NUTRITION IN PLANTS

Chapter 21

A farmer sows about one to one-and-a-half quintals of wheat seed in a hectare of cultivated land. After three to four months, he harvests 20 to 25 quintals of wheat. He also gets a lot of straw.

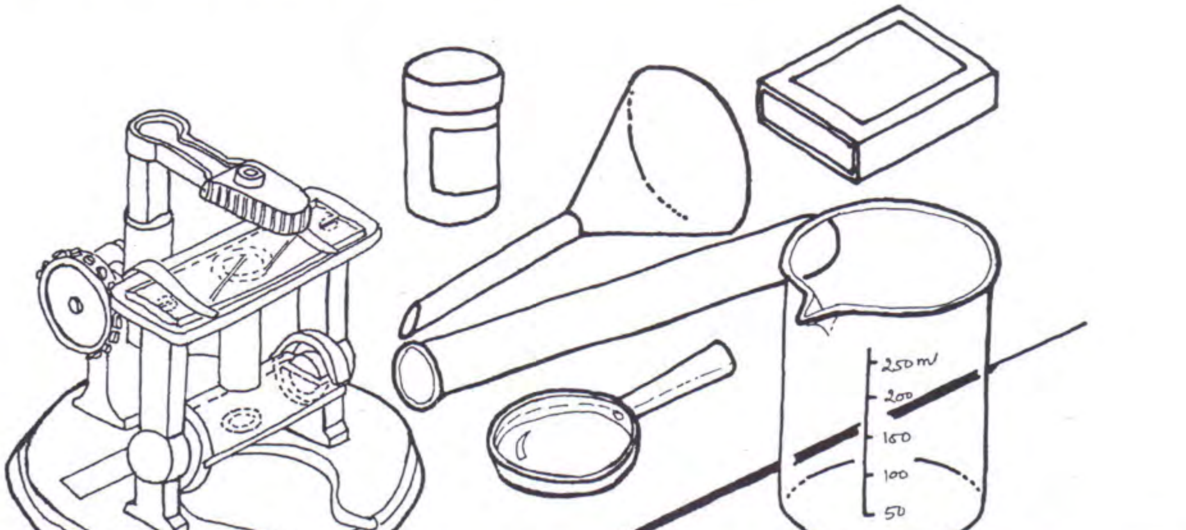
A mango seed grows into a mighty mango tree that yields hundreds of juicy mangoes within a few years.

Have you ever thought where all that wheat and straw comes from? How did the mango tree get so many leaves and grow such a thick trunk and branches?

In the case of human beings, we know that a child eats food every day and grows into an adult.

But how do plants become big without eating or drinking anything? How do they produce so much wheat or mangoes? From the soil? Or from the water used to irrigate them? Or from the air?

People have been thinking about this question from ancient times.



At first they thought plants got everything they needed to grow from the soil. The Greek philosopher-scientist Aristotle believed that, unlike animals, plants did not have organs for digesting food. So they absorbed rotting substances dissolved in the soil. But no one thought of testing this theory until many, many years later, a man from Belgium decided to check whether it was true or not. His name was Jan Baptista van Helmont and he conducted an experiment that continued for five years. The experiment was performed 350 years ago in 1648. Let us see what van Helmont did.

Van Helmont's five-year experiment

Van Helmont took a large pot and filled it with 90 kg of soil. He planted a cutting of a willow tree in it. It weighed 2.268 kg. He irrigated the cutting with distilled water for five years. The pot was large and was buried in the ground. Van Helmont took care to ensure that the soil in the pot remained in contact with air, but he saw to it that no outside dust got in by covering the pot with a metal lid punched with fine holes.

Gradually, the sapling grew into a small tree. After five years, van Helmont uprooted the tree, cleaned it and weighed it. The tree weighed 74 kg. He then dried the soil in the pot and weighed it. Its weight was 89.944 kg, against 90 kg at the beginning of the experiment. He calculated that the soil was reduced by only 56 gm in those five years while the weight of the plant increased by 71.732 kg.

What conclusion can you draw from this experiment? Would it be correct to say that the material needed for the plant to grow came from the soil? Give reasons for your answer. (1)

Van Helmont took five years to conduct his experiment, but a similar experiment goes on in many households even today. You may have heard about the money plant. It is a decorative plant that people grow in their homes. It is kept in a bowl of water and grows quite comfortably without even a bit of soil. So where does the money plant get its nutrition from?

Have you seen plants floating on water in a tank or river, without any contact with soil? If you have, tell your classmates about these plants.

So, is soil necessary for the growth of all plants? (2)

Is water the food of plants?

Van Helmont drew two conclusions from his experiment:

1. The substances needed for the growth of a plant do not come from the soil.
2. The plant grows because of the water it gets.

Were van Helmont's conclusions correct? We shall find out later in this chapter.

Priestley's first experiment

For at least a hundred years after van Helmont conducted his experiment, no one paid any attention to the subject of nutrition in plants. In 1771, Joseph Priestley conducted some experiments that yielded a lot of new information. Actually, Priestley did not conduct these experiments to study plant nutrition. He wanted to find out what gases are present in the air.

You have already performed one of Priestley's experiments in the chapter "Gases". When a lighted candle is covered with a beaker, its flame is extinguished after some time.

Why is the flame extinguished? (3)

We know that oxygen is consumed when a candle burns and carbon dioxide is formed.

When Priestley performed his experiment, no one knew about carbon dioxide and oxygen. Priestley concluded that the process of burning makes the air inside the beaker impure. The candle is extinguished because it cannot burn in impure air.

Priestley's second experiment

Priestley then conducted a second experiment. He covered a small mouse with a beaker. After some time, he saw that the mouse began suffocating. Priestley concluded that the mouse's respiration also makes the air impure.

To sum up, Priestley said that a respiring animal and a burning candle spoil the air in some way. The air can no longer support life or a flame.

You, too, performed the experiment with the candle. Was your conclusion the same as Priestley's? (4)

These experiments set Priestley thinking. There are so many animals in the world and so many fires burning - why doesn't all the air in the world become impure?

Animals, insects, birds and other living things breathe in oxygen and breathe out carbon dioxide all the time. So shouldn't all the oxygen be consumed after some time, leaving only carbon dioxide? But this does not happen. Why?

What do you think is the explanation? (5)

Priestley's third experiment

Priestley managed to partially answer this question in August 1771. He performed an extraordinary experiment. He kept a beaker over a lighted candle. As expected, the flame was extinguished after some time. Priestley then placed a sprig of mint inside the beaker. While doing so, he took care not to allow outside air to mix with the air inside the beaker .

Priestley

After 10 days he lit the candle again. It started burning. He did not remove the beaker to light the candle but used a lens to light it from outside.

Why was the flame extinguished the first time the candle was lit? (6)

Which gas filled the beaker while the candle was burning? (7)

Why did the candle light up the second time? From where did it get the oxygen needed for burning? (8)

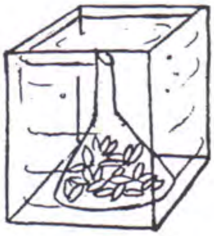
Where did the carbon dioxide in the beaker go? (9)

Write, in your own words, a summary of all three experiments performed by Priestley. (10)

On the basis of these experiments what would you say is the role of plants in maintaining the composition of air in the atmosphere? (11)

Can you imagine how important this experiment must have been in those days?

Priestley concluded that the mint sprig made the air pure again. Today we know that oxygen is consumed when a candle burns and carbon dioxide is formed. The mint sprig absorbs this carbon dioxide and releases oxygen. That is why the candle can be lit again.

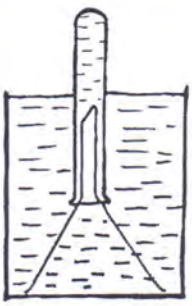


Priestley showed through his experiment that all green plants have this property of purifying the air.

An experiment similar to Priestley's

Let us do an experiment similar to Priestley's, with slight modifications.

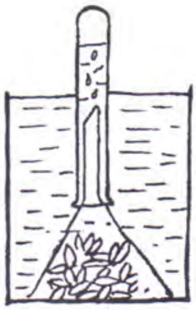
Experiment 1



You will need a beaker, test tube and funnel for this experiment. Both the beaker and funnel should be transparent. Get some sprigs of an aquatic plant. Keep these sprigs in water while bringing them to class to prevent them from drying up. Fill the beaker with water and add some baking soda (sodium bicarbonate). Now arrange some sprigs inside the funnel as shown in the figure. Fill a test tube with water and invert it over the funnel. Take care not to allow any water to spill out of the test tube while doing so.

Place the apparatus in the sun.

Set up a similar arrangement, but do not put sprigs in the funnel this time. Keep this apparatus in the sun as well.

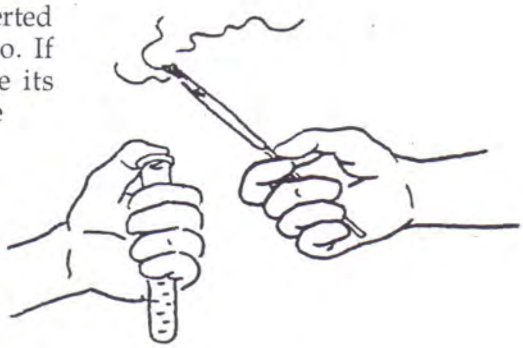


Do you see bubbles coming from the plant sprigs? (12)

Do bubbles form in the apparatus without sprigs? (13)

Let both sets of apparatus remain in the sun for about an hour. Once the test tube is more than half filled with bubbles, we shall try and identify the gas in these bubbles.

Cork the test tube firmly. But ensure that it remains inverted and its mouth is under water while you are doing so. If you do not have a stopper, use your thumb to close its mouth. Keeping the mouth closed, turn the test tube right side up.



Light an incense stick and dip its smouldering tip into the test tube, without letting it dip into the water in the test tube.

What happened? What gas is in the test tube? (14)

Where did this gas come from? What role does the plant play in the entire process? (15)

We used an aquatic plant in this experiment because it was convenient to do so. But Priestley's third experiment shows that all plants perform this activity.

Problems with Priestley's experiment

Priestley's experiment with the mint sprig was not just extraordinary, it was very important as well. When a scientist performs an experiment of such importance, other scientists try to verify it by repeating the experiment themselves. But, when scientists tried to repeat Priestley's experiments, they ran into many unexpected problems. The experiment was successful in some cases but failed in others. In many cases, the scientists could not get the results Priestley obtained. What went wrong? What was the problem?

A scientist named Jan Ingenhausz tried to find out. He repeated Priestley's experiment under a variety of conditions.

Ingenhausz noticed that only the green parts of plants (the leaves) perform the function of purifying air. He also noticed that leaves purify air only if they are kept in a lighted place. When they are kept in the dark, they too make the air impure.

In other words, Ingenhausz discovered that green leaves take in carbon dioxide and give out oxygen in the presence of light. In the absence of light, they do what animals do - they respire, inhaling oxygen and exhaling carbon dioxide.

Ingenhausz thus showed that Priestley's experiments could be repeated and similar results could be obtained if the experiments were performed under exactly similar conditions. It is essential to keep this in mind while verifying experiments done by others.

Experiment 2

The effect of light

In Experiment 1, you saw that plants release oxygen. Change the experiment slightly by placing the apparatus in the shade instead of in sunlight.

Was there any change in the rate of formation of bubbles? (16)

Cover the beaker with black paper or cloth.

Check after some time to see whether bubbles are still being formed. (17)

Food from air?

We learned about several different experiments conducted by scientists. First was van Helmont's experiment, which concluded that plants get their food from water. Then there were the experiments of Priestley and Ingenhausz. These showed that green leaves take in carbon dioxide and give out oxygen in the presence of light.

If we combine the two conclusions we can say that green plants take in water and carbon dioxide to prepare their own food in the presence of light. Imagine, plants survive on air and water!

Food from air and water

More experiments were performed and, gradually, it became clear to scientists that green leaves use water and carbon dioxide in the presence of sunlight to make starch.

This process can be written in the form of an equation:

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{in the presence of sunlight and chlorophyll}} \text{starch} + \text{oxygen}$$

Not only is starch formed but oxygen is also released. This process is called **photosynthesis**.

Synthesis means formation of a new substance by a chemical reaction between two or more substances. Because this process takes place only in the presence of sunlight, it is called photosynthesis (photo means light). In nature, the presence of the green substance in leaves is essential for photosynthesis to take place. This green substance is called **chlorophyll**.

What is needed for photosynthesis

Photosynthesis is an important process. It is how plants make their food. They grow and gain weight. We would have no food if there was no photosynthesis. Do you now understand how 20 to 25 quintals of wheat are produced by sowing just 1 to 1.5 quintals of seed?

You also now know that four things are needed by plants to make their own food (photosynthesis):

1. Water
2. Carbon dioxide
3. Light
4. Green substance present in leaves (chlorophyll)

Where did the water come from?

We know that von Helmont was right when he concluded that plants get their food from water. But that was not the whole truth. Plants get their food from air, too.

That raises an interesting question. Plants get water from the soil through their roots while the process of photosynthesis takes place in the leaves. So how does the water reach the leaves from the roots? What path does it follow?

Let us do an experiment to find out.

Experiment 3

For this experiment we shall use a plant with small white or light coloured flowers, like *sada bahar*, parthenium (*gajar ghas*) or balsam. If possible, get a plant in bloom.

Carefully uproot two such plants of the same species. Remove the soil clinging to their roots. Ensure that the roots are not damaged while you uproot and clean them. Place the plants in a vessel containing fresh water. Do this immediately after uprooting them.

Take two empty bottles or glass tumblers and fill one-third of them with water. Add about four teaspoons of red ink to the water in one bottle. Tie the two plants to two separate dry twigs. Take care not to damage their stems while tying them. Place one plant in the red ink solution. The twig should stand erect in the glass. In the same way, put the other plant in the glass containing plain water. Keep both glasses in the shade for about an hour.

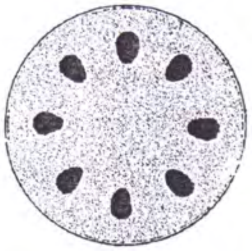
Study both plants and record your observations in Table 1. (18)

Cut the stems of both plants horizontally with a blade. Examine the dissected section with a magnifying glass.

Can you see red colour anywhere in the stem?

Table 1

S. No	Question	Observation	
		Plant in plain water	Plant in red ink solution
1	Examine the leaves of both plants. What difference do you see?		
2	Examine the flowers of both plants. Do you see any change in their colour?		



Are the spots of red colour arranged in the way shown in the figure?

On the basis of your observations, trace the route by which the red water reached the flowers and leaves. (19)

On the basis of this experiment, what conclusion can you draw about the functions of the root and the nutrition of plants? (20)

Farmers sprinkle urea in their rice or wheat fields whenever the leaves turn yellow. The leaves soon become green again.

Why do they irrigate the fields after sprinkling urea? Think it over and give reasons for answer.

How does the sprinkled urea affect the leaves of the plant?

This experiment and the information about urea tell us how and from where plants get water and other nutrients dissolved in the soil.

Exchange of air

Plants get water from the soil through their roots. They absorb carbon dioxide from the air. This job is done by the leaves. The leaves have tiny holes through which the exchange of air takes place. These holes are so minute you can only see them with the help of a microscope. They are called **stomata**. The air exchange takes place continuously through the stomata.

We know that plants take up water through their roots and air though the stomata of their leaves. We also know that the leaves contain the green substance called chlorophyll. What else is needed for photosynthesis?

Examine the conclusions of Experiment 2.

Did bubbles form when the plant did not get sunlight? (21)

Can you conclude on the basis of this experiment that plants absorb carbon dioxide and give out oxygen only in the presence of light? (22)

The next question is whether the process of forming starch by combining carbon dioxide and water also requires light. Let us try to find out.

If light is absent

A description of an experiment is given here. Read it and try and find out what effect light has on the formation of starch in leaves. The experiment was done with a plant called *chandni*, but it can be performed with any plant.

You need to find out if starch is present in the leaves. You already know how to test for starch, but a problem arises if you try this test on leaves. Leaves are green in colour. When iodine solution is put on a leaf, it should turn blue if starch is present. However, the green colour of the leaf disguises the blue colour. So you must first remove the green colour of the leaves if you want to test whether they contain starch. The way to do this is to first put the leaves in boiling water and then boil them in alcohol. This is a bit difficult. You need to be careful while boiling leaves in alcohol.

In the experiment described here, 4 to 5 leaves of a *chandni* plant were plucked in the afternoon. After removing their green colour in the way described above, they were put in an iodine solution. The leaves turned black.

Why did this happen? (23)

In the second part of the experiment, 4 to 5 leaves on the same plant were covered with black paper. The way the black paper was cut and fixed to the leaves is shown in the figure.

Black paper attached to a leaf

These leaves were plucked two days later. Their green colour was removed and they were dipped in iodine solution. The leaves turned black in the pattern shown in the figure given below.

The colour of the leaf after iodine is applied

Can you tell by looking at the figure where starch is present in the leaf and where it isn't? (24)

Did the entire leaf get light after it was covered with black paper? If not, which part of the leaf did not get light? (25)

Did starch form only in the part that got light? (26)

On the basis of this experiment, what connection do you see between light and starch formation? (27)

Do plants produce only starch?

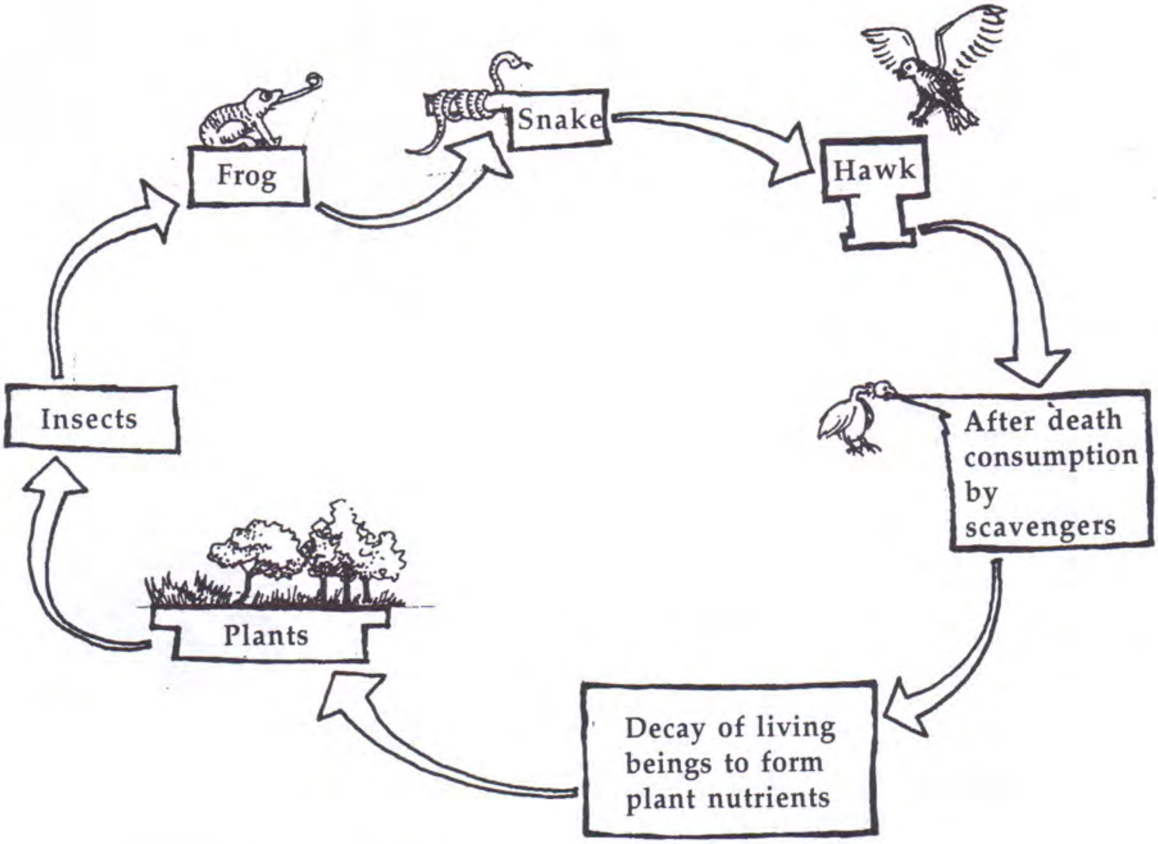
In the chapter "Our food", you read that food contains starch, fats and proteins. They are also present in plants. Where do these substances come from? Once starch is formed, the plant produces the other substances from it. But plants need other nutrient elements to do this. The main nutrients needed are nitrogen, potassium and phosphorus. Plants require many other nutrients as well, but these are needed only in minute quantities. Hence, they are called **micronutrients**. Plants absorb these nutrients from the soil through their roots. However, we cannot perform any experiment to study these nutrient elements at this stage.

Food chain: The link between plants and animals

It is, indeed, remarkable that plants prepare food not only for themselves, but for animals as well. Food is what links animals and plants. This relationship can be explained with the help of a diagram.

Animals and plants are also linked through photosynthesis and respiration.

Both animals and plants respire. Yes, it is important to remember that plants also respire and their respiration is exactly like that of animals. This means plants also inhale oxygen and exhale



carbon dioxide during respiration. This process goes on 24 hours of the day and night. The quantity of carbon dioxide in the atmosphere keeps increasing because so many living beings are respiring all the time. During the day, plants use the carbon dioxide with the help of chlorophyll and release oxygen into the atmosphere. This process of photosynthesis proceeds at a rapid pace. So we do not notice plants respiring during the day.

Questions for revision

1. **In Experiment 1, we used two similar beakers, but only one of them held a plant. Why was a beaker without a plant used?**
2. **State, on the basis of Priestley's second and third experiments, how we can keep the mouse in the beaker alive for a longer time.**
3. **A potted plant is kept in the light for a day and one of its leaves is tested for starch. The same plant is kept in the dark for two days and another leaf is tested for starch. Will there be a difference in the results of the two experiments? Give reasons for your answer.**

New words

Photosynthesis
Chlorophyll
Micronutrients
Stomata
Food chain