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Topic- Hatch and Slack Pathway

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Hatch and Slack Pathway

The discovery of C_4 cycle in monocots such as sugarcane, maize and sorghum has indicated that these plants have solved the problem of photorespiration. The carbon dioxide is fixed in the mesophyll cells. The initial product being a-4 carbon compound, the process is called C_4 pathway of carbon dioxide fixation.

Two Australian botanists Hatch and Slack (1966) discovered that there are two types of chloroplasts in sugarcane. One type restricted to bundle sheath cells have the normal grana. These chloroplasts carry on Hatch-Slack or C_4 cycle. Hence, Hatch-Slack cycle or C_4 cycle has been found in most monocots and some dicots. The plants having C_4 cycle are known as C_4 plants, and the plants C_3 (Calvin cycle) are C_3 plants.

Photorespiration occurs in C_3 plants (Calvin cycle), which leads to a 25 percent loss of the fixed CO_2. Photorespiration occurs in C_3 plants only, as the enzyme Rubisco catalysis both carboxylation and oxygenation reactions of the initial acceptor molecule that is RuBP.

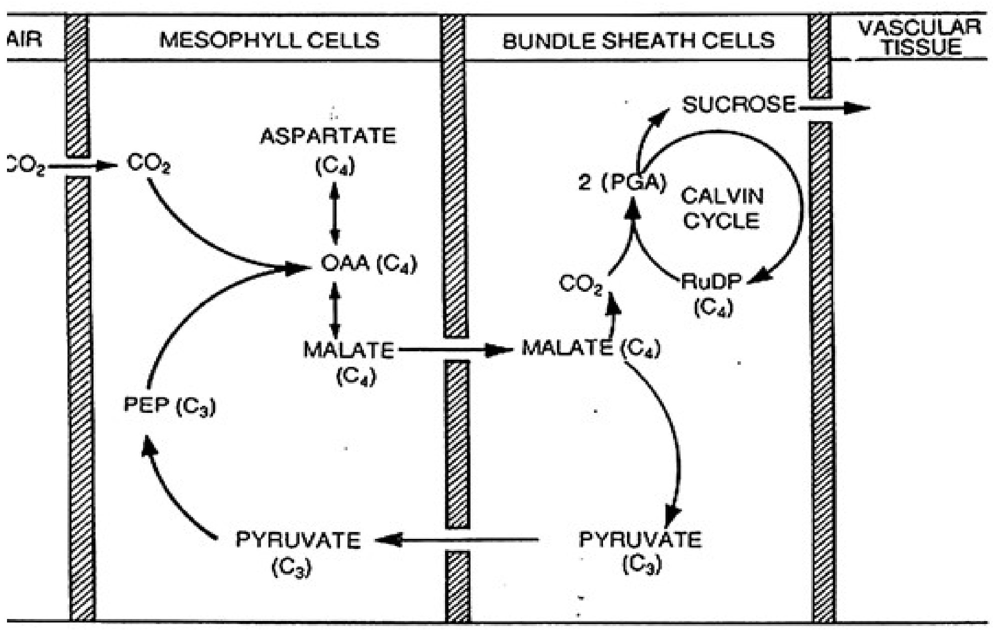

Fig. 5.11. Hatch Slack Pathway of CO_2 fixation.

In C_3 plants, photosynthesis occurs only in mesophyll cells. Photosynthesis has two types of reactions, i.e., light reactions and carbon or dark reactions.

In light reactions, ATP and $NADPH_2$ are produced, and as a result of photolysis of water O_2 is released.

During carbon or dark reactions, CO_2 is assimilated and carbohydrates are produced.

As both light reactions and carbon (dark) reactions occur in mesophyll cells in C_3 plants, it becomes essential for enzyme Rubisco to catalyse both oxygenation and carboxylation reactions of RuBP, simultaneously.

However, in category of C_4 plants, nature has evolved a mechanism to avoid occurrence of photorespiration, which is thought to be a harmful process.

C_4 pathway requires the presence of two types of photosynthetic cells, i.e., mesophyll cells and bundle sheath cells. The bundle sheath cells are arranged in a wreath like manner. This kind of arrangement of cells is called Kranz anatomy (Kranz: wreath). In Kranz anatomy, the mesophyll and bundle sheath cells are connected by plasmodesmata or cytoplasmic bridges. The C_4 plants contain dimorphic chloroplasts. The chloroplasts in mesophyll cells are granal, whereas in bundle sheath cells they are agranal.

The granal chloroplasts contain thylakoids which are stacked to form grana, as formed in C_3 plants. However, in agranal chloroplasts of bundle sheath cells grana are absent and thylakoids are present only as stroma lamellae.

The presence of two types of cells (granal and agranal) allows occurrence of light and carbon (dark) reactions separately in each type.

Here, release of O_2 takes place in one type, while fixation of CO_2 catalysed by Rubisco enzyme occurs in another type of cells.

In C_4 plants (maize, sugarcane, etc.), light reactions occur in mesophyll cells, whereas CO_2 assimilation takes place in bundle sheath cells. Such arrangement of cells does not allow O_2 released in mesophyll cells to enter in bundle-sheath cells.

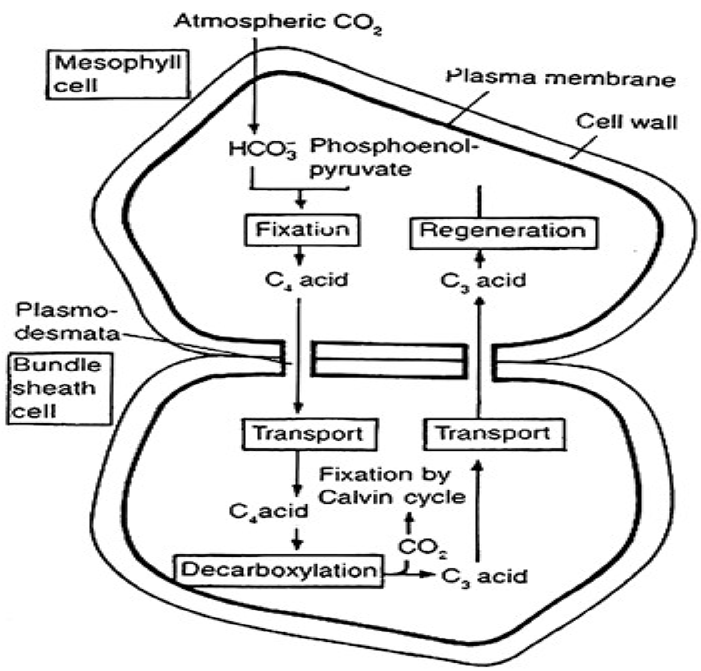

Fig. 5.12. C_4 photosynthetic carbon cycle.

Hence, Rubisco enzyme, which is present only in bundle-sheath cells, does not come into contact with O_2, and thus, oxygenation of RuBP is completely avoided.

In C_4 plants, a CO_2 concentrating mechanism is present which helps in reducing the occurrence of photorespiration (i.e., oxygenation of initial acceptor RuBP). This type of CO_2 concentrating mechanism is called C_4 pathway.

For operation of C_4 pathway, both mesophyll and bundle-sheath cells are required. The main objective of C_4 pathway is to build up high concentration of CO_2 near Rubisco enzyme in bundle- sheath cells. High concentration of CO_2 near Rubisco enhances carboxylation and reduces photorespiration.

C_4 photosynthetic Carbon Cycle:

In C_4 pathway, CO_2 from the atmosphere enters through stomata into the mesophyll cells and combines with phosphoenol pyruvate (3-carbon compound). This reaction is catalysed by an enzyme known as phosphoenol pyruvate carboxylase, i.e., PEPCase. With the result, a C_4 acid, oxaloacetic acid (OAA) is formed.

$$CO_2 + PEP + H_2O \xrightarrow[\text{enzyme}]{\text{PEPCase}} \text{Oxaloacetic acid (OAA)} + H_3PO_4$$

The above-mentioned reaction occurs in cytosol of the mesophyll cells and is called fixation of CO_2 or carboxylation.

Since this gives rise to the first stable product C_4 acid, and therefore, known as C_4 pathway.

The next step of reaction is transport of oxalo acetic acid (OAA – 4 C compounds) from cytosol of mesophyll cells to chloroplasts of bundle-sheath cells, where it is decarboxylated to release fixed CO_2 and high concentration of CO_2 is generated near Rubisco.

The other product of decarboxylation reaction is a 3-carbon compound called pyruvic acid. Now, this is transported back to mesophyll cells, where if regenerates phosphoenol pyruvate to its own for continuation of C_4 pathway.

However, the C_4 pathway is more efficient than C_3 pathway due to absence of photorespiration in C_4 plants.