have worked out morphologically. The differentiation of the tissues takes place for the epicotyl only after the root is growing.

Gibberellic acid has the same effect. It will not have any effect until the embryo gets to that stage.

MODERATOR JOHNSON: I think we had better go on. Thank you, Dr. Barton, for a most interesting talk and discussion

Our next speaker, I am sure, needs no introduction. Dr. Baumgartner is known to all of you for his work as a consultant to the nursery industry. Dr. Baumgartner

Dr. Baumgartner read his prepared paper entitled, "Basic Factors in Good Water and Soil Management for Balanced Plant Growth." (Applause)

BASIC FACTORS IN GOOD WATER AND SOIL MANAGEMENT FOR BALANCED PLANT GROWTH

L. L. Baumgartner

Baumlanda Horticultural Research Laboratory

Croton Falls, New York

When our program chairman asked for a discussion of this subject we were well aware of the fact that it is a broad title and that books have been written on each of its three phases Therefore, if this presentation should be acceptable to you, it will probably represent a greater contribution to the art of organization and condensation rather than a contribution to scientific discipline Our primary objective is to re-examine the handling of water and plant foods in the light of operational problems in nursery management. Some of my statements based on my experience will undoubtedly be contrary to your experiences and I hope that this may provide the basis for further discussion. This subject often appears overly-complicated and possibly mysterious because of the many special circumstances and exceptions which make many facts appear to be contrary to each other. I am certain that this will appear very elementary to some of you and I beg your indulgence as I attempt to develop a subject without including the many exceptions and special circumstances. This is prepared for the non-professional.

WATER

Sources of Water: One of the most controversial subjects revolves around the belief that rain water is better for plant growth than irrigation water. In New England there have been reports that the use of irrigation water actually harmed nursery crops, while in Arizona similar crops could never have been raised without irrigation. Now what might the answer be?

The divinity of water from heaven has not been generally accepted but if it comes often enough it is certainly satisfactory Rain water generally falls in small droplets and continues for an extended period of time. It not only producers a beneficial cooling of the air surrounding the plants but soil can better absorb water that is applied slowly. Rain does entrap some nitrogen and sulfur from the air and carries it to the soil.

In industrial and metropolitan areas rain can often supply the total sulfur requirements of a plant but only an infinitesimal amount of the required nitrogen The greatest advantage of rain is its low cost. Where soil is cultivated or otherwise in good tilth, rain water does seem to penetrate better than water from irrigation systems.

The disadvantages of depending on rain as our sole supply of water are that, 1) it occurs in an unpredictable pattern, 2) it is often unrelated to the growth habits of the plant varieties being grown, and 3) it may occur in either excessive or inadequate quantities For example, the growing season along a sea coast may be longer than that of the interior only because adequate rain is available during each month of the summer season.

To quote a farmer from New Mexico whose viewpoint is rather extreme, "the greatest advantage of rain is that it produces a reservoir of available water for irrigation" This may be extreme, but when one remembers that a plant contains more than 90% of its weight as water, we can see quite clearly that it is important to have water readily available.

The second source of water is from irrigation facilities. This can be a method of sub-irrigation where water is brought to the roots by periodically saturating the soil with water from ditches, or by impounding nearby water to create a high water table. The more common methods employed, however, are overhead watering devices or hand watering from water tanks equipped with water hoses

The advantages of irrigation are, 1) water can be applied when needed, 2) water can be applied in required quantities, and 3) irrigation systems can be used to apply fertilizers, nematocides, insecticides, etc.

The disadvantages of irrigation are, 1) soil structure can be injured if water is applied too rapidly and constantly in excess — irrigation should not be hurried, 2) some (but few), water sources may be harmful to plant growth. The most frequently experienced difficulty occurs when highly alkaline water is used to irrigate plants growing in soil mixtures containing a high quantity of peat moss. The calcium seems to be entrapped in the peat moss with the result that the pH of the mix becomes alkaline and ericaceous plants become chlorotic, and 3) irrigation water is too often used too late as a method of "saving" plants rather than growing plants

How is Water Used by Plants?: Before explaining the advantages of using adequate quantities of water or the dangers of misuse of water it is well that we quickly list the various ways that plants use it. The order in which these uses are listed has no significance.

1. Water can be used to cool plants. Where shading is not practical the use of a mist system is quite a good method of maintaining a cooler atmosphere around plants There is also some evidence that a moist soil maintains a lower and more beneficial temperature in the root zone. This still requires proof but many nurserymen feel that dry soil becomes too hot for good root development for shallow-rooted plants The work of O F. Curtis (1936) provides strong evidence that water passing through plants has no beneficial value. He points out

that there is no difference in growth between plants transpiring at a rapid rate as compared to plants transpiring at a slower rate

2. Water is an essential part of the soil organic matter, for without water the soil micro-organisms cannot be active, and without this microbial activity there can be no conversion of raw fertilizers to usable plant foods.

3. After raw plant foods are converted to usable plant foods, it is necessary to have more water available to dissolve them and transport them to the root zone, into the roots and up the stem to the leaves for further processing into sugars, starches, amino acids, etc.

4. Water performs one additional function which might be considered its most important one. Photosynthesis, or the manufacture of food, is accomplished in the cell sap which is predominantly water Like so many chemical reactions in nature, the manufacture of sugars, etc. is done in a water medium.

What Happens When — — — ?

1 —there is too little water. In extreme cases the plant, of course, dies, but before this happens it will go into a state of wilt Wilting is a protective mechanism that occurs in plants to conserve moisture Plants can be revived from this state by supplying water, but with many varieties of plants the wilting may have induced dormancy and further growth of the plant is finished for the season This is a well-known occurrence in the florist industry but more needs to be known about it in our industry. It has been commonly observed in *Taxus*. With a little skill, it is also possible to adjust wet and dry periods to induce heavier flower bud formation. I have been successful in accomplishing this with dogwood but there must be many other plants that might be equally susceptible. I suspect that flowering in *Pyracantha* might be subject to this influence.

2. —there is too much available water There are many horticulturists who feel that it is more detrimental to plants to use too much water as compared to too little. Many of you have undoubtedly experienced the unusually heavy top growth that can be obtained by using large quantities of water You may also have noticed that roots are more extensive when growing in dry soil. I do not know how to capitalize on this at the moment, but these responses do occur.

The most important danger from over-watering is that of stopping all growth. We call it "interference with soil aeration," but here is what happens. Respiration of plant roots is an essential process and consists of an exchange of oxygen and carbon dioxide. This gas exchange can only occur in a porous soil, thus, if the soil is saturated with water this exchange cannot occur and the roots cannot perform their function of procuring water When soil saturation occurs frequently or for long periods, the plant stops growing and dies. Oxygen is essential for rooting plants and also for root development of established plants.

There is a relationship between excessively wet soil and a high incidence of root-rotting diseases In many instances this is true but it is a complicated subject that can be better discussed at another time

SOIL

What is Soil?: Soil has many definitions such as 1) an earth shell of weathered rocks, 2) the upper six inches of the earth's crust, etc. but for our purpose I propose a more meaningful definition. Soil is a plant food or fertilizer and may occur on the earth's surface or in a plant container holding a special soil mix It is true that soil serves as an anchor for plants, but if it did not also feed plants we would not be interested in it

What is Soil Made of? The most elementary example of soil consists of weathered rocks, which in turn are made up of many chemical elements *including* most of the essential plant food elements These are phosphorus, potassium, magnesium, calcium, manganese, copper, zinc, cobalt, boron, strontium, sulfur and sometimes nitrogen. Freezing and thawing, of course, break large rocks to small rocks but the food elements are not available to higher plants until the dissolving acids from organic matter (consisting of dead and living plants and animals) react chemically with the rocks to release the plant food elements The only other materials a plant requires are oxygen and carbon dioxide which it obtains from the air. and water.

Gentlemen, this is the way that the tremendous reserve of plant food was produced in virgin soil. This warehouse of food has eventually become depleted (as of now) and it is essential to replenish it, but how are we going to do it — by scattering more rocks over the field? You are saying "no," but, is that true? What are you doing when you spread a bag of 10-10-10 or 5-10-5? Where did it come from? The potash is nothing more than rock mined from relatively pure veins of potash rock that occurs naturally in our mountains; the phosphorus (super or triple super) is just rock that accumulated in high concentrations in certain parts of the United States A number of you used to buy and spread ordinary rock phosphate until more economical triple and superphosphate became available, but superphosphate is only rock phosphate that has been chemically weathered to hasten its availability. In manufacturing we use strong acids such as hydrochloric and nitric acid but in the soil the micro-organisms use weak and slow-acting carbonic acid. Some forms of nitrogen come from rock mined in Chile or elsewhere In fact, right here at home we are mining concentrated forms of calcium and calcium-magnesium under the name of limestone Therefore a bag of fertilizer may contain nothing more than ground-up rocks, obtained elsewhere. With this background you will agree with me that our whole fertilizer industry consists of digging and shipping rock from one part of the world to another and spreading it where we want plants to grow There is nothing dangerous in a bag of chemical fertilizer — the danger is in mishandling it

The second component of soil is organic matter which is a term that includes all living and dead plants and animals, and materials that were derived from plants or animals. This would generally include all carbonaceous material such as peat, humus, coal, oil and organic chemicals responsible for producing soil structure In short, organic matter is that dynamic chemical plant that manufactures plant food, warehouses it and releases it in forms and quantities suitable for plant growth and welfare.

Many forms of organic matter, for example manure or compost, are "predigested plant foods" and can in themselves sustain plant life, but generally the best growth for the biggest variety of plants is obtained from a combination of organic matter and rocks (chemical fertilizers).

What is the Function of Rocks?. I have used the term "rocks" rather freely for the purpose of emphasizing the fact that basically soil consists of two major constituents, i.e., 1) particles of inorganic materials in the form of inanimate rocks, and 2) particles of organic materials derived from plants and animals. The term "rock" indicates something large, and therefore, I now wish to modify this term to include coarse stone, fine stone, coarse sand, fine sand, silt and specialty sands such as expanded shale, perlite and vermiculite.

Rocks have these principle functions: 1) These materials can in themselves, or when combined with organic matter, provide suitable anchorage for plants. 2) As mentioned earlier, they serve as a source of plant foods. 3) Their physical soil conditioning action, which as a third use, may be equally important as the food source. Few plants can live long in 100% organic matter, but when the organic matter is made porous with sand or similar material, plants will thrive.

What is the Function of Organic Matter?: I have just mentioned that rocks contribute a physical soil conditioning effect on organic matter, and we now can reverse this story and state that organic matter, especially if it is coarse, will produce a physical soil conditioning effect on mineral materal especially if it contains high quantities of silt and clay. It makes tight compact soils more porous and keeps the very fine soil particles from forming a water-repellent crust on the surface of the soil. Unfortunately, as the organic matter decomposes, the soil again becomes compact.

Organic matter performs another soil conditioning activity called chemical soil conditioning which is even more important than the physical conditioning just stated. Living organisms and residues of dead organisms produce a series of "long-named" chemical materials that literally bind fine soil particles together to form coarse soil aggregates. As these aggregates grow larger, the soil becomes more porous, and thus develops better tilth. You can readily see this difference if you compare some virgin soil near the edge of an old cemetey with the soil of a nearby field which has been cultivated. This is the type of soil conditioning that one should attempt to obtain when using cover crops for soil building.

A third and very important function of organic matter is that of increasing the water-holding capacity of the soil mixture. This is accomplished in two ways: first by absorbing water as a sponge might, and second, by providing an increase of particle surface to hold more capillary water. This last feature is extremely important because this is the only kind of water that plants can pick up.

Its fourth important function is that of providing a living medium for micro-organisms, so that they can accomplish their task of contributing to soil building and plant food conversion.

At this point, in the interest of soil management, we might inject reference to the controversial subject of the function of earthworms. There are some who hold that earthworms build soil, and others who contend that earthworms do not inhabit a given soil until after it has developed a good tilth I take no part in this controversy, but I find that the presence of earthworms and other similar large soil animals is not beneficial to growing shallow-rooted plants or bedding plants, because their presence encourages moles and small rodents. Moles, especially, cause considerable unnecessary damage by lifting newly planted plants and creating tunnels under established plants. Earthworms in containers produce a cementing action of the soil to the container sides, thereby creating a problem in removing the plants I am of the opinion that it is desirable to use an insecticide to keep earthworms and insects at a low level.

SOIL MANAGEMENT

By the above introduction to our subject of soil management I have tried to take apart the various important component factors of water and soil and discuss them separately. Now to put it all back together again is an easy task It can be readily summarized by stating that the objective for soil management or soil preparation is to produce a loose textured material that has fertilizing power It is accomplished by using mineral materials from rocks as a source of food elements, organic material (representing a chemical operation) to release and convert these elements and water as a medium in which the operation can take place and as a vehicle to carry the end products about in the soil and in the plants

The task of the nurseryman is to recognize the interrelationship of these three factors and keep them in a degree of balance

BALANCED PLANT NUTRITION

Assuming that balancing available plant food, organic matter and water are the important components of balanced plant nutrition, the logical question is, "what is an example of a balanced plant diet?" I am forced to say that this seemingly logical question cannot yet be answered, but the following are examples of how plant "diets" can be, and are being, unbalanced.

The present common practice is to feed in excess of assumed minimum requirements, but this has often caused trouble when certain food elements were not completely used in a given period of time or a season and they soon accumulate in toxic quantities Probably the most commonly caused trouble is that of producing soft growth on semi-hardy plants which later became injured from early frosts.

The amount of a plant food or fertilizer that a given block of plants will require is subject to a number of variables, which under most situations are subject to control. Let us examine some possibilities

Probably the greatest violation of controlling a variable is practiced in acidity control. It is not uncommon to adjust the pH of the soil with sulfur or lime to fit a particular type of plant material. Here is a simple example of what commonly happens. a given strip of soil 100 feet wide is planted to azaleas and rhododendrons and the soil is treated with sulfur to make it acid. Three years later all the plants except a few rows are sold. The soil is cultivated and lime is added to make it sweet The important and very difficult question is how much lime is necessary to alter the current pH level plus counteracting any residual sulfur that will in turn counteract the lime. Two years later the remaining rhododendrons and most of the two year-planted "sweet-soil" plants are sold The nurserymen must now adjust the pH of a small sulfured strip, a sulfer-lime strip and any soil adjacent to the original 100 feet strip In other words, he has to adjust three different pH levels Now who is able to bring this mixed-up area back to a uniform pH with one treatment and what operator can afford the time to make a variety of different applications of lime or sulfur on such small areas?

This thing called pH has nothing to do with plants except to help release a different "diet" of food elements from the soil. For example, a sour soil releases more iron and manganese if they are present. In the other extreme, a very sweet soil releases much less iron and manganese but a higher proportion of other food elements. Now for a practical operational procedure, isn't it better to keep a compromise pH level and feed the extra food requirements that would be expected to be in short supply? After all, changing the soil pH cannot encourage the release of food elements that might not be there in the first place!

Another questionable practice is that of starving plants to force early dormancy This practice is effective but does it not reduce the profit that might be produced from a given area? It is generally conceded that root development and caliper increase continue late into fall or early winter — our experience confirms this Now if a plant is starved in mid- or late-summer as forest trees are, where will the food be obtained to produce the additional late growth? Would it not be more profitable to employ a heavier feeding program and take precautions to see that there is not an excess of nitrogen in late season, or in other words, to maintain a "balance" of major elements?

Another common source of trouble occurs when high levels of fertilizer are maintained without consideration to water availability. One case, as an example, occured in 1957. Nurseryman "A" borrowed a fertilizer program from nurseryman "B" who also had a good water supply. The program was a relatively heavy one, but also fairly well-balanced. A severe drought occurred in late June, July and August. The plants in nursery "A" stopped growing, but in nursery "B" where systematic watering was practiced, the plants added considerable new growth. September was a very wet month and the plants in nursery "A" broke bud and started growing vigorously, but most new growth was seriously frozen back by an unanticipated freeze on September 21st. The September growth in nursery "B" was quite small and very little damage occurred.

I am not prepared to prove the reasons for these two different responses We have considerable experience to demonstrate that high fertility programs return the greatest profits, but that these programs will not be productive if not balanced with an adequate and regular water supply.

Many other examples can be given, but these were selected to demonstrate that water, soil and plant food are interrelated and none of them should be used without giving careful consideration to the others.

LITERATURE CITED

1 Curtis, O. F. 1926. What is the significance of transpiration? Science 63: 267-271.

* * * * *

DR. CHARLES HESS. I think you have taken a very difficult subject and have generalized many cases to a point where I feel your explanations are of questionable use and sometimes questionable accuracy. I would like to see you take these theoretical approaches and work out a practical use for them In other words suggest a soil mixture which will have the proper drainage and a fertilization program which will provide the proper nutrients.

DR BAUMGARTNER It might be very well. In the last eight years I have been working on a production basis with nursery superintendents and people who do not understand, because of their interest and their efforts, in an altogether different direction It is a matter of transplanting the significance of some of our important technical material to rule-of-thumb or common language. It is a most difficult thing to do.

MODERATOR JOHNSON: Thank you It was a stimulating talk that should create some arguments, but I think we had better defer them until after the lunch period, since we are now exactly on time.

Another subject connected with the soil problem, a subject dear to the hearts of many of us in the Midwest and adjoining parts of Canada, is iron chlorosis. Dr Brown is with the U.S D.A. Agricultural Research Service at Beltsville, and he will address us on this problem of iron chlorosis.

Dr John C. Brown presented his address on "Genotype of Rootstock as a Factor in Plant Nutrition with Emphasis on Iron Chlorosis." (Applause)

GENOTYPE OF ROOTSTOCK AS A FACTOR IN PLANT NUTRITION WITH EMPHASIS ON IRON CHLOROSIS

JOHN C. BROWN
Soil and Water Conservation Research Division
U S Department of Agriculture
Beltsville, Maryland

Chlorosis is a general term which denotes a yellowing in plants, a condition related to a large number of abnormalities. The more specific term, iron chlorosis, refers to a "chlorosis" which can be alleviated by providing the plant with suitable iron compounds. This disorder is particularly prevalent on calcareous soils where it is difficult to keep iron in forms which are available for all plant growth. It may occur on neutral or slightly acid soils, especially where so-called acid-loving plants such as azaleas, rhododendrons, and blueberries are grown. Growth medium, fertilizer, organic matter, and water are all contributing factors to this yellowing or iron deficiency (1). Soil and/or plant treatment for control is often difficult, but can be achieved by the care-