriers. These barriers can be a thin, waxy layer on the plant's surface or the presence of spines and hairs. These physical defenses can deter herbivores from feeding on the plant. They can range from larger, visible structures like spikes on a plant to microscopic changes in the thickness of the plant's cell walls. Some common physical defenses include spines, hairs, tough leaves, minerals incorporated into the plant's tissues, and wiry stems that branch out at wide angles. Hardened leaves, known as sclerophylly, are particularly effective in reducing damage from herbivores by making the plant less attractive and harder to digest.

Spinescence means that some plants have things like spiky spines, sharp thorns, or prickly thorns. It has been found that plants have hairs on their stems, leaves, and fruits that help protect them from insects. These hairs can come in different shapes and sizes, like straight, spiral, or hooked. Researchers have also found that certain characteristics of the plant, like the shininess of the leaves and the coloration of the leaf sheath, can also make the plants resistant to certain types of flies.Secondary metabolites are chemicals that are made by plants. These chemicals don't change how a plant grows or develops, but they make the plant's tissues taste bad to animals or insects. These chemicals can be made by the plant all the time, or they can be made when the plant is under attack by insects or microbes. The first ones are called phytoanticipins and the second ones are called phytoalexins. Phytoanticipins are substances that are mainly activated by β-glucosidase when plants are eaten by herbivores. This activation then leads to the release of various harmful metabolites. A well-known example of phytoanticipins is glucosinolates. These substances are broken down by myrosinases, which are natural enzymes found in the plant's tissues. Other natural substances that fight against pests and diseases in plants are called phytoanticipins. One example of these substances is Benzoxazinoids (BXs), which are found in many different types of grasses. When plants get hurt, special enzymes inside them help break down certain substances called BX-glucosides. This makes chemicals called biocidalaglycone BXs, which help plants fight off insects.

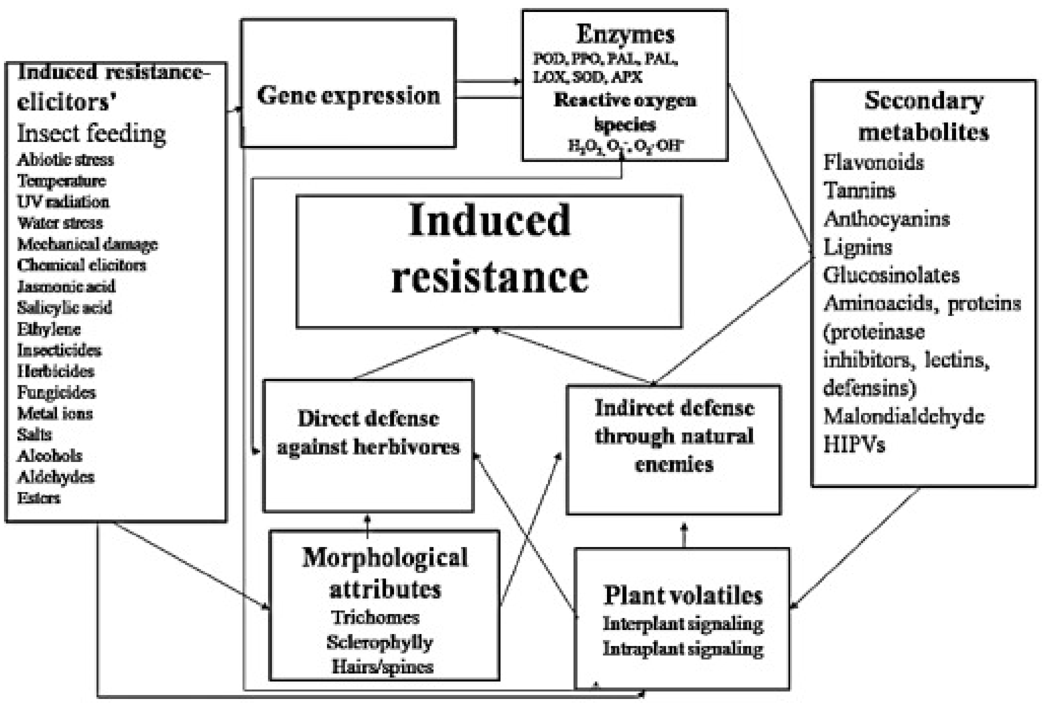

Figure 1: Representing the Mechanism of induced resistance in plants [NCBI].

These aglycone BXs are part of a group of chemicals called phytoalexins, which can stop herbivores from eating and surviving well. These chemicals also help plants stay healthy and strong. It is said that maize protects itself from corn earworm mainly because of certain chemicals called C-glycosyl flavone maysin and chlorogenic acid. Another chemical called 4, 4-dimethyl cyclooctene is responsible for protecting maize from shoot fly A. Sorghum S has a high resistance to a disease called "soccata". Bicolor is a term used to describe something that has two different colors.Secondary compounds have mainly been researched for their role in protecting plants, but there is still a lot of work to be done in understanding their hidden or newly discovered ways of communicating. Mass spectrometry is a helpful tool in studying chemicals and genes. It has made the field more interesting and cheaper. Research on chemicals produced by plants that are not essential for their growth and development could help scientists find new molecules that help plants defend themselves against animals that eat them and other harmful situations. In the end, scientists could figure out which genes and enzymes are responsible for making these substances in our bodies. Below, we will talk about the importance of certain chemicals produced by plants in protecting themselves.

Plants make chemicals that keep them safe from harm. These chemicals don't stop the plant from growing, but they do make the plant's parts less tasty to animals. It can be stored in inactive forms or activated in response to insect or microbe attack.

The defensive metabolites are special compounds in plants that help protect them from plant-eating animals. These compounds can target specific organs in the animals, like their nervous, digestive, and endocrine systems. They can act as repellents for animals that eat a variety of plants, but animals that only eat certain plants have to use their energy to get rid of these compounds.Plants have a defense mechanism that activates as soon as they get damaged by herbivores.

This defense mechanism involves changes in the electrical charge across the cell membrane, followed by changes in the amount of calcium inside the cell and the production of hydrogen peroxide. Kinases are enzymes that detect four plant hormones - jasmonic acid, ethylene, salicylic acid, and nitric oxide - within a short time. After about 1 hour, genes start to become active and this leads to changes in metabolism.

When insects attack, protein inhibitors are produced to fight back. There are also many other proteins that help protect plants from being eaten. Certain enzymes, like polyphenol oxidase and threonine deaminase, restrict the amount of protein that is available in the midgut of insects. On the other hand, other enzymes weaken the protective covering of insects called peritrophic membranes.

Plants use many different types of chemicals, like terpenoids, alkaloids, phenylpropanoids, glucosinolates, lipids, and nonprotein amino acids, to defend themselves.When plants get eaten by herbivores, they release certain substances that can alert nearby plants or tissues to possible attacks. These substances are a mixture of different compounds. Volatiles make it difficult for bugs to lay eggs. They also bring in helpful bugs that attack and eat the bad bugs.

In nature, insects and plants need each other to survive and rely on each other for their well-being. Insects always search for a real and healthy plant that can give them the right food and is good for mating, laying eggs, and feeding their babies. Insects need similar nutrients to other animals. When insects can't digest and use plant proteins correctly, it has big effects on their bodies. Changes in gene expression caused by stress, such as insect attacks, can lead to both quality and quantity changes in proteins.

These proteins are important for transmitting signals and protecting against oxidative damage. Some plant proteins that insects eat can stay stable and intact in their digestive systems, and even move into their bloodstream. When the protein's amino acid content or arrangement changes, it affects how the protein works. Similarly, the ability of a toxic protein that is easily broken down by enzymes to repel insects can be enhanced by giving it protease inhibitors (PIs). These PIs stop the toxic protein from being broken down, allowing it to effectively defend against insects. If we can learn more about how proteins are shaped and changed inside the stomach of plant-eating animals, it will help us figure out how toxic they are and how they protect themselves from plants. New research methods have shown that many types of proteins play a role in plants protecting themselves from plant-eating insects. Different insects eat plants in different ways, so plants have different ways of signaling to produce these protective proteins, such as jasmonic acid (JA), SA, and ethylene (ET).

CONCLUSION

The importance of plant defense mechanisms is very big. In a world where plants are always in danger of being eaten or getting sick, these mechanisms help protect them. Plants are really smart and creative when it comes to making different chemical substances that help protect them. They can make all sorts of stuff like alkaloids and terpenoids, which are really important for keeping away harmful things. These chemicals not only help plants stay safe from predators but also affect how they interact with other living things in their environment.Molecular strategies make the plant's defense system even more advanced.

The complex ways plants communicate and respond to threats show how well they can sense and react to danger. The idea of induced resistance shows that plants can remember and adjust to past obstacles, giving them extra protection when they really need it.Plant defense mechanisms affect how plants interact with their environment, not just for their survival, but also for the way they impact the overall ecosystem.

The way plants choose to grow and protect themselves affects how they interact with other plants, animals, and insects. In addition, knowing about these mechanisms can help with sustainable farming. It can help farmers control pests without using chemicals as much.Studying how plants protect themselves shows the complex interactions that happen in ecosystems. It shows how plants and other organisms interact and how nature uses resilience and adaptability to maintain balance. As we learn more about how plants protect themselves, we also learn how we can use these strategies for farming, nature, and health. The story of how plants protect themselves is proof of how smart nature's strategies are and how well it can survive and live together with other things.

REFERENCES:

[1] M. R. Kant *et al.*, “Mechanisms and ecological consequences of plant defence induction and suppression in herbivore communities,” *Annals of Botany*. 2015. doi: 10.1093/aob/mcv054.

[2] K. A. Yadeta and B. P. H. J. Thomma, “The xylem as battleground for plant hosts and vascular wilt pathogens,” *Frontiers in Plant Science*. 2013. doi: 10.3389/fpls.2013.00097.

[3] F. Amil-Ruiz, R. Blanco-Portales, J. Muñoz-Blanco, and J. L. Caballero, “The strawberry plant defense mechanism: A molecular review,” *Plant and Cell Physiology*. 2011. doi: 10.1093/pcp/pcr136.

[4] R. Gutzat and O. Mittelsten Scheid, “Epigenetic responses to stress: Triple defense?,” *Current Opinion in Plant Biology*. 2012. doi: 10.1016/j.pbi.2012.08.007.

[5] B. Gong and G. Zhang, “Interactions between plants and herbivores: A review of plant defense,” *Acta Ecol. Sin.*, 2014, doi: 10.1016/j.chnaes.2013.07.010.

[6] L. Desprès, J. P. David, and C. Gallet, “The evolutionary ecology of insect resistance to plant chemicals,” *Trends in Ecology and Evolution*. 2007. doi: 10.1016/j.tree.2007.02.010.

[7] A. Vitti, E. La Monaca, A. Sofo, A. Scopa, A. Cuypers, and M. Nuzzaci, “Beneficial effects of Trichoderma harzianum T-22 in tomato seedlings infected by Cucumber mosaic virus (CMV),” *BioControl*, 2015, doi: 10.1007/s10526-014-9626-3.

[8] M. Wink, “Allelochemical properties or the raison d’être of alkaloids,” *Alkaloids Chem. Pharmacol.*, 1993, doi: 10.1016/S0099-9598(08)60134-0.

[9] K. Vijayakumari, K. C. Jisha, and J. T. Puthur, “GABA/BABA priming: a means for enhancing abiotic stress tolerance potential of plants with less energy investments on defence cache,” *Acta Physiologiae Plantarum*. 2016. doi: 10.1007/s11738-016-2254-z.

[10] J. M. Mesa, D. R. Scholes, J. A. Juvik, and K. N. Paige, “Molecular constraints on resistance–tolerance trade-offs,” *Ecology*, 2017, doi: 10.1002/ECY.1948.

CHAPTER 11

PLANT HORMONES AND SIGNALING PATHWAYS: GROWTH, DEVELOPMENT AND RESPONSES

Devendra Pal Singh, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- dpsinghevs@gmail.com

ABSTRACT:

The chapter starts by explaining how important plant hormones are as chemical messengers that control different functions in plants. This text highlights the different jobs that hormones do in controlling growth, development, and reactions to outside signals. This includes tasks like helping plants grow from seeds to flowers, dealing with stress, and protecting the plant from harm. Plants have a complex system of hormone interactions that help them adjust and grow well in different environments.As the story continues, the chapter talks about different types of plant hormones. These include auxins, gibberellins, cytokinins, abscisic acid, ethylene, and brassinosteroids. Each hormone has an important role in different processes, such as helping cells grow longer, helping seeds begin to grow, affecting the immune system, and controlling the closing of small openings on leaves called stomata. The discussion reveals details about how plants make and move substances within their bodies, and how these substances affect their growth and development. This shows that plant signaling networks are complex and intricate.In addition, the chapter looks at how different hormones work together to adjust plant responses and communicate with each other. The plant can combine different signals and adjust its responses based on its surroundings and how it is growing.We are talking about the larger effects of knowing about plant hormones and pathways of communication. It looks at how this information can change farming methods, affecting how many crops are grown, the quality of the crops, and how well they can handle stress. Furthermore, the information given can help with coming up with new ways to improve crop production, make farming more accurate, and even create sustainable solutions using biotechnology.

KEYWORDS:

Cells, Hormones, Plants, Reactive Oxygens, Species.

INTRODUCTION

Plants are really important for life on Earth. They help create ecosystems, give us the air we breathe, the food we eat, and the beautiful landscapes we see. Underneath their calm appearance, there are complex biological activities happening in these living things that have interested scientists and fans for a long time. The study of plant biology explores the different parts of a plant, from its tiny cells to its large beautiful landscapes. It looks at how plants adapt to their surroundings and how they interact with other living things. We also learn about the processes that keep plants alive.

Plants are amazing because they come in many different shapes and sizes.Learning about plant biology is like entering a beautiful and diverse garden. Plants come in many types and there are lots of them in the world. They are found all over, like big trees in rainforests and small mosses in deserts. They are able to live and grow in many different places because they use many different strategies. They have intricate roots that keep them in the ground and special structures that use sunlight to make energy.

The Dance of Cells: Exploring the Structure and Shape of Plants. In simple terms, the cells in plants work together in a harmonious way. The beginning of studying plant anatomy shows how cells, tissues, and organs work together to do important tasks. Every part of a plant has an important job to help it stay alive. The xylem and phloem move water and nutrients to the leaves. The stomata control how the plant breathes by allowing gases in and out. In addition, studying how plants look reveals the many different shapes and designs they have, like the beautiful petals on flowers or the sharp spines on cacti[1], [2].

The life cycle of plants is an interesting story that happens over multiple seasons and periods of time. This text explains the different stages that plants go through, such as when they start growing, reproduce, and get older. Seeds, which carry the possibility for future generations, start to grow when the right conditions are met. They become seedlings, which then grow into fully-grown plants. Plants have developed ways to successfully produce offspring. They have intricate ways of transferring pollen, forming fruits, and spreading seeds. These adaptations show how natural selection and coevolution work and are very beautiful.Photosynthesis is a process that helps plants create food and energy. It is essential for their growth and survival.Photosynthesis, which is often called the "elixir of life," is an important part of plant biology. Photosynthesis is how plants use sunlight, carbon dioxide, and water to make food and oxygen. The beginning of photosynthesis explains how plants use light and a process called the Calvin cycle to grow and support life on Earth. It shows how molecules work together to make this happen[3], [4].

The way plants interact with their environment and how they change to survive and react.Plants are not just watching and not doing anything in their surroundings; they actively engage and communicate with the world around them. The beginning of plant-environment interactions examines how plants have changed over time to adjust to different surroundings. Plants can sense and react to things like light, temperature changes, and water levels in their surroundings. They are really good at this. Additionally, studying how plants interact with helpful microbes, harmful germs, and cooperative partners helps us better understand their complex relationships.The study of plants is mainly about genetics and how molecules in their cells work together. The beginning of plant genetics teaches us about how plants inherit certain traits from their parents, how they can be different from each other due to genetics, and how genes control the characteristics of plants. Studying how genes work involves looking at the detailed processes that control how they are used to make proteins. This includes understanding how information is copied from DNA to RNA, and then how that RNA is used to create proteins. Understanding these mechanisms is crucial for discovering the genetic reasons behind how plants adapt, grow, and react to stimuli.

The study of plant biology is more than just scientific curiosity. It can be used for many different things in areas like farming, protecting nature, studying living things, and studying the environment. This information talks about how studying plants can benefit us in different ways like improving crops, managing land sustainably, and creating new medicines using plant compounds.In short, the beginning of learning about plant biology is an invitation to explore and discover more about the complex world of plants.

Plants come in many different shapes and have ways to survive. They also have special chemical processes that keep them alive. Looking at plants helps us see how amazing nature is. As we learn more about plants, we discover the amazing ways they can adapt and work together. This trip helps us understand and like different types of plants more, and it also helps us find answers to important problems that affect people and the Earth. As we begin this journey, we unlock a world of information that helps us understand life better[5], [6].

DISCUSSION

Plant growth and development are regulated by nine different small molecules called phytohormones, which have unique structures. In the past 20 years, scientists have studied how signals are transmitted in cells, from the receptors to transcription factors. They mainly used Arabidopsis thaliana and rice as examples to understand this process. Phytohormones can be divided into two groups based on where their receptors are found in the cell. One group has receptors in the cytoplasm and can dissolve, while the other group has receptors on the cell membrane and cannot dissolve. Soluble receptors help control how our bodies respond to certain substances like auxin, jasmonates, gibberellins, strigolactones, and salicylic acid. They signal to our cells either by directly affecting certain proteins that regulate our body's processes, or by indirectly causing those proteins to be destroyed. The effects of abscisic acid are mainly controlled by certain receptors that can dissolve in a liquid. These receptors indirectly control how proteins are modified through phosphorylation. Receptors that cannot be dissolved control the way our body reacts to certain substances. These substances include cytokinins, brassinosteroids, and ethylene. The receptors communicate their message through a process called protein phosphorylation. This chapter compares the different parts of these signaling systems and talks about how they are similar and different.

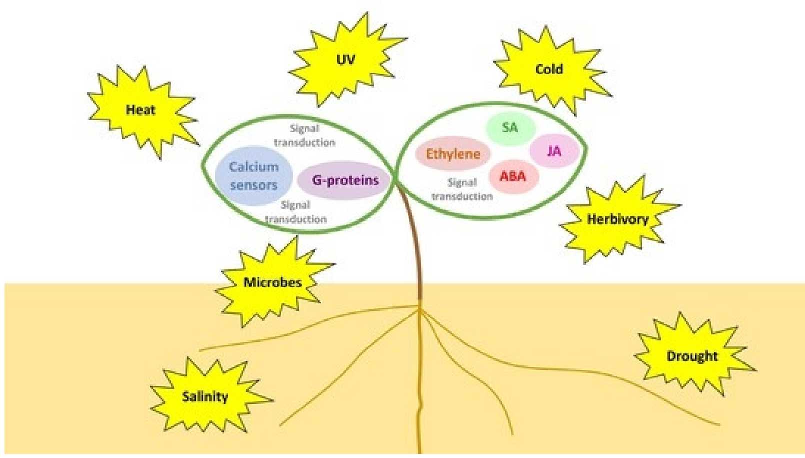

Figure 1: Representing the overview about plants signialing pathway [MDPI].

ROS can control how plants grow and develop because they can interact with different parts of cells. They are talking about different types of reactive molecules like superoxide (O·-2). There are two types of molecules that are important for sensing and can be found in cells. The first type is called hydroxyl radicals and singlet oxygen, which have a short lifespan and can be sensed where they are produced. The second type is hydrogen peroxide, which is more stable and can be sensed both within and between cells. ROS are made in seeds from when the embryo starts growing until it starts to sprout. This happens in cells that are active and using energy, and also in cells that are dormant and dry during the time after the seeds ripen and are stored. The way this happens depends on how much moisture is in the seeds (Figure 1). Although scientists have made progress in understanding how cells communicate using reactive oxygen species (ROS), plant cells still have unidentified sensors that can detect ROS and use this information to trigger specific molecular responses. During imbibition, when water is absorbed by the embryo cells, they stretch and elongate before germination is fully complete. This stretching is necessary for the radicle, the first part of the young plant, to break through and start growing. This kind of cell growth is managed by the outer covering of the cell (cell wall) and it needs to become less tight. In addition to the way in which reactive oxygen species (ROS) break down the cell wall polysaccharides, cell wall remodeling proteins also help loosen the cell wall and promote cell growth during germination and seedling growth[7], [8].

Researchers have found that there is communication between two processes in seeds. One process involves the presence of reactive oxygen species (ROS) and the other process involves hormones. This communication helps with things like making the seed stop being dormant, allowing it to ripen, and helping it to start growing. The build-up of ROS outside of cells in a seed's root and energy supply is controlled by development and hormones. This means that ABA can stop endosperm rupture and cause the seeds of Lepidiumsativum to not germinate. However, GA can counteract the ABA and make the seeds start to grow. In 2011, a study found that a process called ROS-mediated dormancy relief in barley seeds depends on controlling the activity of certain genes that produce proteins involved in the production and breakdown of a plant hormone called gibberellin. These genes are called GA2ox3 and GA20ox1. Another set of genes, called ExpA11, are also involved in this process and are activated by gibberellin. Interestingly, the authors also suggested that when these seeds undergo changes triggered by ROS, they do not interact with ABA signaling, even though there is a slight increase in ABA content. Furthermore, it is understood that in cereals, reactive oxygen species (ROS) are involved in the programmed cell death (PCD) of aleurone cells, which is regulated by phytohormones. This process is started by GA, which causes the buildup of ROS, while ABA keeps low levels of ROS by activating the alternative oxidase pathway and the systems that remove ROS. The instances of PCD happening in plant tissues when they are under stress or when seeds are starting to grow, clearly show that ROS and phytohormones play a big part in controlling these processes[9], [10].

However, we don't know much about the molecular regulators that control the process of cell death (PCD), which is triggered by reactive oxygen species (ROS) and hormones, like LSD1, EDS1, and PAD4, during the beginning of plant growth. In this passage, we talk about new discoveries related to LSD1/EDS1/PAD4 and other substances that help plants respond to stress. These substances also play a role in the development of seeds.The exploration of plant biology has been truly amazing. As we learn about plants, from their tiny cells to their big ecosystems, we discover how they adapt, interact, and stay strong in the natural world. This conversation talks about the deep things we learned from studying plants and how it affects science, society, and the planet.The conversation starts by recognizing how plants have changed and improved over a very long time. These changes show how genes and the environment work together to help plants grow well in many different places. Plants are very clever in how they evolve to survive. They have thick leaves to save water and pretty flowers to attract insects that help them reproduce. This ability to adjust and change is evidence of how life on Earth is always changing and how natural selection and the environment work together.Interconnectedness means how things are related or connected to each other. Ecological dynamics refers to the way different living things interact and how the environment changes over time. Because plants can make their own food using sunlight, they have not been able to move around like animals. This has limited the way plants have evolved, and their cell walls are quite stiff. When cells in plants took in and merged with chloroplasts from bacteria a long time ago, it greatly affected how plants communicate with each other. Plants need to sense their environment in order to grow, and this is connected to their development. Temperature, light, touch, water, and gravity can all start natural growth processes. Out of all these things, light is very important. It gives plants the energy to make food and helps them grow from seeds into flowers. Therefore, plants have the most variety of ways to sense light out of all living things. These cells can detect how much light there is and what kind of light it is for the plant. Phytochromes are like sensors that detect red and far-red light. These are enzymes that activate in response to red light and are capable of changing between two different forms when exposed to light. When red light is shone on them, they move from one part of the cell to another where they interact with certain proteins, like PIF3. These proteins attach to special parts of genes that respond to light, which then causes the genes to be turned on and start making copies of themselves. So, phytochrome signaling involves communication between the nucleus and the cell's liquid part.

Comparing the genes of plants like thale cress and rice, scientists have found many chemical signals that are similar in both animals and plants. The fact that plants and animals have similar ways of sending signals suggests that their differences have come about through changes to their basic communication methods over time. However, this basic similarity is found along with many new things or themes. Overall, plants and animals have similar ways of organizing themselves. This means that they use the same group of important genes and pathways to communicate and develop in different situations. The RAS genes can be used as a good example to show this argument. RAS genes are a type of protein family called small guanosine 5´-triphosphatase. They control many important activities inside cells such as signaling, moving things around, and carrying things into the nucleus. They are seen as switches that toggle between a working and a resting state. This makes sure that information flows, but it uses up a molecule called guanosine 5´- triphosphate. This tiny switch is thought to have been created a long time ago, and as time went on, it changed to do different jobs. There are five families of small G proteins: RAS, RAB, ARF, RAN, and RHO. They work with other proteins to form changing groups that control many important activities in cells. In plants, they have found genes from the RAB, ARF, and RAN families, but not from the RAS family. A new group of small proteins in plants is called ROP, which stands for RHO of plants. It seems that only certain families that are important for moving substances around in cells have been kept in plants. It is possible that plants, because they don't move, need to carefully control how they release substances in order to control how their cells grow. In this situation, it is very important for plants to have control over their cellular membrane compartments, moving large molecules between different parts of the cell and the outside, and transporting things in and out of the nucleus. This helps plants to be successful in evolution.

The study of plant biology helps us understand how different parts of our environment are connected and how plants form complex relationships. Plants are a part of complex ecosystems and they affect the lives of other organisms that live there. In the conversation, we talk about how plants are important because they make food and give energy to animals that eat plants, animals that eat other animals, and also to decomposers. In addition, studying how plants and microbes work together shows us the amazing partnerships that plants have with helpful microbes. These partnerships help with things like getting nutrients, fighting off diseases, and keeping the soil healthy.Photosynthesis is the main process in plant biology. This conversation emphasizes the extremely important process where plants use sunlight to make energy that keeps life on Earth going. The study of photosynthesis, which includes capturing energy from light and using it to turn carbon into food, shows how molecules work together to make living things grow and reproduce.Plants have to navigate a changing environment with good and bad things. This conversation talks about how plants can sense and react to things in their environment. For example, they can tell which way light is coming from and they have ways to deal with not having enough water, changes in temperature, and not having enough nutrients. The study of how plants respond to stress and protect themselves shows how amazing plants are at adapting to their environment. They can change their chemistry and how their bodies work to deal with challenges.Understanding the way genes work and how they affect the body is a complicated process.

Scientists use genetics and molecular mechanisms to study and figure out this complexity.Progressions in the study of genes and small particles in biology have given us a way to understand the detailed workings of plants. The conversation talks about how genes affect plants, including how they are passed down from parents and how they influence the way plants grow and behave. It shows how the tiny workings inside cells control the characteristics and reactions of plants. Studying the differences in genes and using genetic modification methods show that we can change plants to make them better in different ways, like having better qualities, fighting off diseases, and giving bigger harvests.Applications in science and society refer to how scientific knowledge and discoveries are used in practical ways to benefit people and the world around us. This could include things like using scientific research to develop new technologies and medicines, implementing sustainable practices to protect the environment, or improving industries and transportation systems. These applications play an important role in advancing our understanding of the world and improving the quality of life for individuals and communities.The knowledge learned from studying plants goes beyond scientific interest. This conversation talks about how certain things affect society in different ways. In farming, knowing how plants work and interact with their surroundings helps us create better crops. This means we can grow more food, make it more nutritious, and develop plants that can handle dry conditions. Moreover, the possibility of creating biofuels, medicines, and eco-friendly materials from plant substances emphasises the connection between plant science and technology in a positive way.The discussion is about how important it is to take care of plants and use them responsibly. Because humans are harming biodiversity and messing up ecosystems, it's important to study plants so we can come up with good ways to protect them. Plant biologists play an important role in protecting endangered plants, restoring their habitats, and preserving their genetic diversity. By doing so, they help maintain the fragile balance of nature.

Overall, learning about plant biology helps us understand that the world is complex, diverse, and all living things are connected. From tiny things that happen inside cells to the amazing view of land, plants show how beautiful and complicated life can be. The things we learn from studying plants can be applied to many different areas like medicine, farming, the environment, and technology. This shows us all the different things we can do with plant biology. This journey is not something that one person does alone. It is something that a lot of different people, like scientists, educators, policymakers, and regular people, work together on. They all have the same goal of understanding and protecting the delicate balance of life. As we move forward, using what we know about plants, we are more prepared to deal with the problems caused by a changing climate, sustainable farming, and the protection of different types of plants and animals.By studying plant biology, we appreciate the strength and attractiveness of plants and find out the secrets that link all living beings. This talk is not a final point, but a request for action, a invitation to learn about plants and take care of the Earth and the many different forms of life on it.

CONCLUSION

Plant hormones are not alone; they work together to control every aspect of plant biology. Hormones control various processes in plants, such as cell growth, flowering, response to stress, and opening of stomata. They work together like conductors in a symphony, where every note plays a part in the overall composition.This text talks about certain hormones, how they are made, how they travel in the body, and how they work. It shows how complex these processes are. The way hormones interact and communicate show how plants can combine different information and change their responses according to their surroundings and stage of growth.In addition, learning about plant hormones has benefits that go beyond just wanting to know more about science. This knowledge has a lot of potential to change and improve agriculture. It can make crops grow better, withstand challenges, and use resources more efficiently. Studying signaling pathways can help us solve global problems in food security and sustainable agriculture by improving growth and reducing stress.As we think about our study of plant hormones and signaling pathways, we understand that it is about more than just doing research. It is about finding out how plants can survive and change to fit their environment, and what they are capable of. From the research lab to real-life applications, the information gained from this chapter provides solutions that align with what people need, advancements in technology, and maintaining the delicate balance of nature. By understanding how plants communicate, we can learn more about them and find a way to live in a more sustainable and peaceful way with nature.

REFERENCES:

[1] R. Puga-Freitas and M. Blouin, "A review of the effects of soil organisms on plant hormone signalling pathways," *Environ. Exp. Bot.*, 2015, doi: 10.1016/j.envexpbot.2014.07.006.

[2] A. Li, M. Zhou, D. Wei, H. Chen, C. You, and J. Lin, "Transcriptome profiling reveals the negative regulation of multiple plant hormone signaling pathways elicited by overexpression of C-repeat binding factors," *Front. Plant Sci.*, 2017, doi: 10.3389/fpls.2017.01647.

[3] S. Gimenez-Ibanez, A. Chini, and R. Solano, "How microbes twist jasmonate signaling around their little fingers," *Plants*, 2016, doi: 10.3390/plants5010009.

[4] C. Wang, Y. Liu, S. S. Li, and G. Z. Han, "Insights into the origin and evolution of the plant hormone signaling machinery," *Plant Physiol.*, 2015, doi: 10.1104/pp.114.247403.

[5] Y. Jaillais and J. Chory, "Unraveling the paradoxes of plant hormone signaling integration," *Nature Structural and Molecular Biology*. 2010. doi: 10.1038/nsmb0610-642.

[6] R. Pierik and C. Testerink, "The art of being flexible: How to escape from shade, Salt, And drought1," *Plant Physiol.*, 2014, doi: 10.1104/pp.114.239160.

[7] C. Ellis and J. G. Turner, "A conditionally fertile coi1 allele indicates cross-talk between plant hormone signalling pathways in Arabidopsis thaliana seeds and young seedlings," *Planta*, 2002, doi: 10.1007/s00425-002-0787-4.

[8] J. M. Davière and P. Achard, "A Pivotal Role of DELLAs in Regulating Multiple Hormone Signals," *Molecular Plant*. 2016. doi: 10.1016/j.molp.2015.09.011.

[9] R. Li, A. M. Rashotte, N. K. Singh, D. B. Weaver, K. S. Lawrence, and R. D. Locy, "Integrated signaling networks in plant responses to sedentary endoparasitic nematodes: a perspective," *Plant Cell Reports*. 2015. doi: 10.1007/s00299-014-1676-6.

[10] E. H. Colebrook, S. G. Thomas, A. L. Phillips, and P. Hedden, "The role of gibberellin signalling in plant responses to abiotic stress," *Journal of Experimental Biology*. 2014. doi: 10.1242/jeb.089938.

CHAPTER 12

MINERAL NUTRITION AND ION TRANSPORT IN PLANTS: NOURISHING GROWTH

Upasana, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India,
Email Id- upasana35954@gmail.com

ABSTRACT:

The chapter starts by talking about how important minerals are for plants to grow. Important minerals, which come from the soil and water, are used to make important molecules, help enzymes work better, and control how cells work. These nutrients are very important for plants because they don't just help them survive but also affect their growth, flowering, and how they respond to the environment.As the story continues, the chapter explores how plants get minerals from their surroundings in a detailed way. This text is about how plants take in nutrients. It talks about the different parts of the plant that help with this, like the roots and the structures inside them. It also mentions how a certain kind of relationship with fungi can help plants absorb minerals. The talk is about how plants can get the important nutrients they need to grow and what things can affect their ability to access these nutrients.Furthermore, the chapter explains the complicated system of moving ions within plants. This study explores how molecules control the transport of minerals through cell membranes and make sure they are sent to different tissues. The idea of ion selectivity is important for plants because it allows them to tell the difference between ions by considering their charge and size. This helps plants regulate the nutrients they take in.

KEYWORDS:

Elements, Growth, Minerals, Nutrients, Plant.

INTRODUCTION

Earth's crust that is necessary for the growth, development, and maintenance of living organisms. These mineral nutrients are absorbed by plants from the soil and are essential for various biological processes such as photosynthesis, respiration, and protein synthesis. They are also important for the formation of bones and teeth in humans and animals.Soil is important for plants to grow. plants is important for their uptake and utilization.Plants need nutrients to grow and stay healthy. Nutrients are like food for plants. essential nutrients needed by the body for growth, development, and overall health. It involves the process of obtaining and digesting food, extracting the necessary nutrients, and using them to support bodily functions. Nutrition is important for maintaining good health and preventing diseases.There are three sources from which higher plants get the energy they need to grow and develop.The things that make up our environment are the air around us, the water we have, and the ground we walk on. The air gives us carbon and oxygen in the form of carbon dioxide.During photosynthesis, carbon is decreased and during aerobic respiration, oxygen is used[1], [2].

If a plant doesn't have the necessary elements, it doesn't grow properly and shows signs of not getting enough nutrientscauses changes in how the body processes energy and leads to an early death. the universe, oxygen is one of the most abundant and important. Oxygen is a gas that is essential for life on Earth. It makes up about 21% of the Earth's atmosphere and is necessary for humans and other animals to breathe. Oxygen is also a component of water and many organic compounds. Without oxygen, life as we know it would not be possible.Out of all the tissues in plants, only 16 are necessary for every type of plant. They are the elements C, H, O, N, P, K, Ca, Mg,These are the chemical elements symbols: Sulfur, Zinc, Copper, Iron, Manganese, Boron, Chlorine, and Molybdenum. cannot survive Without all of the necessary components, plants will not be able to live.Developing deficiency symptoms that are typical of the lacking nutrient and dying at a young age.Macronutrients are essential nutrients that our bodies need in large amounts. They include carbohydrates, proteins, and fats. These nutrients provide energy, support growth and development, and help maintain overall health. Macronutrients can be found in a variety of foods, such as grains, fruits, vegetables, meats, and dairy products. It's important to have a balanced intake of macronutrients to ensure optimal nutrition and well-being[3], [4].

These macronutrients include elements such as nitrogen, phosphorus, and potassium. Plants need these macronutrients in larger amounts compared to other elements. They are essential for the healthy growth and development of plants.This is a device that generates heat to increase the temperature of the system. This is where the heating element and the materials being processed are placed. It holds everything together and allows the heat to be evenly distributed. These are the components that undergo a change or transformation during the process. They can be liquids, solids, or gases. A control system: This is responsible for regulating and maintaining the desired temperature, pressure, or other variables during the process. Overall, these essential elements work together to facilitate the desired outcome of the process.Plants need certain elements like carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur to grow. Out of these elements, Carbon, Hydrogen, and Oxygen are important nutrients.Plants get their nutrients from the air and water. important nutrients for plants. They are found in fertilizers that plants need to grow.Plants take in nutrients from the soil, which are then given to them as chemical fertilizers[2], [5].

Micronutrients are nutrients that are needed in small quantities by our body for proper functioning and overall health.The nutrients that are necessary in smaller amounts are known as micro-nutrients. Minor or micro nutrients, also known as trace elements, are essential substances that are required by living organisms in small amounts for proper growth, development, and overall health. Plants need small amounts of micronutrients to survive.The elements that help plants grow are zinc, copper, iron, manganese, molybdenum, boron, and chloride.Tracer elements are small components that are used to track or identify something.The important nutrients plants need are sometimes marked and used for researchways or processes.Tracer elements are the organs of plants. They can be either stable or decay.There are different kinds of elements, and they are also known as isotopic elements.Radioactive materials like 14C, 32P, 65Zn, 56Fe, 60Co, and others.Hidden hunger, also known as micronutrient deficiency, refers to a lack of essential vitamins and minerals in a person's diet. This can occur even if the person is getting enough calories and not experiencing outward signs of malnutrition. Hidden hunger can lead to various health problems and can particularly affect children's growth and development.

When plants cannot get what they need, it could be because they are missing one or more important things they need to grow.The plants will not get enough of certain elements, so they will go hungry. In the beginning ofbe used to identify their lack.Plants may show changes in their physical appearance and functioning when they lack certain important elements.Hidden hunger is when you have a lack of certain nutrients in your body.Building the structural components of the plant, such as cell walls and tissues. Serving as a catalyst for various chemical reactions within the plant. Regulating the plant's metabolism and growth. Maintaining overall plant health and functioning. Assisting in the uptake and transport of water and nutrients. Contributing to the plant's ability to produce food through photosynthesis.Playing a role in the plant's response to environmental stressors. Supporting the reproductive processes of the plant.There are three reasons that support this statement.

This means that while these elements are not necessary for everyone, they are necessary for certain individuals or under certain conditions. In simpler terms, the idea is that not all essential elements are necessary for everyone all the time. Some elements may only be necessary for certain individuals or in specific situations.These elements may be referred to as functional or metabolic elements instead of essential elements. For example, in chlorine-bromine, chlorine is called a functional. Instead of using chlorine, bromine can be used instead.Elements in phloem are classified into three types based on how easily they can move around.This text is difficult to understand and needs to be simplified. Mobile elements are the substances N, K, P, S, and Mg.They bought groceries and household items. After that, they went to a restaurant to have dinner. Then, they drove back home and watched a movie before going to bed. Elements that cannot move: Calcium, Iron, and Boron.Medium level: zinc, manganese, copper, molybdenum Simple level: These are the elements zinc, manganese, copper, and molybdenum.

DISCUSSION

Plants need nutrients from the soil to grow and develop. Mostly, plant roots soak up these important nutrients and move them to different parts of the plants to do different jobs.The way nutrients are transported to plants depends on the type of soil they are in. Plants need sixteen minerals to grow. The tiny hairs on the roots take in thirteen of these things. These minerals include nitrogen, magnesium, potassium, phosphorus, calcium, and sulphur, among others. These six important minerals are known as micronutrients.Mineral nutrients transportation refers to the process of moving essential nutrients, that are needed for plants to grow, from one part of the plant to another.Water and minerals are taken up by the roots of plants and then distributed throughout the plant in two different ways.Active method means doing something instead of just talking or watching. It involves taking action and being engaged in a task or activity.Plants get nutrients using energy from their cells. This process relies on ions moving between the outer cells and inner cells.There are many ways minerals are brought to plants.Soil particles come in different sizes and contain all the nutrients needed by plants. These particles also come together to form soil aggregators. But most plants are unable to access the extensive area covered by soil aggregates. Plant roots wrap around, or grow around, the aggregators instead of inside them[6], [7].

As a result, only a small amount of minerals can directly touch the root hairs. Root interception is not the best way for nutrients to travel.Plants lose water through their leaves, and this is called transpiration. To make up for the loss, roots absorb water from the ground. Soil water normally has three types of negatively charged ions: sulphate, nitrate, and borate. Because roots cannot fully absorb water from the soil, the minerals in the water cannot reach the roots. So, the amount of these three nutrients that goes to the roots can change a lot. It is a very important way for plants to get nutrients.Plants' scientists have shown that the roots of plants have a lower concentration on their surface. The soil aggregators also mix together some nutrients that have positive charges, such as calcium (Ca^{++}), potassium (K^{+}), and magnesium (Mg^{++}). In simple words: The upper layer of soil clumps together more in some areas. So, these ions move to roots by spreading out. Plants need to take in mineral ions, even when the concentration of these ions is higher outside their cells. This process is important for their survival.The passive method is when someone is not actively involved or taking action.This way of absorbing nutrients happens without using extra energy from the body's metabolic processes.Phloem transport is the process by which plants move sugars and nutrients from one part of the plant to another (Figure 1).Besides these two important ways, there is also another way that helps move food and minerals from leaves to other parts of plants. After plants make food in their leaves, it turns into a sugar called sucrose[8], [9].

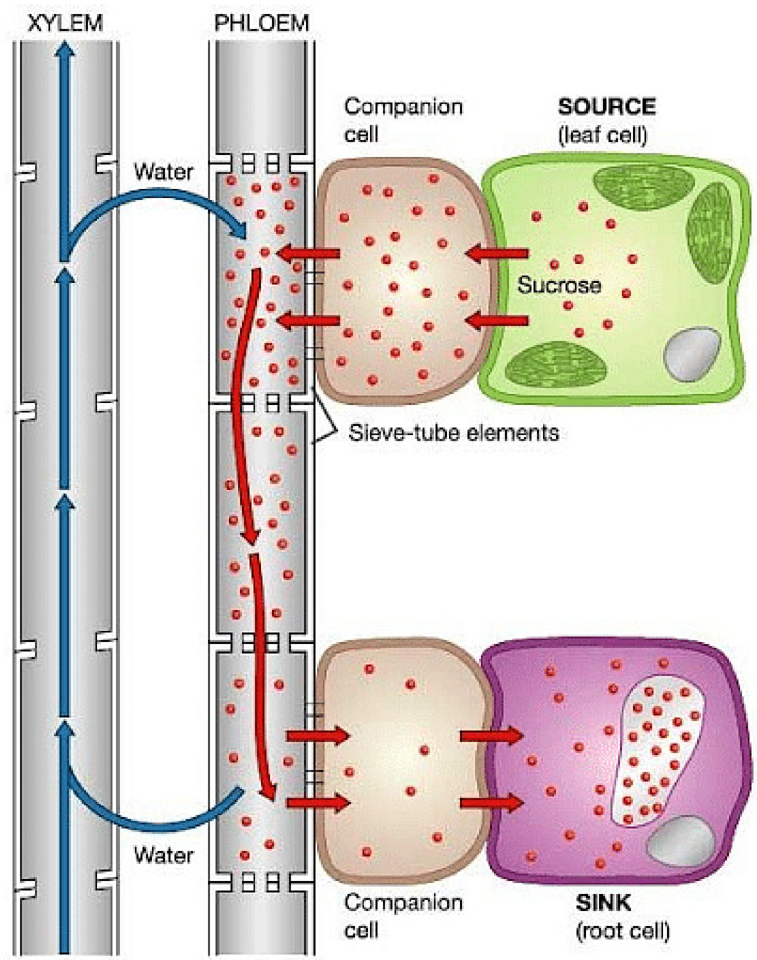

Figure 1: Representing the overview about plant mineral nutrient transportation [Quora].

This sugar then moves to other parts of the plant through special tissues called Phloem.This movement happens from one place to another. Also, the movement of phloem transport can go in both directions. For instance, during the beginning of spring, the nutrients move from the roots to the growing buds in an upward way. Minerals that are taken in by the roots travel to the leaf through many tube-like vessels. The distribution of nutrients that the plant gets to different parts is also an important part of the conversation. This chapter looks at how plants move minerals around their bodies and how they decide which parts of the plant get the most nutrients. They do this to help with things like making food, growing, and making new plants. The complicated way plants distribute nutrients shows how they use their resources effectively to survive.

Additionally, the chapter explores how minerals interact with the overall functioning of plants. This looks at how the nutrients plants have affect how they react to things that stress them out, like environmental changes and living things. It also affects how well they can handle these challenges. The talk also explains how the minerals plants get from their food affect the chemicals they make that help them grow and protect themselves.Minerals are very important for plants to grow and change. They help with getting the necessary nutrients and distributing them in a smart way. Minerals play a big role in how plants grow and adapt. The information we gain from this research helps us understand plants better and can lead to new ways to improve agriculture, manage resources more sustainably, and grow crops that are full of nutrients to solve worldwide problems. The story of mineral nutrition shows how plants rely on a careful balance of elements to survive and thrive[10], [11].

In the past, it was believed that minerals from the soil were absorbed by plants at the same time they absorbed water. However, it is now known that the absorption of minerals and water are two separate processes. Plants take in mineral salts from the soil solution in the form of ions. These substances are mostly taken in through the growing parts of the roots that are close to the ends. But, some mineral salts can also be taken in at different parts of the root surface or all over the root surface, like the area where the root grows longer and the root hairs, which is determined by how much of those minerals are nearby and how much the tissues in those areas need them. The membrane of the root cells does not allow all ions to pass through. It can choose what goes in and out. Not all the ions from a salt are absorbed at the same speed. Some ions are absorbed more quickly than others. The first thing that happens when our bodies absorb mineral salts is something called Ion Exchange. This process doesn't use up any energy from our bodies, and it actually makes it much easier for us to absorb the mineral salts. Ion exchange occurs when ions that are attached to the walls or membranes of root cells are swapped with ions of the same charge from the outside solution. For instance, the positive potassium ion in the soil outside the plant may switch places with the hydrogen ion attached to the root cells. Also, an anion can be swapped with the OH- ion.

In this theory, ions that stick to the surface of root cells and clay particles are not held tightly but move around in a small area. If the roots and clay particles are close together, the ions on the roots and clay particles may mix together and swap places without dissolving in the soil. Plants can also gather a lot of mineral salts against the natural flow of concentration. For instance, in the alga Nitella, the liquid inside the cell gathered a high amount of K+ and phosphate ions. These ions were much more concentrated in the cell sap compared to the water in the pond where the plant was living. This cannot be explained by simple diffusion or Donnan's Equilibrium. It has made people think that absorbing and gathering mineral salts against the concentration difference is an active process that uses energy from respiration.

Lundegardh and Burstrom (1933) thought that there was a clear connection between breathing and the intake of certain particles called anions. Therefore, when a plant is moved from water to a salt solution, its breathing speed goes up. This faster breathing rate than usual is known as anion respiration or salt respiration. When salt respiration is stopped and CO and cyanides are used, the absorption of certain particles by the mitochondria is also stopped. This led Lundegardh to suggest a theory called the cytochrome pump theory. This theory assumes that the absorption of positive and negative particles is done differently. Negative ions are taken in by a chain called cytochrome through an active process. Cations are taken in without any effort.

In 1956, Bennet-Clark suggested that a protein called lecithin, which is associated with the phospholipids in cell membranes, could be responsible for carrying certain enzymes. He also believed that the different types of phosphatides in the cell would match the number of known competitive groups of positive and negative ions. The ions are released inside the membrane when the lecithin is broken down by the enzyme lecithinase. The carrier lecithin is made again from phosphatidic acid and choline with the help of enzymes called choline acetylase and choline esterase, as well as ATP. The second one gives us energy.

Cell membranes are mostly made of fats and proteins. There are two main types of membrane lipids: phospholipids and sterols, like cholesterol. Both types of substances can dissolve in organic solvents and also have a part that can dissolve in water. This property of lipids, which means they can be attracted to both water and fats, is important because it helps them form the structure of cell membranes. Membrane proteins can be divided into two general types. There is a type of proteins called extrinsic proteins. These proteins are attached to the charged surface of the bilayer by weak bonds. They can also stick to another kind of protein called intrinsic proteins. The proteins inside the phospholipid bilayer are called intrinsic proteins. Typically, membranes that play a role in metabolism have more protein in them. The structure of the cell membrane makes it very flexible, which is perfect for cells that are growing and dividing quickly. However, the membrane is also a strong obstacle, as it only allows certain dissolved substances, or solutes, to go through while stopping others (Figure 2). Some small and lipid-soluble molecules can pass through the membrane, but the cell membrane does not allow big or water-soluble molecules and electrically charged ions to pass through. Certain types of proteins help transport important substances in different ways. Some proteins form open channels that let ions directly enter the cell. Other proteins, called facilitators, help solutes pass through the lipid barrier.

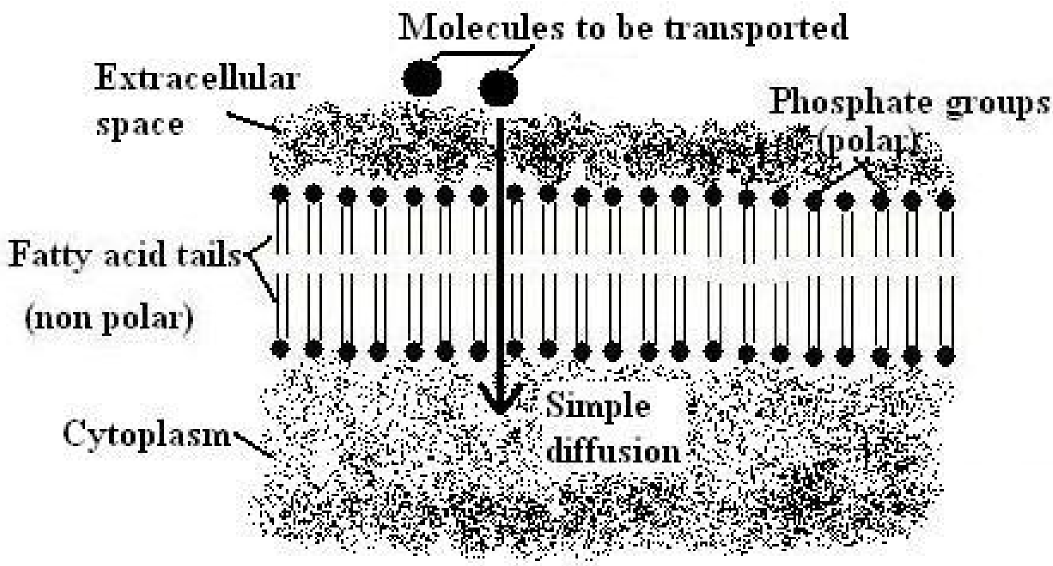

Figure 2: Representing the minerals transport by simple diffusion [Peoi.Org].

There are also proteins called pumps that push solutes through the membrane when they are not concentrated enough to pass through on their own. Tiny particles that are too big to spread out or be moved by a pump are usually swallowed or spit out completely by a membrane that opens and closes. Ion pump carrier is a device that transports ions. Plants take in mineral salts in their ionic state and carry them around within their bodies. Some substances like sugars can be moved through membranes without having an electrical charge. For substances that don't have an electrical charge (non-electrolytes), how they move across the membrane depends on the difference in their concentration on either side of the membrane. However, when there are substances that have an electric charge (such as electrolytes), things are not the same. When solutes move into the cytosol through a membrane (like the plasma membrane or tonoplast), it's called influx. When they leave the cytosol, it's called efflux. In the past few years, researchers have been studying how substances can pass through cell membranes, particularly the outer membrane of cells and the membrane surrounding the vacuole. They have discovered different proteins that help these substances move through the membranes. These proteins that transport things have a very specific job and are made up of many parts. Scientists have come up with different ideas to explain how they work.

CONCLUSION

Studying how plants get nutrients from minerals helps us understand how they grow, reproduce, and respond to their environment.Mineral nutrition is really important for plants. It doesn't just affect one plant, but also has a big impact on the environment and how nutrients move around the world. The talk showed how plants have a big impact on the minerals that are available to plant-eating animals, meat-eating animals, and things that break down dead plants and animals. This is important because it helps to make sure that energy can move smoothly through the natural world.The complex process of moving ions within plants shows how plants can adjust to different environmental conditions. Plants have an amazing ability to adjust their responses to different amounts of nutrients.

They can control how much essential minerals enter, move around, and are used in their bodies very accurately.In addition, plants use minerals they obtain to help with different body processes like making food and protecting themselves. This shows that plants are smart about using their resources to grow well and adjust to their environment. This allocation shows that the plant can focus on important things depending on the current situation.The talk has also showed the overall importance of mineral nutrition for farming, taking care of the environment, and staying sustainable.

The study of ways to manage nutrients, like using fertilizers and precision agriculture, can help increase crop production, prevent nutrient waste, and lessen the harmful effects on the environment caused by farming.As we learn about how living things get and use nutrients, we start to understand how everything is connected on Earth. The tale of how plants get the nutrients they need is a remarkable example of how everything in nature works together to keep plants healthy and support the balance of life on Earth. In the end, the knowledge gained helps create new and improved ways of farming, solve problems with nutrition, and work better with nature for a sustainable future.

REFERENCES:

[1] R. J. Tang and S. Luan, “Regulation of calcium and magnesium homeostasis in plants: from transporters to signaling network,” *Current Opinion in Plant Biology*. 2017. doi: 10.1016/j.pbi.2017.06.009.

[2] M. S. A. Blackwell, “Wetland Ecosystems,” *J. Environ. Qual.*, 2011, doi: 10.2134/jeq2011.0002br.

[3] A. K. Shanker, C. Cervantes, H. Loza-Tavera, and S. Avudainayagam, “Chromium toxicity in plants,” *Environment International*. 2005. doi: 10.1016/j.envint.2005.02.003.

[4] M. A. Grusak, “Enhancing mineral content in plant food products,” *J. Am. Coll. Nutr.*, 2002, doi: 10.1080/07315724.2002.10719263.

[5] B. Sattelmacher, “The apoplast and its significance for plant mineral nutrition,” *New Phytologist*. 2001. doi: 10.1046/j.1469-8137.2001.00034.x.

[6] J. Park, Y. Y. Kim, E. Martinoia, and Y. Lee, “Long-distance transporters of inorganic nutrients in plants,” *Journal of Plant Biology*. 2008. doi: 10.1007/BF03036122.

[7] D. P. Schachtman, R. Kumar, J. I. Schroeder, and E. L. Marsh, “Molecular and functional characterization of a novel low-affinity cation transporter (LCT1) in higher plants,” *Proc. Natl. Acad. Sci. U. S. A.*, 1997, doi: 10.1073/pnas.94.20.11079.

[8] S. C. McDowell *et al.*, “Elemental Concentrations in the Seed of Mutants and Natural Variants of Arabidopsis thaliana Grown under Varying Soil Conditions,” *PLoS One*, 2013, doi: 10.1371/journal.pone.0063014.

[9] J. Le Bot, S. Adamowicz, and P. Robin, “Modelling plant nutrition of horticultural crops: A review,” *Sci. Hortic. (Amsterdam).*, 1998, doi: 10.1016/S0304-4238(98)00082-X.

[10] A. Honsbein *et al.*, “A tripartite SNARE-K+ channel complex mediates in channel-dependent K+ nutrition in arabidopsis,” *Plant Cell*, 2009, doi: 10.1105/tpc.109.066118.

[11] C. A. Blindauer and R. Schmid, “Cytosolic metal handling in plants: Determinants for zinc specificity in metal transporters and metallothioneins,” *Metallomics*. 2010. doi: 10.1039/c004880a.