ters of an hour but to be fair to the remaining speakers on the program this morning, we will have to stop this section at this moment.

We now want to go on directly to the next phase of this discussion of container stock production which deals with water relations. I don't know how many of you commercial people particularly follow the scientific literature on various subjects of plant growth, but if you do, undoubtedly you have formed the opinion that our next speaker is probably the foremost person in the country as far as water relations on plant growth is concerned I have heard Dr. Kramer speak on this subject a good many times, and I know that he is going to have some very worthwhile information for you

It gives me a great deal of pleasure at this time to introduce Dr. Paul Kramer of Duke University. (Applause)

DR. PAUL KRAMER: Thank you, Dr. Chadwick. It is a pleasure to be here and renew some old acquaintances and make some new ones.

I am afraid this is quite a change in pace, however, because after these good discussions on the more or less practical side, I am going to turn to a more or less theoretical discussion of water relations, which I am sure you can apply. This will be better for me to do rather than to attempt to apply it with my somewhat limited knowledge of nursery practice

Dr Kramer presented his prepared paper on "Water in Relation to Plant Growth". (Applause)

WATER IN RELATION TO PLANT GROWTH

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INTRODUCTION

Everyone who grows plants appreciates the necessity of an adequate supply of water for good growth, but we seldom give much consideration to the reasons why water is essential. This is unfortunate, because the more one knows about the role of a factor such as water in plant growth the easier it is to manage it efficiently and deal effectively with the problems which arise in connection with it.

There are two principal aspects of plant water relations, that is the effects of too much water, and the effects of too little water. I will deal first and in most detail with the effects of too little water, that is, the effects of water deficits on plant growth, because this is the most common problem.

I will deal with the problem under three headings; (1) why water deficits injure plants, (2) why water deficits develop in plants and (3) how to measure and prevent water deficits

Most of the illustrations must come from crop plants because little research has been done on ornamentals other than roses. Even the information on roses seems to be rather inadequate, compared to that for apple trees.

It is obvious that we need much more research on the physiology of ornamental plants, including some on plant water relations.

WHY WATER DEFICITS INJURE PLANTS

It is a basic biological principle that the quantity and quality of plant growth is controlled by its hereditary potentialities and its environment, acting through its internal physiological and biochemical processes. The only way in which cultural treatments or environmental factors such as light or the water supply can affect plant growth is by affecting its internal processes and conditions. In order to understand why water deficits reduce plant growth it is necessary to understand how they affect the internal processes which control growth

Water serves the following four general functions in plants:

1. It is an important constituent, comprising about 90 per cent of the fresh weight of young leaves and stem tips and over 50 per cent of the fresh weight of trees. Any serious reduction in water content of protoplasm always results in reduced physiological activity.

2 Water is a reagent in processes such as photosynthesis and starch digestion.

3. Water is the solvent and the medium in which salts, sugars, and other solutes move from cell to cell and organ to organ.

4. Water is essential for the maintenance of turgidity. A certain minimum turgidity is essential for the enlargement of cells and the maintenance of form of unlignified tissue. Loss of turgidity reduces or stops growth.

I wish to repeat that the only way in which water deficits can reduce growth is by affecting the internal processes and conditions of the plant which control its growth. It is probable that every process which occurs in plants is more or less unfavorably affected by water deficits and I will discuss a few to illustrate this fact

Growth is particularly sensitive to water deficits because a certain degree of turgidity is essential for cell enlargement. Thut and Loomis concluded that the supply of water to the growing points (i e , buds) is the most important factor affecting the rate of growth. Apparently water deficits are caused more often by excessive water loss than by deficient soil moisture This explains why many plants grow more during the night than during the day in clear, hot weather. It also explains why many plants grow better under partial shade than in full sun.

Water deficits not only reduce total growth, but they also change the pattern of growth. The root-shoot ratio often is changed, and the distribution of dry matter among roots, stems and leaves is affected by even moderate wilting in barley

Even small water deficits, too small to be visible to the eye often measurably affect plant processes and growth. Australian workers found that short periods of moderate wilting affected growth and metabolism in herbaceous species. Goode, in England, found that small decreases in soil moisture tension which had no visible affect measurably reduced the growth of apple trees. It seems probable that herbaceous plants never completely recover from severe water deficits, and it is doubtful if woody plants recover very rapidly. It probably is a serious mistake to assume that no damage is done to plants by allowing them to dry out until they are visibly wilted

More study is needed on the complex relationships between mineral nutrition and water relations. It is often stated that fertilization increases the efficiency of water use by crops. In some cases this seems to be true, possibly because the leaf area decreases in proportion to other parts of plants, so the amount of water lost per unit of dry matter produced is decreased. It has been claimed that an abundance of nitrogen increases the water binding capacity of the protoplasmic colloids and decreases the rate of water loss, thereby increasing drought resistance.

Stomatal opening is a very sensitive indicator of internal water deficits. As the soil dries out, the stomates of many species of plants close earlier each day. Premature closure of stomates reduces water loss by transpiration, which is desirable, but it also interferes with the entrance of carbon dioxide needed for photosynthesis, which is undesirable. The relation of stomatal behavior and leaf structure to efficiency of water loss deserves further study.

Plant water deficits reduce photosynthesis directly by reducing the photosynthetic capacity of the protoplasm and indirectly by reducing stomatal opening. Some studies show reduction in photosynthesis before visible wilting occurs and all studies indicate a serious reduction after wilting occurs. This cuts down the supply of food available for growth.

Moderate water deficits often increase respiration. Increased respiration, combined with decreased photosynthesis, might seriously reduce the food supply.

Water deficits often change the course of various biochemical reactions, resulting in changes in chemical composition. The decrease in ratio of starch to sugar in plants subjected to drought, caused by hydrolysis of starch, is well known. In tobacco, water deficits often increase nicotine and nitrogen content, and decrease sugar and burning quality. Even moderate wilting of tomato plants decreases uptake of nitrogen and phosphorus and causes changes in leaves resembling senescence. You are all familiar with the premature death of the lower and older leaves on plants subjected to severe water deficits. Apparently water deficits seriously disturb the nitrogen metabolism of plants. Gates and Bonner, for example, found that water deficits speed up destruction of RNA and decrease its accumulation This is one reason for the deterioration of leaves on wilted plants.

Occasionally a moderate water deficit produces desirable changes in chemical composition. For example, the rubber content of guayule plants is increased by a moderate water deficit. The aroma and body characteristic of Turkish type tobacco is obtained only if the plants are subjected to water deficits. Tobacco grown in the shade and high humidity for cigar wrappers is deficient in aroma compared to that grown in full sun. Some kinds of fruits are higher in sugar when grown with moderate water deficits than when given an abundance.

It is doubtful if water deficits are ever helpful to ornamental plants.

WHY WATER DEFICITS OCCUR IN PLANTS

Water deficits and water stress' develop in plants because the loss of water by transpiration tend to exceed water absorption, even when plants are growing in moist soil.

Crop plants lose an amazing amount of water by transpiration. A single corn plant may lose 50 gallons of water during a season, and this means that it loses over a gallon each day during hot, sunny weather. A tree can easily lose a barrel of water on a sunny day and the water loss from large plants in containers must amount to several quarts per day. Often there is a complete turnover of all the water in a plant on a sunny day.

The water balance of a plant is fluctuating and unstable, because it depends on the relative rates of water absorption and water loss. The rate of absorption depends on; (1) the rate of transpiration, (2) the extent and efficiency of the root system, (3) the amount of available water in the soil, (4) soil temperature and (5), soil aeration, because they affect efficiency of roots as absorbing surfaces. The rate of transpiration depends on, (1) plant structure, (2) stomatal opening and (3) atmospheric factors affecting evaporation.

It is not surprising that two processes which are partly controlled by two different sets of factors do not always keep in step. Even when the soil is moist, absorption tends to lag behind transpiration because of the resistance to water movement which exists in the roots On hot, sunny days, even plants in moist soil often suffer from temporary water deficits because transpiration greatly exceeds absorption, although on cool, cloudy days plants in a much drier soil may be subjected to relatively small water deficits because the rate of water loss is so low.

This explains why the behavior of plants cannot be explained fully by either soil moisture or atmospheric conditions. Plant growth really is controlled by its internal water balance or water stress, not by soil or atmospheric factors The latter are important only to the extent that they modify the internal water balance

It might be interesting to know that when water deficits develop in plants there is competition for water among the various organs and tissues. Growing stem tips and young leaves usually can obtain water from older leaves: Very young fruits can compete with leaves, but older fruits lose water to leaves.

HOW TO PREVENT WATER DEFICITS

The obvious way of preventing water deficits is to water plants adequately. This is more easily said than done How can we know that we are watering plants adequately? If we water too frequently injury can result from poor aeration of the saturated soil, and at the least, water and labor are wasted. If we water too little, growth will be retarded by water deficits.

I wish to remind you in connection with watering plants that any given mass of soil can hold only a certain amount of water which is available to plants. If a surplus of water is added it displaces the air from the noncapillary pore spaces and roots suffer from lack of oxygen, unless the water is drained away promptly. If there is good drainage the water content quickly falls to the field capacity. Any further decrease in water content results from evaporation and removal of water by the plants growing in the soil. As the water content decreases, the remaining water is held more firmly in the smaller capillary pores and in the thinner and thinner films around the soil particles The rate of absorption decreases until it finally falls so far behind the rate of transpiration that the plants remain permanently wilted The water available for plant growth, that is the water between permanent wilting and field capacity, varies with the type of soil.

A cubic foot of the following soils, (about 7 5 gallons) will contain· (1) about one quart of water for sand (3 per cent of volume). (2) about three quarts for sandy loam (10 per cent of the volume), and about (3) 6 or 7 quarts for a silt loam or clay (25 per cent of the volume).

Obviously, sandy soils must be rewatered more often than silt or clay soils.

There seems to be four approaches to the problem of watering plants, ie,. (1) measure water loss from container in which plant grows, (2) measure the rate of evaporation and calculate the water loss, (3) measure the soil water stress and (4) measure the plant water stress.

Let us examine the advantages and disadvantages of each of these methods.

1. Measurement of actual water loss from plants is possible only if the plants are grown in containers. It is very precise, but it requires weighing of large containers and generally is impractical, except for research projects.

2. Calculation of the water loss from soil by evaporation and transpiration has proven fairly successful in some experiments and even in field operations. Thornthwaite in this country and Penman in England claim that water loss from an area of land covered with vegetation is determined chiefly by the solar energy it receives because most of the energy is used in the evaporation of water. This means that the loss of water would be the same from all kinds of low vegetation, provided that it covers the soil completely, it is rooted to the same depth, and it has the same color. If this assumption is correct one can calculate the rate of water loss by evapotranspiration (ET) from the average rate of evaporation. There are some errors in these assumptions but it is a usable method under some conditions.

For example, the average rate of evaporation of, water in the Raleigh, N.C. area is 0.2 inches per day in midsummer If a certain kind of plant occupies a soil mass to an average depth of 12 inches and this mass holds 1 4 inches of available water, then it is obvious that after a week without rain, irrigation would be necessary. If rain falls, the amount of precipitation is deducted from the possible loss by evaporation. This system of controlling irrigation has worked well on tobacco in the Carolinas and it probably has other uses

3. Another approach is to measure the soil water stress Measurement of water content is not satisfactory because 20 per cent of water by weigh may mean saturation in one soil and below the permanent

wilting point in another soil. A number of tensiometers, irrigation meters, and resistance block devices are on the market to measure the soil moisture tension and indicate when water should be added. The principal difficulty with these gadgets is their initial cost and the problem of locating them so they indicate the water stress in the soil area from which plants are absorbing water. In soils drier than field capacity water moves quite slowly, so water is removed only from those regions which are occupied by roots Unless these instruments are installed in the root zone they may give a misleading picture of the soil moisture situation.

4. Measurement of plant water stress is at least theoretically the best measurement, because it is the water stress in plants themselves which really controls growth.

Unfortunately, this is rarely measured except in research projects, because it is somewhat difficult to determine.

Too often we wait until the plants are visibly wilted before watering them, simply because we have no other way of measuring their condition. This is too late for best results, because growth has already been retarded by an invisible water deficit before any visible symptoms exist. We need a good indicator to predict the approach of a water deficit so it can be avoided by adequate watering.

In Hawaii certain sugar planters control irrigation of sugar cane by measuring the water content of a selected leaf sheath. In Israel, irrigation of citrus and other crops sometimes is controlled by measuring the stomatal opening. As mentioned earlier, stomates tend to close prematurely in the morning when plants are suffering from water deficits. This premature closure can be detected by failure of kerosene, turpentine, benzene, or some mixture of liquids of low surface tension to infiltrate the leaves when applied to their lower surface.

What we really need is some kind of electronic moisture meter which can be carried out in the field or nursery and which when slipped over a leaf will give a reading of the water content.

For research purposes we need a measure of plant water stress expressed as DPD so it will be in the same units used for expression of the soil moisture stress One serious failure of our research projects up to date is that we have not measured plant moisture stress. This failure is responsible for many contradictory conclusions and inconclusive experiments on the relation between soil moisture and plant growth and plant processes.

SUMMARY

1 The essential factor in plant water relations is the internal water balance or water stress in plants, because this affects the internal physiological processes and conditions which control growth More research is needed on the relation between plant water stress and plant processes.

2. Water deficits develop in plants because the rate of water loss by transpiration tends to exceed the rate of absorption, even in moist soil. In dry or cold soil water absorption is greatly decreased, resulting in serious plant water deficits.

3. Water deficits sufficient to reduce growth often develop before plants are visibly wilted. We therefore need methods for predicting the need for irrigation before plants have wilted. This is being done more or less successfully by measuring changes in soil moisture with tensiometers and by calculating water loss from rates of evaporation.

4. The best indicator of plant water stress and need for irrigation is the degree of water stress in the plant itself, since it is plant water stress which really controls plant growth. Such measurements have been made on a few crops, chiefly by measuring stomatal aperture. We need to develop better methods for making such measurements, including some kind of electronic moisture meter.

5. Finally, those carrying on research on water relations of plants should measure the plant water stress by measuring the relative turgidity or DPD of the plants. Quantitative measurements of the water stress in plants are essential to an understanding of how plants respond to various water regimes.

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MODERATOR CHADWICK· Thank you, Dr. Kramer, for that very fine discussion on water relations both in plants and in soil.

For the next part of this panel discussion we are going to ask each one of these men to say just a few words on the techniques that they are following in watering container stock. After this we will plan to spend the rest of the morning on questions.

Bob De Wilde, do you want to start in on your comments?

MR. BOB DE WILDE: All right, Dr. Chadwick, I will attempt to tell you a little bit about water and its relation to our container operation. First of all, I would like to say something about environment.

We place our cans in a large wooded area which has been cleared and thinned. The trees in this area definitely modify the climate and, consequently the water relations of plants By using the woods as a shade area, we get less air movement and less evaporation.

When placing the plants in beds which are six feet wide, they should be grouped in accordance to their water requirements. For example, all of your shubbery material should be placed together. Your yews should be separate Your two-year junipers are very different from such plants as viburnum and cotoneaster The leafy material must be watered much more frequently.

The next consideration is the surface upon which you place the plants. This is very important, and I think it is one of our biggest problems. The surface should provide excellent drainage because you must apply large quantities of water to these plants. If you cannot drain the surface upon which your plants are resting, the water cannot filtrate through the potting mixture, and leave the can. The air spaces in the medium after you have irrigated will be gone, and you will in effect get a drowning of the plant.

We use the California irrigation type system, with the aluminum pipe and Skinner rotary nozzles for our entire watering system. They are placed at 40-foot intervals. Our laterals are 40-foot and the water source is a spring-fed pond that we have. We use a Fairbanks-Morse pump and it pumps water through a four-inch main to our laterals which run parallel to the beds. The rotary type nozzles give you an overlapping pattern which I am sure you are all familiar with. We operate at a constant pressure of approximately 125 pounds. We are putting on an acre of water in three hours. We irrigate approximately two acres at a time. It does a very good job of distributing the water. We have applied hydrated lime to this water and raised the pH one point. Just by observing the way this lime falls you can tell the very fine and even distribution which you receive.

Being in a woods area trees occasionally block the rotary pattern and we must hand-water where we have a few plants which are missed by the nozzles. You can always figure that you probably will have to do some supplemental hand-watering

As far as determining when to apply water is concerned, we use moisture-resistance blocks, which are imbedded approximately in the center of the cans, which in turn are located at what we consider strategic points throughout the area They are placed with regard to the variety of plant or a large group with similar water requirements. For example, we have one for yews, one for viburnums, and one for junipers, etc. We have about 15 or 20 of these scattered throughout our area, which through experience give us a fairly good indication of when to water before the plant actually shows that it needs water.

We have also used the old rule of thumb method on a shrub such as *Pyracantha,* which will exhibit a slight drooping at the tip It seems to be our first plant which exhibits signs of the need for water.

MODERATOR CHADWICK: Thank you, Bob. We will go right on to Jack Hill.

MR J. B. HILL· I should like to start by agreeing entirely with Dr. Kramer on this matter of plants being almost irreparably damaged by wilting. I want to assure you that once a pfitzer juniper has wilted it just never comes back. It may continue to grow a little bit, but it never really regains the vigor it once had.

Next, I would like to disagree with Dr. Kramer over this matter of water availability. It is my understanding that for all practical purposes in any given volume of soil, despite variations in mixture which might range from glass marbles to very finely shredded peat moss, there will be found the same amount of water available to the plant. In the peat moss there is so much water held hydroscopically, in the glass marbles there would be almost none. There is however, almost the same amount of water available to the plant even though the mixes themselves hold entirely different quantities.

To get on to what we shoot for in Dundee, I would like to deal first with this matter of determining when you should irrigate. We have tried moisture blocks and potentiometers. We finally came down to a very good system, which was suggested to us by a gentleman of

German extraction who visited our nursery one time He referred to it as the "fierct knuckle" method. you stick your finger into the can up to the first knuckle and you can tell whether or not it needs water.

Without being facetious, though, we use the medium to tell us when to water We simply knock a few plants out and look at the medium. You also get so you can almost tell by lifting one whether or not you actually do need water in those containers at that time. Therefore, our determining when to irrigate is anything but scientific, very much a rule of thumb. The white-smocked scientists which Jim Wells referred to sometime ago, turned out to be all brown and don't speak English They speak a sort of a Spanish and they are able to do a pretty good job

In our method of applying irrigation water we have felt uniformity of application was of prime importance. Admittedly we went to a good bit of trouble in the setting up of various fixed head sprinkler systems to determine whether we could get the uniformity that is required under these growing conditions Quite frankly, we were not able to do so. Since water is admitted to be one of the really prime factors in growth rates, this uniformity is entirely essential.

We have gone to this little moving sprinkler. It is a tool that has to be used carefully, as any tool must be If it is used correctly, the savings realized are almost unbelievable For example, one man can literally take care of the irrigation and feeding requirements of four acres of container stock. Now the economics involved in this are quite obvious.

We are currently irrigating all our one-gallon containers automatically with the moving sprinkler. This unit gives us exactly the same amount of water in each can We adjust the nozzle opening on these sprinklers to the point where they are applying approximately three quarters of an inch of water on each application. The three-quarters of an inch of water gives us some leaching through the bottom of the can. We do not want to take a chance on accumulation of soluble salts in the container, so we figure to leach a little with each irrigation

What we call five gallon cans — they are technically an egg can and are not five gallons any more than a No. 10 envelope is 10 inches long — are watered by hand. At one time we thought that we would irrigate these by mechanical sprinklers by making multiple runs up and down the beds. That has turned out not to be practical under our conditions. Our frequency on these is about every five days. Our one gallon containers are irrigated on the frequency of four times a week throughout the entire season. Very early and during the hot season they are irrigated every day. When growth slows down they are irrigated every other day or perhaps every two days. Thank you.

MODERATOR CHADWICK: Thank you, Jack. You will notice there is some disagreement among the experts. We will go back to Dr. Kramer in a few minutes to comment on the point Jack has raised. We will have a comment from John Mahlstede now

DR. JOHN MAHLSTEDE· As has been discussed, the application of water to ornamental plants growing in containers on top of the ground can be either from overhead or from a ground or sub-irrigation facility. Even though the grower has what he believes to be uniform stock, growing in a medium of uniform consistency, there are pockets and areas within a block which require more water than adjacent areas or individual containers. There is no machine yet that can be set to operate mechanically to apply just that amount of water which is optimum for each plant within each container. Generally there has been no substitute for spot watering by an operator with a water wand or similar gadget.

Using either the tile or plunge technique for growing, containers are brought to field capacity after planting, or prior to plunging. In our experiments all stock placed in wire baskets (having the polyethylene bag either on the outside (for tile growing) or on the inside (for plunge) was held for a period of one month, in a shade area, on top of the ground. This allowed for establishment before field placement. Most of the stock was well rooted by this time and little loss was sustained in the planting operation. Both systems were located under overhead irrigation lines, where water could be uniformly applied over the entire experiment. Most groups, however, required little supplemental irrigation since they rooted out into the surrounding soil area where rainfall supplied sufficient water for growth during the 1958-59 seasons.

In the plunge system, where plants were plunged in baskets, it was quite important to locate the surface of the medium just below the surrounding soil line. If this was not done, stock growing in such mediums as sphagnum moss and sphagnum moss and perlite would dry very rapidly. These mediums literally serve as wicks, which fanned by drying winds rapidly deplete the moisture supply within the medium. By the same token a light mulch, on sphagnum containing mixtures plunged in tile is also warranted, especially during the first year when stock is becoming established and the medium receives little shade from the growing plant.

MODERATOR CHADWICK. Thank you, John. We will go on to Ken Reisch for his comments

DR. KENNETH REISCH: Just one comment here about the general factors involved in irrigation techniques. Certainly, we have to consider the economics since this is the basis for selecting a particular commercial operation. I think logically we can do a better job hand-watering a lot of this material because we would give it better and more constant care.

We have to worry about money occasionally at Ohio State University and have not been able to afford to hand water 10,000 or 12,000 containers. As a result we have used a couple of techniques Although we haven't run any research studies on it, we have observed that the rotating sprinkler has given us uneven coverage. That is, we have an excessive amount of water in the interior part of the run and so often not a sufficient amount on the outer edge We had an excellent example with firethorn, which were all yellow towards the center of the circle from continuous leaching but were excellent around the outer edge of the spray pattern

With an automatic system we run into the problem of controlling the amount of water applied to the plant. I think under and over-watering is critical, as has been indicated earlier by Dr. Kramer, and should definitely be controlled in some way, whether by the first knuckle or some other technique It is not something you can leave on and go fishing and come back on Monday and expect the plants to be all right. It is quite different from handling plants growing in the field.

In a study several years ago we found that on a sunny day in Columbus, it takes about four hours for an average plant, growing in a gallon container, to reach a point close to the wilting condition. It was found that these plants required a morning and afternoon watering during the summer and on extremely hot days.

We do want to bring up one point, and that is on the use of a traveling sprinkler like Jack Hill has described. We have used it and think it is an excellent means of watering containers We have had some trouble with compact or dense crowned plants. It is very difficult to get water into the container proper, particularly where you have a moving sprinkler and the water is there for a relatively short time. Maybe Jack can give some comments on that in a moment.

Some nurseries in Ohio (one in particular) has used subirrigation, using plants in a bed lined with polyethylene plastic. I think many of you realize that is a good way to water, but you do run into disease problems, since the water spreads diseases. However, this has been tried and the operators feel it is very economical and very effective, particularly in sales areas where they have the plants ready for sale.

One other point, back to this discussion of polyethylene. We did use a polyethylene bag for marketing purposes and found we could maintain adequate water in the medium by taking the plant out of a can and putting in a bag and closing the top. It worked out very effectively as a means of marketing the plant It was lighter, cheaper, easier to handle, and a good means of maintaining the moisture.

MODERATOR CHADWICK: Thank you, Ken.

I would like to have the microphone passed down to Dr. Kramer now for comment on this point Jack Hill brought up.

DR. KRAMER: I don't happen to have any data on the water-holding capacity of marbles I do have in mind data from some California studies indicating that a particular sand, held about three-tenths of an inch of readily available water In a silt loam and clay they were working with, 2.8 inches and 3 inches per vertical foot of water was held in a day. In other words, a very considerable difference.

Would you care to elaborate a little bit on your question?

MR. HILL: I will restate the hypothesis I had in mind. This is that a given volume of medium will hold almost the same amount of water available to the plant as will another medium. Is that correct?

DR. KRAMER: I disagree From my experience with soil I don't believe it at all.

MR. HILL. The background of the statement partially traces to Mr Hoogendoorn's question earlier, ie, "Does not the sand and peat dry out rather readily in our greenhouse bench?"

It has always been our feeling that porosity as such in a growing mix does not necessarily increase the frequency of irrigation. Obviously, the plant is only going to get so much out of it.

MODERATOR CHADWICK. We may have to put these two men off in a corner this afternoon to talk this things over.

Before we open this session to questions, I want to call your attention to one part of the program that was omitted The last phase of this discussion this afternoon will be on winter protection of container stock. Dr. Reisch will lead off and then will be followed by the panel.

Now if we can proceed to the questions, and here again I would suggest that you confine your question as much as possible to water relationships.

Now, Case, you started here about half an hour ago to get up. We will let you have the first question.

MR HOOGENDOORN: I would like to direct my question to Dr. Kramer. I want to say I am very happy that we have a moisture expert on the program for a change. The question I am going to ask him is the old perennial question that has been in controversial for years. When we get a dry spell do you suggest that we stop, or continue cultivation?

DR. KRAMER· I doubt that I am the most competent one to answer that question. I doubt that cultivation saves much water, if that is what you have in mind, because the surface is dried out so very quickly It will dry out whether it is either cultivated or uncultivated. As to the importance of a dust mulch, so far as I know, if you would like to quote someone, several years ago you might as well have sat on the porch as to try to conserve what was in many soils.

MR. HOODENDOORN: If you don't cultivate, your ground bakes and will crack. If you dig anything during a dry spell, you will find out that you will have more moisture where the surface was loose rather than where the surface was baked

DR. KRAMER: It is certainly true that if the ground cracks badly this does increase water loss. Some soils I know in Texas are rather bad and they do dry out faster. This may be of some importance there. I wouldn't want to generalize about the effect of mulch. This data that are available are rather contradictory, and that is why I would say I wouldn't bother to cultivate. There is some movement of water in soil in the form of vapor toward the surface, under certain conditions. How important this would be in our climate is rather difficult to say; it is doubtful. In some dry climates this is quite noticeable, although it isn't likely to be important in the summertime because the temperature gradient isn't right for it.

MR. JIM WELLS: I would like to ask Dr. Kramer to elaborate on this paraffin test on leaves. I would like to know the time of day that it is best used, the best type of leaf to use it on, how much paraffin to apply, and what do you look for?

DR. KRAMER: This test is based on the assumption that the stomata, the little miscroscopic pores in the leaves, tend to close prematurely when a plant is suffering from a water deficit. Therefore the test is usually made in the morning, say around 9.00 o'clock, because the stomata on almost all plants are open at that time of day. If they are suffering from a water deficit they may have begun to close by that time.

In the case of several of the plants, citrus, for example, kerosene oil was used for a good while. They are using turpentine and they are using a mixture of kerosene and turpentine, I believe, with a heavier paraffin oil. Ordinary mineral oil can be bought at the drugstore to get various viscosities. It has been used on coffee trees successfully and on wheat and on corn with different mixture The trouble is, I can't give you a general recommendation for all crops since there is so much variation in leaf characteristic. After you have selected the most suitable material you can tell whether or not infiltration is occurring because you will have a water-soaked appearance, if it goes in. If it doesn't go in you won't get that appearance and obviously the stomata are closed.

MR WELLS: Is the infiltration quite quick?

DR. KRAMER: It is practically instantaneous.

MR. WELLS: Do you use it on a mature leaf or a young one?

DR. KRAMER: Principally a mature but not over-age leaf. You should stick to leaves of the same age. Obviously, you are going to kill a little spot in the leaf with the infiltration.

MR. FLEMER (Princeton, N.J.): I would like to describe a potentiometer which we use very successfully for broadleaf plants at our nursery.

They cost 15 cents apiece and they are saleable at the end of the current season for 60 cents apiece. It is *Hydrangea macrophylla* the common florists hydrangea. We place this species in our blocks out in the field and also use it in our limited container operation

Our experience has shown that this variety of hydrangea exhibits wilting when the field is below optimum conditions for the rest of the plants, and should be irrigated It seems to be very accurate. The hydrangea hardens off as it gets older just as we want our field plants to harden off. We are able to accurately irrigate right up to the close of the growing season.

If it is extremely dry, this variety will even wilt in early September. We find that we sometimes have to water late If the soil is only moderately dry, it doesn't wilt and that means optimum conditions for broadleaf plants at that stage of their growth.

MR VERKADE: Bob, you very briefly went by something in your talk about water. What is wetter water. and I was wondering how it is applied and how beneficial it is?

MR. BOB DE WILDE: The question was, "How beneficial is the water wetter, commercially known as Aqua-gro?"

It is a water wetter just exactly as the name says; it makes water wetter. It enables the water to penetrate the soil more rapidly and more thoroughly We applied it in one application in July. This, we feel, is definitely beneficial. It obviously gave us more rapid penetration, better water distribution throughout the soil mix It has been used a great deal on golf courses, and so forth.

Also, I would like to add that in order to apply moisture more effectively, we do a lot of night irrigation.

MR. WALTER F. GRAMPP (Red Bank, N J.) · How do you apply it?

MR. DE WILDE: It is applied directly through the irrigation system It is injected into the irrigation system.

MR GRAMPP· Do you think this characteristic would remain in the soil?

MR. DE WILDE· It is not a lasting effect that will remain forever in your medium.

MODERATOR CHADWICK: I believe Hugh Steavenson has a question.

MR. STEAVENSON: I would like to ask a question concerning water. We have two sources of water, that is from deep wells and from pond water which is derived from hillside runoff. Our deep well water is not satisfactory because of the mineral content and its build-up in the cans over a season. Our concern with the surface water comes from the University of Californias' bulletin in which caution is made concerning the presence of water molds in surface water. While we haven't been able to observe any detrimental effect but I wonder if that is an actual or potential danger?

DR. KRAMER· We do know that diseases are spread in surface water in tobacco, for example, and this is a definite problem in irrigation. That is the only contribution I can make

MR. HILL: I wonder if Mr. Steavenson can tell us what the mineral content of the deep well is that renders the water unsuitable for irrigation. Is it sodium, potassium, carbonate, or a bicarbonate product?

MR. STEAVENSON: It has been analyzed, but I can't recall it's analysis. It is a hard water. For field irrigation it is all right, but for container growing we get an accumulation of salts during the season and rapid elevation of pH beyond what we want. Furthermore, in sprinkling, we get a deposit on the foliage which is, of course, not beneficial. Our pond water, thus far seems to be excellent, although I have been concerned about the possibility of molds. I can't observe any trouble. I just wondered if anyone had a problem from using runoff water in container irrigation?

MR. HILL: We use nothing but well water. Toward the end of this season we did find it necessary to run an analysis on the water we are getting from our well. The results indicated we had a rather high bicarbonate fraction in this water, so for the upcoming season we are going to use iron sulphate right with our fertilizer and I hope it will work out most of that problem

DR. CHARLES HESS: Jack, I don't think you answered the question Ken Reisch posed before, as to the watering difficulties with an automatic sprinkler on plants which form a canopy over the top of the can.

MR. HILL. We use the Rain King manufactured by Sunbeam, K-20B is the model number.

The water emerges from a rotating sprinkler held some 24 inches above the ground on the stem. This entire sprinkler moves automatically at a rate determined by the function of both water pressure and water flow. Therefore, the application to an individual can within the radius is automatically controlled.

Now we feel because the pattern of water from this sprinkler moves as the sprinkler approaches a plant, the first drop of water enters that can rather obliquely from one side As the sprinkler passes that plant, and is retreating, the last drop enters from the other side. Therefore, where it may not do an adequate job of watering a plant which has an absolutely tight canopy, it will come closer to doing a better job than any fixed head or anything short of hand watering the can.

We, in truth, have had no trouble in getting adequate water on some compact pfitzer junipers. With the typical conifers that produce that canopylike growth we have never felt that watering was a problem with this type of sprinkler.

DR. REISCH: We are using the same type of sprinkler and I will agree with Jack Hill. I think it is probably the best you can get.

MR. LANCASTER (Portsmouth, Va.): For a long time we thought hand-watering was the only way We have reverted now to a square head sprinkler and it will do a very good job. I think the capacity of this particular head is five gallons per minute, so you can see that a lot of water is coming out.

DR. SIDNEY WAXMAN (Storrs, Connecticut): I would like to direct this question to Dr. Kramer. Would you care to comment on the relative rates of water loss from plants exposed to sunlight on a quiet day as compared to the rate lost on a windy, cloudy day?

DR KRAMER: I don't have any quantitative data in mind on this question There is no doubt that wind increases water loss. The worst day, as you all know, is a sunny, windy day. I can't give you the relative rates of water loss, however, on a windy, cloudy day as against a bright, sunny day.

I would like to follow up the point of the efficiency of night irrigation. I think the efficiency of night irrigation is greatly over-estimated. What water is evaporated during the day while you are putting it on is simply water that is evaporated from the mist. This water would probably have been evaporated anyway to a large extent. From the standpoint of water, you don't save as much as you think you might by irrigating at night. As Mr DeWilde has pointed out, it is sometimes quieter at night and, therefore, more efficient, but I doubt if you save very much water.

MR. DE WILDE: There is one thing I would like to add. I think we are all in accord that no matter what watering technique we use, it can still be improved upon. I will not defend our rotary type system as being highly efficient, but we do use extremely high pressures and we do get a smaller droplet than the ordinary rain droplet. The Skinner head has come up with a few modifications which improve it considerably over their older type They have a spring loaded head now which keeps the rotation at a constant speed, we use complete overlapping.

MR FLEMER· I would like to disagree with Dr. Kramer obout night versus day irrigation, particularly where you are growing crops. We have a large area exposed to the air. We have actually placed square pie pans under dense shrubs that we irrigated during the daytime and irrigated again at night. Of course, there was more wind during the day, but on putting down an inch of water we found we gained an eighth of an inch by irrigating at night. That doesn't seem like very much, and when you are pumping water and moving the pipe around, that really small amounts mounts up by the time you are through.

DR. KRAMER: But where did that eighth of an inch of water go? If you didn't lose it by evaporation from the irrigation system you lost it from evaporation by the plants during the day. This is just a matter of energy balance. I think we really kid ourselves about this a good deal, and I doubt there is really enough water saved to make it worthwhile.

The point I am trying to make is that if the plants were not irrigated during the day they would lose the equivalent of an eighth of an inch more or less of spray water As soon as you turn on the water you will stop transpiration. In the night instead of the water coming from the plant, it is evaporated from the plant This is my line of argument.

MR. FLEMER: My line of argument is that you want the water in the soil and therefore I would like to know if those plants really would evaporate a full eighth of an inch during one sunny day.

MODERATOR CHADWICK: We want water in the plant, not in the soil.

MR. HILL: We regard the creation of a specific climate around those plants when they are most active, as being very important This is why we actually want water evaporating in the air. I think the daytime is best.

MODERATOR CHADWICK: When Harvey Templeton set up the program, I was informed that we should stop at 11:40 One announcement, however, before we adjourn, Mr. President.

PRESIDENT NORDINE: Because of the great numbers of new people attending the meetings for the first time this announcement concerns how the Plant Propagators Society operates relative to membership. Visitors are invited to attend one meeting as a guest, the invitation being obtained from a member. They then can obtain an application blank from our Secretary and apply for a membership. Rather than to take time at this particular time to read the rules in regard to membership, we will refer you to the Secretary for further qualifications

I believe that is all at this time Remember that the meeting begins this afternoon at 1:30.

The session recessed at 11:45 o'clock