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PRINCIPLES OF TREE GROWTH

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Mr. Chairman and Pupils: For this really is a school. However, I hardly feel like a teacher without being able to ask you a lot of questions or possibly give you an examination. I think it always happened when I was a student and the teacher didn't have his lesson prepared himself, that he always gave us an examination. I wish I could do that today.

I thought I was put on this program and given a subject that would keep me from talking about avocados. The subject, as it appears on the program, is "Principles of Tree Growth." Of course, that should be "Principles of Plant Growth" because the tree is simply a plant that has the ability under some conditions to grow to a considerable size. This talk is going to be fundamental science, not practical science. Mr. Wahlberg gave us the practical side of things and most of the rest of your program will be on that phase, but this is supposed to be fundamental science—to learn facts for the purpose of learning facts. However, after you have your facts, sometimes you can put them to quite a good and practical use. Really this is going to be a botany class rather than an agricultural class.

Besides the privilege of asking questions and giving out examinations, one of the things the teacher does is to lay out text-books. If any of you are particularly interested in this science I have a couple of very good books that you can look at later in the day. These are books on plant physiology, simply stated, with many excellent illustrations which I think you would find very interesting. (Botany: Principles and Problems by Sinnott) and (Text-book of General Botany by Holman and Robbins.) You know it is rather peculiar, that this science of Botany, particularly that branch of it which deals with the growth of plants, has been neglected for so long. You know Botany was looked on rather as a feminine science. It was nice to learn about the pretty flowers and parts of the flowers, their Latin names, etc. That is all the botanists did a good many years ago. Then they became interested in plants for their medicinal properties and a good deal of work was done along that line. It is only comparatively recent that Science has turned its attention to the fundamental part of Botany—How Plants Grow. At a talk before the San Diego Advertising Club, one day, it was announced, "France is going to talk on why plants grow and *'how.' "There* are a great many things about plant growth that are not understood. Lots of things seem very simple. Yet scientists can't agree on how sap rises in a tree. There are all sorts of theories, yet no one knows just how the sap gets clear to the top of a tall tree as it does. The most important things plants do which are fundamental to all life are not understood. We know they do it. I hate to try to pronounce one of the most important functions—Photosynthesis. The plant with the aid of its green leaf is able to do that which no chemist or laboratory has yet been able to duplicate today. A plant takes a little water, a little carbon-dioxide gas, and with the aid of sunlight, makes a new product which is the basis of all food—glucose or grape sugar. It produces its own food, feeds all animal life, practically clothes the human race, and provides much of our shelter, provides a great deal of the energy that we use in industry—just because it can do that apparently simple little thing. You just take the energy principle from light, split a molecule of carbon dioxide gas, add it to a molecule of water, and produce sugar. From that point on all of our foods are built up.

There are several things that we call by the wrong names frequently. We speak about the "plant food in the soil." There is no such a thing as plant food in the soil. There are certain things in the soil that the plant requires for the manufacture of foods but the plant uses the same kind of foods that you and I do—sugars, starches, fats, and proteins which it makes itself. The fundamental difference between animals and plants is that the plant manufactures its own food whereas the animal is dependent on plants or other animals for its food supply.

This matter of plant physiology is pretty much involved. It would take a long time to delve very deeply into it so I am going to try to confine my talk this morning to four things the plant does in its physiological processes: The first is Absorption, the second is Photosynthesis—these are the two most important things the plant does. It absorbs nutrients and water from the soil, takes carbon dioxide from the air, unites it with a molecule of water and produces .the food supply. Then there is a third thing in plant processes that is called Respiration, and a fourth, Transpiration. Those four phases in plant physiology are the ones I am going to discuss briefly today.

You are practically all familiar with the main parts of a plant. You know it has a root system which serves the purpose of taking in these supplies from the soil, also to help anchor the tree or plant in the soil. It has a stem, the purpose of the stem being largely to spread out this leaf surface to the light, to help hold the leaves up where the light can shine on them. Plants branch and divide themselves up as wide as they can to provide as big an exposure as possible. Then the stem acts as a transportation system between the roots and the leaves. The plant has leaves where this work of photosynthesis can take place. It has its fruiting system as well. But the principal parts of the plant are the roots and the leaves—the other things are incidental.

How does the plant take in or absorb these things from the soil that it requires? In the first place they must be in solution and water, of course, is the solvent that holds them. Botanists differ somewhat on the number of elements that are essential for plant growth but they all will agree on about ten: Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, Calcium, Potassium, Magnesium, Iron, and Sulphur, and with the exception of carbon, practically all of these materials enter from the soil either as water or materials in solution in the water. Now how do they get into the roots? The roots have no openings in them but a tight skin all the way around, there are no little holes at the end of each little I rootlet for the water to run in. It isn't done in that way at all. To understand I that will take us into the Science of Physics and Chemistry, and what not, before very long—just to understand how a plant grows. All plants, all life is made up of cells. Some are complete with one cell. Most of the plants and animals are made up of many millions of cells. Cells have different functions to perform, they vary in size, shape, and condition but in general they have certain things in common. In the first place they have a cell wall. It may be irregular in shape—there are some square, some octagonal, some round, some no particular shape at all. The cell-wall is made up of a material we call cellulose, manufactured by the plant, and inside of that cell-wall, this outer wall, occurs what is called protoplasm, which is the very life of the plant itself. All living cells do have protoplasm within them. Ordinarily this protoplasm will occur just inside the outer cell-wall. That protoplasm is very complex. It contains a great many different things which we won't mention now. Then it has a sap cavity inside. You might liken it to an automobile casing, for example. The outer tube, inside that the protoplasmic layer, the inner tube, and the air inside would take the place of the cavity in the center. These cells are always full, if they are healthy cells, of water and material in solution in the water. A root does not absorb moisture from the older portions of the root, but close to where the root is growing. The older portions of the root have a hard, tight cover and there is no chance for water to get through them, they are impervious to water. But near the growing ends of these roots, a short distance back from the very tip, are microscopic projections, called "root-hairs." Now the cellular structure of the root is made up of a great many cells, all of which are fastened together, and on this outer layer of cells, a special type of cell is developed which may be something like this (drawing on the board) or like this, and you may have another here and down here, and then the same thing happens again. These are the root-hairs. These are very tiny, thin-walled, soft-tissued cells but there are no openings in them. The water and the soil minerals pass through in solution by a process which is called "osmosis" which simply means the diffusion of a liquid through a membrane.

As to this question of Diffusion, let us talk about some of these things that are absolutely fundamental. "We have a dish of water and put salt crystals in it. That salt crystal will dissolve and in time we will find an equal amount of salt in every part of that solution. Substances in solution or in the form of a gas tend to travel from the points of greatest concentration to the points of least concentration until they are evenly distributed throughout. If we place salt water on this side and put a membrane through which salt and water will pass, and then we place fresh water in the other side, in a short time, the salt water will penetrate back and forth. Or if we take salt in this one and sugar in this, the two will pass back and forth, provided the membrane will allow both of these substances to pass. We do not know why certain membranes will allow substances of one kind to pass and not another. However, it is a very fortunate thing. For example, these root hairs are simply cells full of material on the inside and a great deal of sugar has been manufactured by the plant and is stored in these cells. That membrane will not allow sugar to be diffused and be lost in that way but it will allow the mineral salts to enter which the plant requires. There are a lot of things about diffusion and osmosis that are not understood. If you have a concentrated solution on one side of a membrane and a pure water or dilute solution on the other side, the material dissolved will pass through and the water will also pass toward the concentrated solution on the other side, but they do not pass at the same rate. The pure water travels faster than the dissolved solution. As a result this water passing into this concentrated solution builds up a pressure within that cell. That pressure is partly responsible for the rise of sap to the top of the tree—not entirely but it has something to do with it. Surrounding the root-hairs, you have the soil solution, that is the water in the soil containing these various soil minerals. Because the plant maintains in general, especially when it needs these materials, a higher concentration in the cell than occurs in the water outside, that means that this material here moves to the point of higher concentration. As this moves in, this material becomes more dilute. This cell has not as high a concentration as this and it continues to move until eventually passing through the cell-walls, it will reach the tube-walls, veins, and roots through which the moisture passes under pressure and pull. We do not know why—this matter of osmosis and diffusion is extremely interesting and important in plant life and development. It is possible for a plant to take in mineral elements from the soil without taking water from the soil which is contrary to what was formerly believed. It was thought a tremendous amount of water was necessary to pass through the plant in order to bring in this mineral matter, but as a matter of fact these minerals will pass in without water actually passing.

Question: If these little hair rootlets are out near the end of the roots, as the tree grows older and older, the fertilizer next to the trunk would not amount to so very much?

Mr. France: That is very true. However, a tree will tend to throw roots back toward the points of good food supply. Some of the trees have a number of younger roots close up to the crown. Roots in their habit of branching vary quite differently from stems—they branch apparently any place while stems branch only at nodules or buds. However, the tendency is for roots to get away from the region immediately surrounding the trunk.

Plants contain these various substances—more than ten which are essential: Carbon, Hydrogen, Nitrogen, Oxygen, Phosphorus, Potassium, Calcium, Magnesium, Iron, Sodium, Silicon, Chlorine, Manganese, Zinc, Boron. Not all of these are essential, however, but they are found in the plants. Occasionally Iodine is found in plants. There was a time these elements were considered all to be essential because they were found in the plant but now we know they are not. Silicon and Chlorine are not essential. The fact they occur in the plant doesn't mean they have to be there. The plant in taking in materials has to take most of the things dissolved in that solution whether it wants them or not.

To get away from the elements to the actual composition of the plant itself. Water, of course, is found in the plant giving Hydrogen and Oxygen. Sugars, starches, and fibres all contain Carbon, Hydrogen, and Oxygen. The proteins have added to that, Nitrogen and Sulphur, and in some cases Phosphorus. These various minerals are all of some importance though they are all of them not understood. Nitrogen is necessary for growth. Just how it affects growth we do not know but we know it is essential because it is an integral part of all proteins and the life substance or protoplasm contains proteins. Phosphorus is a part of the substance called "chlorophyll," which we will discuss pretty soon, and also a part of those proteins that are found in seeds and grains which contain a considerable amount of Phosphorus. We do not know just how Potassium works or how essential it is, but we do not get development or storage of sugars unless Potassium is present. Calcium is a common mineral whose real use is not understood. Apparently it has something to do with root growth. Magnesium is also an essential part of the chlorophyll. It is necessary that iron be present in order that the chlorophyll may develop, but iron is not found in the chlorophyll itself. Sodium, Manganese, Zinc, and

Boron are required, but only in very small amounts. Years ago when they were using chemically pure solutions, so-called, it was considered that Manganese, Zinc, and Boron were not required because the plants seemed to get on very nicely without them. But the difficulty was that these solutions were not chemically pure and had just sufficient amounts of these minerals to meet the plants' requirements. These minerals are taken in by absorption through the roots and are transported through the stems to the leaves where photosynthesis takes place.

Photosynthesis does these things—it stores energy in the plant in a most remarkable way. It takes energy from the sunlight and ties it up temporarily so it can be released some place else. I do not know how to explain it or whether there is a way to explain it. Possibly you might visualize your carbon-dioxide molecule. It is made up of Carbon and Oxygen. The green chlorophyll of the leaves and the sunlight apparently pull that carbon atom away from the carbon-dioxide molecule, and when it pulls it away, it is apparently like stretching a spring—there is energy stored up there. Then when you take that molecule of glucose and use it up in the plant cell some place, it releases the spring, the spring closes back, and you get Carbon again and water and you have used up your energy. Photosynthesis stores up the energy taken from the sun, the only source of energy we have, puts it in a form we can use and in which it can remain for a time, and then on demand releases it again. This process uses carbon-dioxide. It takes the carbon away and lets the oxygen go free. This process takes place only in green plants—only in the cells that have this green coloring matter, chlorophyll. All of it does not take place in the leaves, the green stems carry on this process as well. It constructs food and increases weight. So here we have the first two physiological processes of the plant—Absorption and Photosynthesis.

The next process is Respiration. "Where there is life, there is hope," we say. Well, where there is life there is respiration. We usually think of respiration as breathing, the most obvious form of respiration we have, but any breaking down of food and use of energy in a living cell is respiration. Photosynthesis goes on only when there is light. Respiration goes on all of the time and respiration is just exactly the opposite of photosynthesis. Photosynthesis builds up energy and respiration releases it and does work. You are constantly releasing energy as you do your work and the more active you are the more energy you release and the more food you must have. Respiration liberates carbon dioxide. We know that in our own breathing. It absorbs oxygen. This process takes place in all plants and animals, in fact in all living cells. When your respiration is done, your cell, your plant is done. It destroys food as compared with the construction of food by photosynthesis. It decreases weight by using up energy and material.

I talked before a group of Portuguese children a while ago on why plants grow, and asked them what the most beautiful color was. There were all sorts of answers. Then I asked them what the most important color was. They had it right from the start. They said it was green because that is the color of the green leaves. That is the whole thing in a nutshell. Perhaps we do not have to understand just how the green coloring matter and the sunlight can provide us with the necessities of life, but it is something we at least should appreciate.

Question: Is there ever a deficiency of carbon dioxide in the atmosphere?

Mr. France: Apparently not. While there is only three-tenths of one per cent present, the plants seem to get along very well. However, we have found that plants can use a larger amount of carbon dioxide than normally occurs in the atmosphere. That has been done in greenhouses where you have a confined space and can increase the carbon dioxide. But we have to take these things pretty much as they are and there is no way to increase the amount of carbon dioxide present.

Question: If a plant receives 95% of its material from the atmosphere taken up into its system as carbon dioxide, I should think it would be very important to see that there would be no deficiency?

Mr. France: Of course, such a condition does not occur but if there were a deficiency of carbon dioxide, it would slow the process of photosynthesis down to a great extent.

Comment: I know an orchard that has produced maximum crops for years, one of the best orchards in the state. For years that orchard has received nothing but a mulch of barley straw and an addition of nitrogen phosphate and potash increased production way out of proportion. Isn't it possible that as that material broke down, it released carbon dioxide.

Mr. France: It sounds reasonable for when you have a decomposition taking place on the surface, there you have that liberation of carbon dioxide. I should think there might be something to that but I do not know whether the amount of help from an increase of carbon dioxide liberated would be as great a gain as having that material deeper in the soil would be.

Comment: I am wondering if the specialists are not paying too much attention to the materials in the soil and not enough to the materials gained through photosynthesis. I move we start a movement to get photosynthesis.

Question: I read that carbon dioxide would stop decay on green fruit during shipment.

Mrs. Peterson: Whether decay is retarded or not depends upon the percentage of carbon dioxide used. One amount hastens ripening, one amount retards it, and another amount causes the fruit to spoil.

Question: Some plant foods are available and some not available. How do the non-available ones become available?

Mr. France: Plant foods are sugars, starches, proteins and fats. Those are the plant foods which support growth and life in the plant. These other materials which the plant does not make but takes in, let us call these "nutrients." Of these we have seven essential minerals. They are simply broken down from the decomposition of rock particles in the soil. As organic matter decays, part of the process of decay is the formation of certain acids nitric, and others in very minute amounts, rather dilute, and this hastens the breakdown of these mineral particles and makes them available. That is one of the reasons why we preach so hard and long on the organic system of fertilization. Our soils are not very well supplied with organic materials like the eastern or humid regions where we have a very great proportion of organic materials and not enough mineral. The minerals have been dissolved out by this process of decay and washed away by heavy rainfall. Back there we have to add these mineral fertilizer elements whereas out here there is usually an abundant supply in the soil, though possibly locked up and not available and the easiest way to make them available is through the use of organic matter. The plants here need the minerals just as well as they do in Illinois, but it is rather foolish to add a lot more to the soil when you already have an abundance. Perhaps all you need is to set them free by getting some organic matter into that soil to help decomposition.

There is another branch of plant physiology that is called TRANSPIRATION, which is the movement of water through the plant which may be out of proportion to the amount of soil minerals the plant requires. We used to think that the principal function of the movement of the water through the sap was to carry these minerals from the soil. That *is* one of its functions, but as previously explained, you can actually bring in minerals without any water through diffusion, and the amount of water that the plant uses in photosynthesis is very, very small, that is, this molecule of water it uses to tie on to the molecule of carbon. But it apparently needs a large volume of water passing through its tissues. Every cell must be full to capacity or it is not functioning properly. It must be turgid. In wilting the cell loses this turgidity when it has lost its pressure. When that happens, the cells do not function. Plants require a tremendous amount of water as compared to the amount of their own dry weight. Under ordinary conditions, a corn plant will use water in amount equal to four hundred times its own dry weight in developing that amount of dry weight. This water goes through the cells and all living parts of the plant, passes up through the stem into the leaves, spreads itself in what is called the air spaces between the cells, and then leaving evaporates out through the leaf surface through a little valve called "stomate." Just exactly why this water goes through the surface is not fully understood. It has a good deal to do with temperature, keeping the plants reasonably cool. Plants are cold-blooded creatures and ordinarily do not have the same kind of temperatures that we have. They warm up and cool down and under some conditions they need to be kept cool. But anyway we do know that a tremendous amount of water does pass through the plant and it is necessary that this water balance be maintained.

Plants have a number of other functions, of course. The matter of growth is a pretty complicated thing. It takes place at the growing tips, both at the ends of the roots and the ends of the upright-growing tips. It takes place on the cambium layer, which is a thin layer of cells which adds new wood on the inside and what we call bark on the outside. Thus transpiration has to do with the conduct not only of the sap but the plant foods, the sap rising containing in it the minerals in solution taken through the roots, rising through the cells, and then the sap which really contains the plant food, sugars, starches, proteins, etc., corning down just outside the cambium layer.