Chapter Four

Growth and Physiology of the Tea Plant

4.1 What is happening inside a growing plant

For farmers to understand why things happen in the tea crop - - - for example, why fertilizers are necessary or why a root-rot causes symptoms on the leaves - - - farmers need to know how a plant works. A plant is like a team of workers building a house, or like a team of football players: many different parts, each doing a different job, and each contributing to the success of the entire team. Some of the most important "jobs" that are happening inside a tea plant are:

4.1.1 The leaves breathe in air, breathe out water, and make sugars from sunlight

On the bottom of each leaf are many small openings called "stomata". You can see these if you look at a leaf with a magnifying glass. The stomata usually are open. When they are, the leaf breathes in carbon dioxide from the air (carbon dioxide is the gas that people and animals make when they breathe out). The leaf also breathes out oxygen that it creates (oxygen is the gas that people and animals need to survive).

If leaves do not have any wounds, are they safe from diseases?

Not necessarily. Many diseases can enter leaves through the stomata, which are natural openings that are present on every leaf (even on leaves that do not have any wounds). Twigs and branches also have natural openings ("hydathodes" and "lenticels").

However, it is easier for diseases to enter through wounds. The same is true for people: diseases like "athlete's foot" (a fungus) and AIDS (a virus) can enter through unwounded skin, but can enter more easily through wounds.

When their stomata are open, leaves also breathe out water. Inside the branches and trunk of the plant, small tubes connect the leaves to the roots. These tubes ("xylem") are filled with water. When the leaf breathes out water, it evaporates into the air. As one droplet of water evaporates, it pulls the next droplet out of the tube underneath it. So, evaporation from the leaves sucks water up the tubes. As water travels up the xylem tubes, it carries fertilizer and water from inside the roots into the stem and the leaves.

Is it helpful to fertilize right after pruning?

No, for two reasons:

1. The plant doesn't have enough leaves to evaporate water and pull water up the xylem tubes to move the fertilizer from the roots into the stems and leaves.
2. Because there are no leaves to produce sugar, the roots do not have enough energy to absorb fertilizer from the soil. Absorption of fertilizer is <u>not</u> like a sponge absorbing water; instead, it is a complicated process that takes energy.

So: fertilize a month before, or a month after, pruning.

One of the most important jobs of the leaf is to use the carbon dioxide to make sugar. The energy for this job comes from sunlight. Making sugar from carbon dioxide using the energy of sunlight is called "photosynthesis". The sugars are transported down from the leaves into the stems and the roots through a second set of tubes, called "phloem".

Whenever the plant has its stomata open, it is losing water by evaporation. When the soil is dry, or when the sun is hot, the plant loses more water than the roots can absorb. When this happens, the leaves start to wilt. To protect itself, the plant closes the stomata on its leaves to stop breathing out water. But, closing its stomata also stops the leaves from breathing in carbon dioxide. This means that the leaves cannot make sugar. That is why plants grow slowly during droughts; they do not have any energy (are not making any sugar).

Is it a good idea to apply foliar fertilizers when the sun is hot?

No, for two reasons:

1. If the sun is hot, it will evaporate some of the spray from your backpack sprayer even before it reaches the leaf.
2. While the sun is hot, the leaves will have their stomata closed. Foliar fertilizers are absorbed through the stomata. But if stomata are closed, they cannot enter the plant, and so they will just evaporate on the outside of the leaf.

So: apply foliar fertilizers in the cool late afternoon.

4.1.2 The twigs and branches contain tubes that transport water, fertilizer, and sugar

Water moves up from the roots through tubes ("xylem") inside the branches and twigs. The water carries fertilizer along with it. Sugar produced by the leaves moves down the twigs and branches to the roots through a separate set of tubes, called phloem tubes.

The "red borer" caterpillar lives in the trunk; so why does it cause symptoms on the leaves?

Because the leaves must get their water and fertilizer from the xylem tubes that pass through the trunk. If the tubes are blocked (by insects or diseases), then the leaves will not get enough fertilizer or water. So, if you see leaves with symptoms of nutrient deficiency, it doesn't necessarily mean that your soil is poor. The real cause might be a problem inside the trunk or branches.

4.1.3 The buds grow new tissue to make new leaves and shoots

Many buildings are made from cement blocks or bricks stacked next to and on top of each other. Plants are built the same way: from cells, which are tiny rectangular blocks. New cells are produced in the "dividing zone" (meristem) hidden inside each bud.

When a bud becomes active, cells at the top of the bud (in the dividing zone) divide in half to make new cells. Then, those new cells swell up to become longer. These two steps (production of new cells and elongation of the cells) push the dividing zone upwards. The dividing zone is now sitting on a layer of new cells. The dividing zone is like a brick-layer moving himself upwards, one layer of bricks at a time. Cell by cell ("brick by brick"), the dividing zone moves upwards, leaving below it the new shoot and new leaves that it has built. To get energy for this work, the dividing zone uses sugar that was stored in the roots (discussed below).

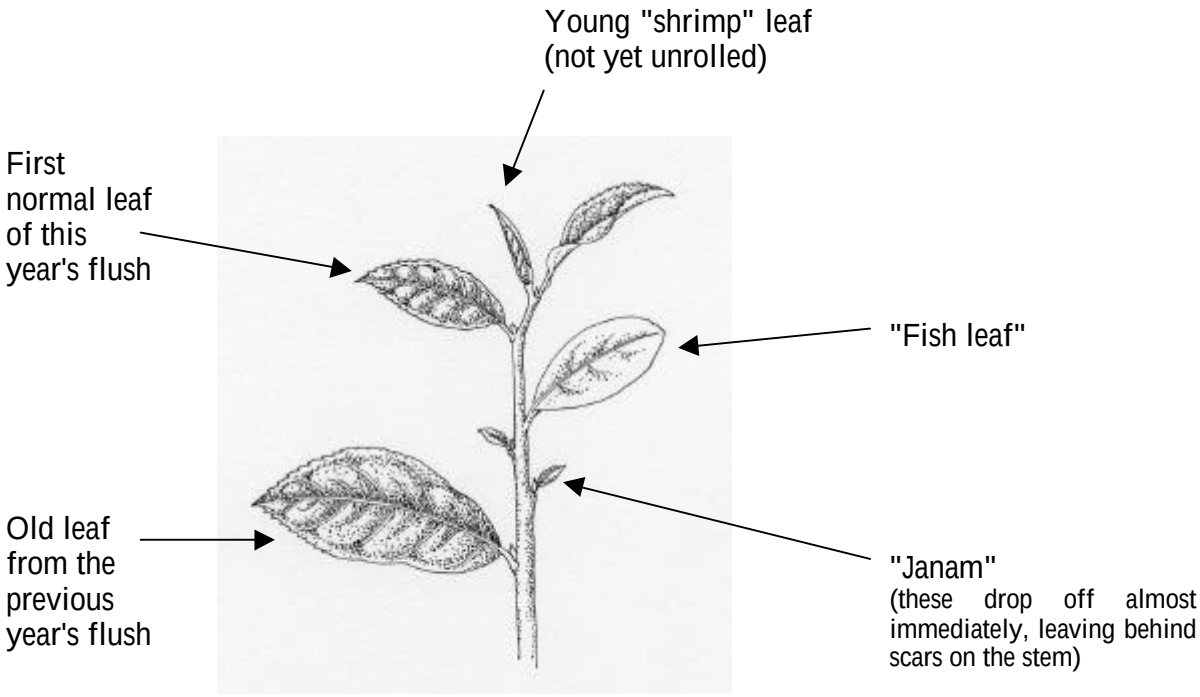
4.1.4 When a bud "builds" a new shoot, not all the leaves are alike

To better understand how to pluck tea, farmers should observe the order of leaves that are "built" by the dividing zone of a bud:

When the tea is growing actively (during the "flush"), find a bud that is just waking up. Mark it so you can find it again (for example, tie a strip of cloth around the shoot). Each week, visit the shoot and draw a picture of what you see.

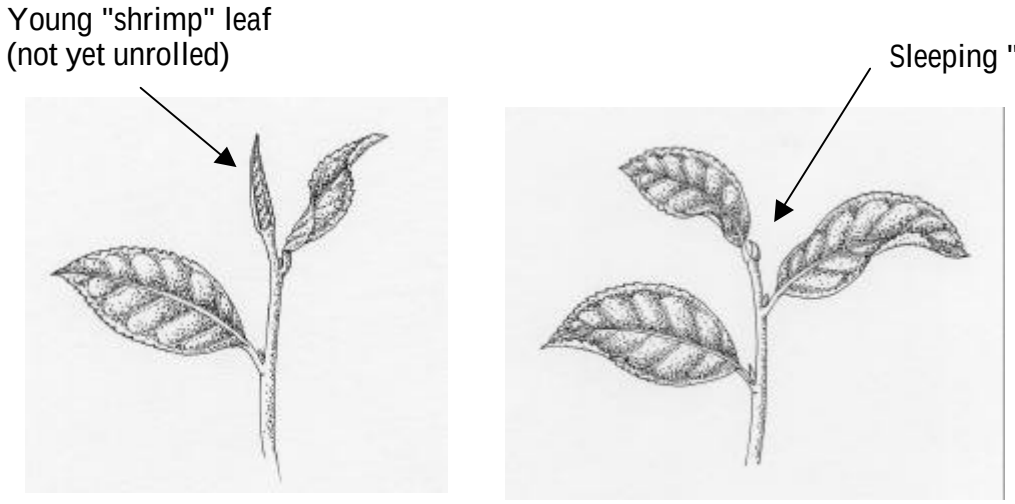
When a bud wakes up, the first leaves that it "builds" are the tiny "janam" leaves. The shoot grows taller, with the bud and its dividing zone always on top. The janams often drop off the shoot, leaving behind scars. After the janams, the first leaf that the bud "builds" is not a normal leaf. Instead, it is a "fish leaf". The fish leaf is smaller than a normal leaf and usually has a smooth edge. It is important to remember that a fish leaf is very active: it produces more sugar from photosynthesis than a normal leaf.

After the fish leaf unfolds, the shoot grows taller and normal leaves unfold one after another, at the rate of one new leaf every 5-10 days (see drawing).



An actively growing tea shoot. Source: original drawing by Wendy Gibbs.

Shoots are usually plucked at the 2-3 leaf stage, before they have enough time to complete their growth (see Section 6.3.8). But if the shoot is not plucked, the bud eventually completes it work (finishes a new shoot with many leaves). When the last leaf unfolds, it reveals a small sleeping bud. This kind of sleeping bud (at the top of a completed new shoot) is called a “banjhi” bud, and is much smaller than a growing bud (see drawing).



An actively growing tea shoot. A shoot that has finished growing.

Source: original drawings by Wendy Gibbs.

There is another kind of sleeping bud: the buds on the sides of the shoot. The reason the side buds are sleeping is because the growing bud at the tip of the shoot produces high concentrations of the hormone auxin (see Section 6.3.7 for more information about hormones). Plucking removes the growing bud, and therefore removes the auxin, which allows the side buds to wake up and start growing shoots. This is why plucking or tipping (light pruning) makes many small branches grow.

4.1.5 The roots store starch, and absorb fertilizer and water

The sugar produced by the leaves travels down through the phloem tubes to the roots. Much of the sugar is stored in the roots, in the form of starch. The more starch is stored in the roots, the more energy a plant can send to its buds (so that the buds can grow new shoots to recover from pruning or plucking). To check how much starch is stored in the roots:

Cut the end of a root and rub it with iodine. When iodine touches starch, it forms a blue colour. The darker the blue colour, the more starch is stores in the root (see Section 6.2.6 for more details about this test).

Roots do not store all of the sugar as starch. Instead, roots use some of the sugar as energy. To absorb fertilizer, the roots must pump the fertilizer from the soil into the root. This takes energy, which the roots obtain by "burning" sugar. This burning takes oxygen, which roots must breathe in from the soil. This is why a plant in "waterlogged" (saturated) soil shows symptoms on the leaves. The wet soil does not provide enough air to the roots to burn sugar for energy. So, the roots cannot absorb fertilizer. And, the leaves become deficient in fertilizer and show symptoms. If the soil stays wet for many days, the roots will die from lack of oxygen, and the plant will then die.

The roots also absorb water from the soil. But this does not require the roots to burn sugar. Instead, the water is "sucked" into the roots by the xylem tubes, because water is evaporating (and "sucking") from the stomata on the leaves.

4.2 Growth stages of the tea plant

In all of its growth stages, the tea plant does all of the jobs that were described above (making sugar, moving water from the roots to the leaves, etc.). Nonetheless, as the plant grows, its structure changes, and the jobs that it is doing change. To understand better how to care for the plant, the farmer needs to understand how the plant changes as it develops from seedling to commercial stage to ageing stage.

4.2.1 Seedling stage

This stage begins when the seed or cutting is planted, and ends when the young plant is pruned for the first time. For plants grown from seeds, the seedling stage often lasts for 2-3 years. In contrast, plants grown from cuttings only require about 1 year in the nursery. However, the duration of the stage does not depend only on time, but also on the development of the plant. Normally, experts consider that at the end of this stage, the diameter of the main stem must be more than 0,7 cm, and the height of the plant must be more than 70 cm.

Most of the energy that the young seedling needs comes from "burning" starch and oil that are stored in the seed. For this reason, seedlings do not need much fertilizer. Young plants that grow from cuttings do not have a seed to provide them with energy. Therefore, they need very careful tending. Until it grows roots, the cutting can only absorb a tiny amount of water from the soil. And until it grows more leaves, the cutting can only use the sugar produced by its single leaf.

Whether seedling or cutting, the young plant uses its energy to grow both roots and leaves. On most seedlings, a single bud (or very few buds) are active; the rest of the side buds are sleeping.

> ☞ Farmers should do the exercise entitled "Crop development: Seedling stage" to learn how the plant changes during this stage.

4.2.2 Branch formation stage

This stage begins at the first pruning (when the main stem diameter is more than 0,7 cm and the plant height is more than 70 cm). It ends at the last "formation" pruning (the last pruning made to shape the frame of the tea bushes). Tea plants grown from seeds need three formation prunings, whereas plants grown from cuttings need two.

Tea yield and quality is best when the tea bushes are broad and have many strong, healthy branches. To get broad, strong bushes, farmers must give the bushes good tending during the branch formation stage.

One part of tending is pruning. As was explained in Section 4.1, pruning removes the growing buds at the tips of shoots. This lets the buds on the sides of shoots "wake up" and start growing. During branch formation stage, the purpose of pruning is to shape the way that the main frame of large branches are growing, so that the bush develops a strong frame of big branches. The frame should be low and broad with a large canopy capable of producing many shoots. The plucking table should be stabilized at a height of 70 cm.

During branch formation stage, bushes do not yet need large amounts of water or fertilizer (see Section 6.2). But, farmers should supply enough nitrogen for the growth of stems and leaves, and to increase the number of branches. The bushes are using most of their energy to grow large branches and to enlarge their root systems.

> ☞ Farmers should do the exercise entitled "Crop development: Branch formation stage" to learn how the plant changes during this stage.

4.2.3 Commercial stage

This stage begins after the last formation pruning, and continues for as long as the tea is growing vigorously (usually several dozens of years). This is the stage when tea produces the biggest yields and is the most profitable.

During the commercial stage, the main frame of the tea bush has already been formed. Bushes use most of their energy to produce a flush of green tender shoots. Plucking removes the leaves and top buds, which wakes up the side buds. Then, the shoots that develop from the side buds are plucked, and their side buds wake up and start growing. So, the bush is kept very busy constantly producing new leaves and buds. The tender green buds and shoots that are removed during plucking contain lots of protein, which is rich in nitrogen. So, plants during commercial stage need lots of nitrogen (balanced with other nutrients) to continue producing new leaves (see Section 6.3 for specific recommendations).

Farmers should do the exercise entitled “Crop development: Commercial tea stage” to learn how the plant changes during this stage.

4.2.4 Degraded tea

Some old tea fields start to show the following problems:

- low yields
- increasing number of empty spots due to death of weak bushes
- branches become thin and diseased
- increasing rate of diseases of the top and of the roots
- increase in the proportion of unproductive (brown and woody) tissues on tea plants.
- buds and crown buds are small and scarce
- many shoots at the base of the bush, or sprouting up from the ground

This combination of problems is often called degraded tea. Sometimes the name "ageing tea" is used. However, the problem is probably caused more by bad management than by actual age. This is shown by the fact that some plantations planted in 1958 are still healthy and productive. But, most tea fields will probably start becoming degraded after 30-40 years.

When a tea plantation becomes degraded, it is often best to rejuvenate the bushes by heavy pruning close to the ground (see Section 6.4) so that they grow a completely new frame of young branches. However, sometimes it is better to re-plant the field with new tea bushes.

Farmers should do the exercise entitled “Crop development: Ageing tea stage” to learn how the plant changes during this stage.

4.3 Root growth

The white-colored “feeder” roots are most important for absorbing fertilizer. The feeder roots are thin, white-colored, and have many branches. Most of the feeder roots are located in the top few centimeters of the soil (although about one-third of them are deeper than 30 cm). As they get older, feeder roots get thicker and their color changes from white to cream and finally to red. The older, red-colored roots do not have much ability to absorb.

The central "carrot root" of the tea bush stores most of the starch, but starch also is stored in the larger red roots. As was discussed in Section 4.1.5, the starch stored in the root provides the energy for bud development. So, the better the root system, the better the bud and shoot development will be.

The deep carrot root is important for the seedling, because it helps to anchor the plant and allows the plant to suck water from a deeper volume of soil. Plants that are grown from cuttings usually do not develop a carrot root, and usually have a somewhat more shallow root system even after they are fully grown into large bushes. How important is the difference between the root systems of bushes that were grown from seedlings and cuttings? Here are some things to consider:

- If you take seeds and cuttings from the same tea variety, the bushes that were grown from seedlings will usually have somewhat deeper roots than the bushes that were grown from cuttings. This difference can last even 20 years after planting.
- A deep root system can help a tea plant resist drought. This is especially important for young plants; the extra few centimeters of the carrot root might make a big difference. For larger plants, the difference may be less important.
- With a bit more care in tending, you should have no problem growing healthy tea bushes from cuttings. Also, if you want to have the deepest possible root system, you should think about choosing a variety with good root growth. A good variety grown from cuttings, can have a deeper root system than an ordinary variety grown from seeds. So, if you want your plants to have deep root systems and resist drought, choose an appropriate variety.

Farmers should examine the root system of healthy bushes during each of the crop stages (seedling or cutting, branch formation, commercial, and ageing). Digging up a bush to see its root system is a lot of work, and may kill the bush. But, it is worth doing for two or three bushes for each crop stage. The only way that farmers can learn to recognize if root growth is not normal (because of root-rots, nematodes, hard-pans in soil, etc.) is to have experience observing normal healthy root systems.

Remember that root systems of bushes that are planted close together will be smaller than root systems of bushes that are planted farther apart (see Section 5.4.4 for a discussion of planting density). So, when examining root systems with farmers, try to look at bushes from several fields with different planting densities. Also, mulching increases the production of feeder roots in the surface layer of the soil. So if possible, compare root systems from bushes grown with and without mulch.