IRRIGATION MONITORING IN WESTERN FOREST TREE NURSERIES

Stephen E. McDonald
Western Nursery & Greenhouse Specialist
State & Private Forestry
USDA, Forest Service
Lakewood, Colorado

<u>Outline</u>

A. Why is it important to monitor irrigation practices in tree nurseries?

B. How is tree seedling irrigation being monitored in the west?

1. Data Collection
2. Results
    a. Bareroot
    b. Container

C. Is what's being done enough?

D. Summary

References Cited

Appendix - Sample Questionnaire

A. <u>Why is it important to monitor irrigation practices in tree nurseries?</u>

Almost every plant process is affected directly, or indirectly, by water supply. This is largely because higher plants, like other living creatures, have evolved with biochemical systems that operate in an aquaeous medium. Consequently, biological function is completely dependent on water, and the properties of life are often directly a result of the properties of water. Water makes up 80 to 90 percent of the fresh weight of many plants (Leopold and Kriedman, 1975). Within certain limits the metabolic activity of cells and plants is closely related to their water content. This relationship is illustrated in Figure 1, which shows the correlation between water content and respiration in a rye seed. Plant growth rates and photosynthesis are closely tied to water availability in the plant. Well, there's no use belaboring the point. We all know water is important as a structural and chemical component of plants, and we know that plants must be well-watered to grow and develop like we want them to.

The absorption of water is not an independent process, but is related to, and largely controlled by, the rate of water loss by transpiration, at least when water is readily available to the roots (Kramer, 1969). Absorption and transpiration are linked by the continuous water columns in the xylem system of plants. The rate of water movement through this system is controlled by the slowest process, that is, the stage at which the greatest resistance to water movement occurs. Transpiration lowers water potential (increases negative tension) at the evaporative sites in leaves and this effect is immediately translated to the root system via the plant's vascular system. If all plant processes are to proceed uninhibited, the demand for water must be satisfied continuously. Figure 2 illustrates how transpiration can generate a gradient in water potential that is followed by water uptake within the root system. Soil water potential drops exponentially with decreases in soil water content, as shown in Figure 3, so that transpirational pull becomes decreasingly effective in satisfying the plant's water requirements. The relationship between moisture tension, or water potentials, in different parts of the system are shown in Figure 4. This classic diagram by Slatyer illustrates what happens in terms of negative bars of tension as a plant and soil dry-out over a period of days. Scientists tell us that, before any visual symptom of moisture stress is apparent, many physiological reactions have already occurred within the plant (Leopold, op cit., p421). Well, again, we have all been exposed to some water relations theory. It is probably enough to say that water availability is extremely important to plants. Consequently, we need to know how much internal stress exists in the plant, or, as a second choice, what the soil water content or tension is, so we can decide when to irrigate. This is what we mean when discussing irrigation monitoring practices; what indicators and guides do we use when deciding when to irrigate?

There are a couple of other points to make before leaving this subject. First, water affects the nutrition of plants in a number of ways. In most plants a suitable level of nutrient availability to plants expedites the use of available water (Hausenbuiller, 1972). So proper plant nutrition will not only yield benefits by supplying proper elements to the plant that facilitate growth and development, but also will provide better use of applied water.

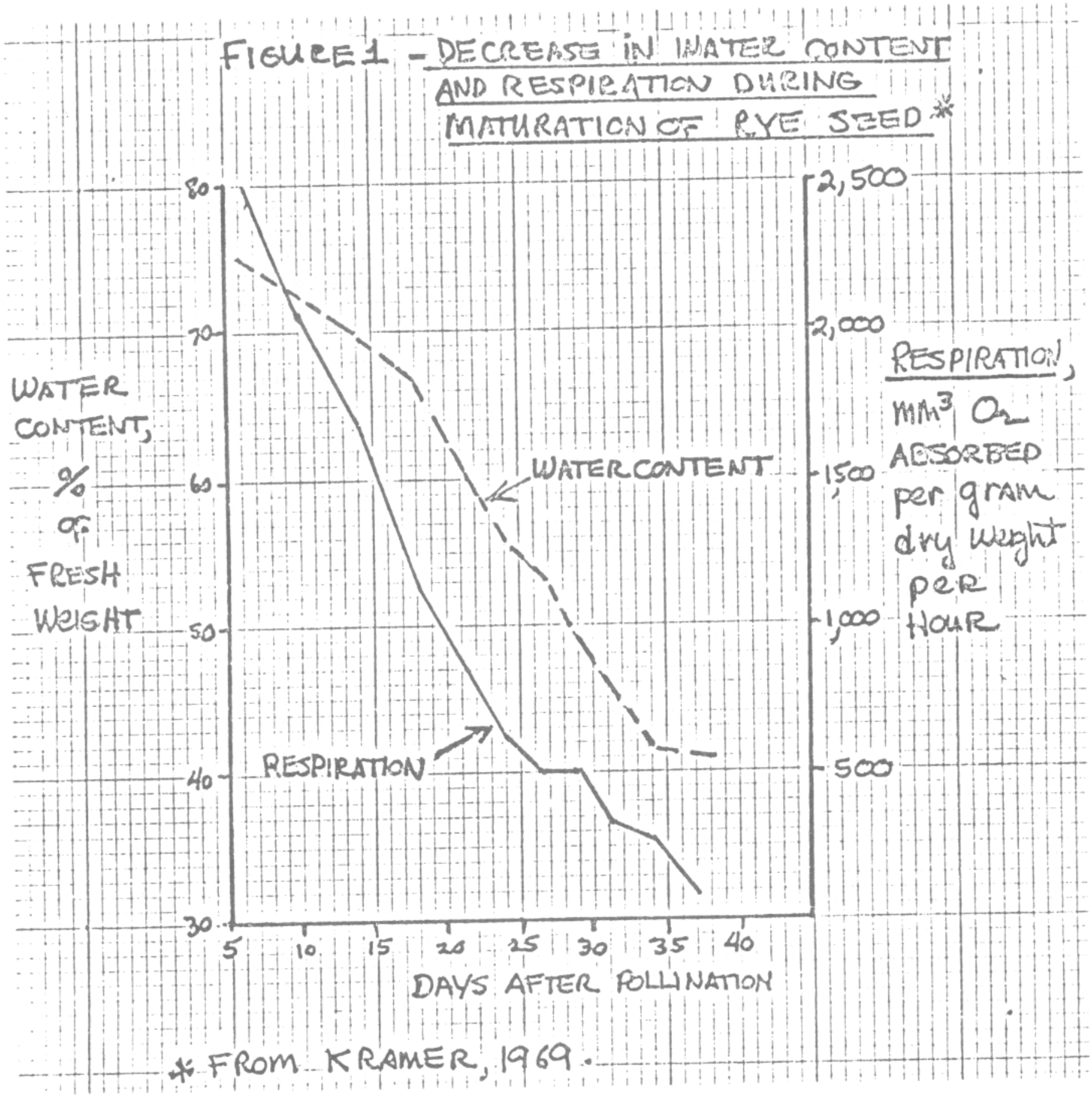
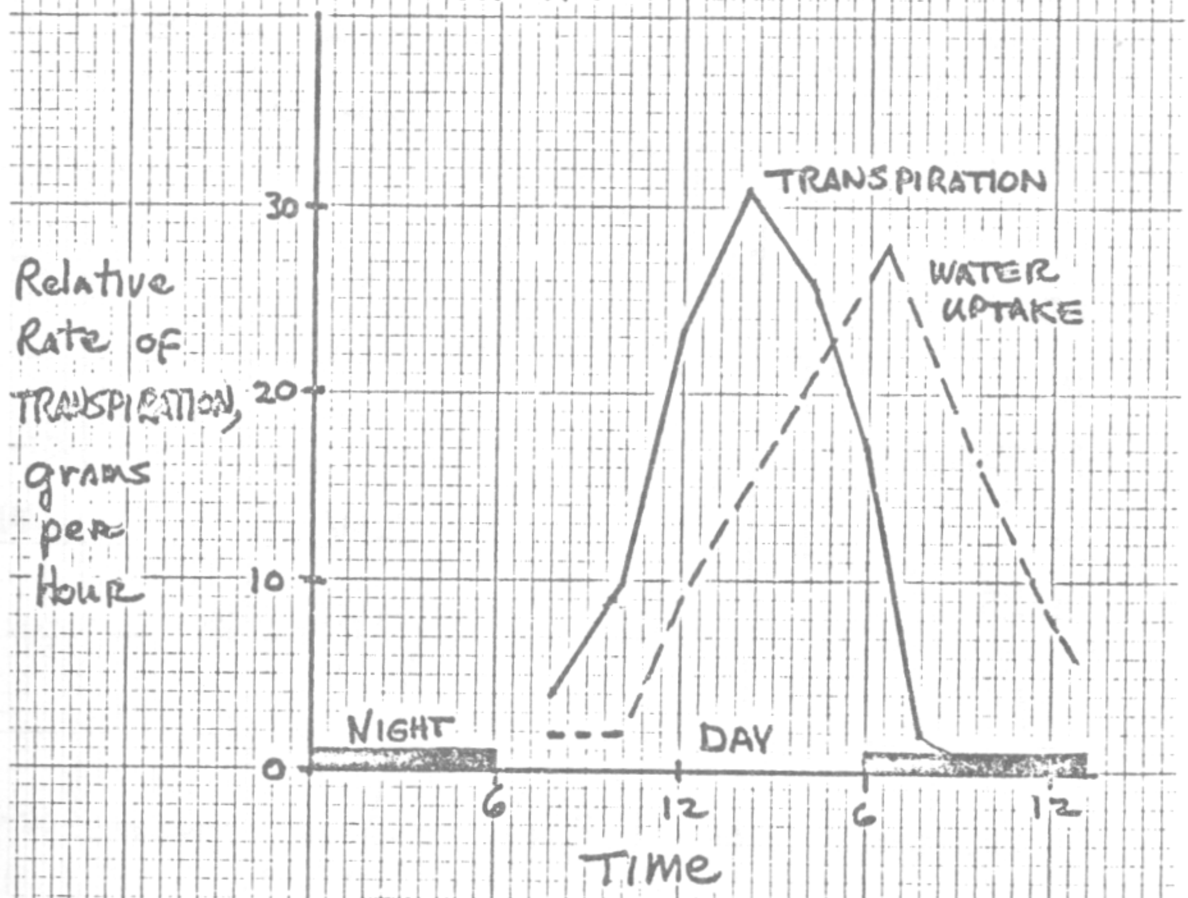


FIGURE 1 - DECREASE IN WATER CONTENT AND RESPIRATION DURING MATURATION OF RYE SEED*
WATER CONTENT, % OF FRESH WEIGHT
RESPIRATION, MM3 O2 ABSORBED per gram dry weight per HOUR
WATER CONTENT
RESPIRATION
80
70
60
50
40
30
2,500
2,000
1500
1,000
500
5
10
15
20
25
30
35
40
DAYS AFTER POLLINATION
* FROM KRAMER, 1969.

FIGURE 2 - DIURNAL RISE IN TRANSPIRATION PRECEDES THE RISE IN WATER UPTAKE*



* FROM LEOPOLD, 1975

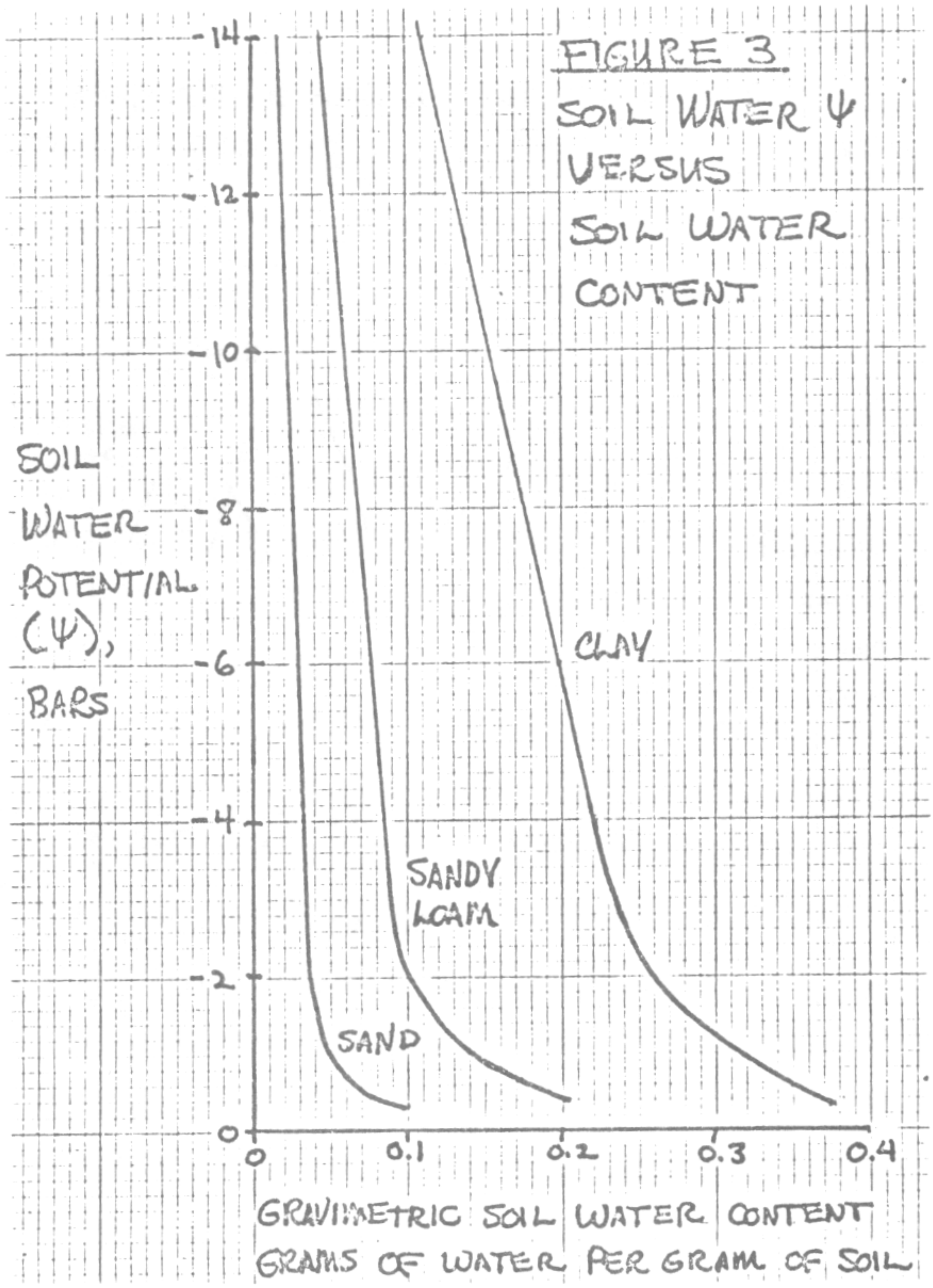
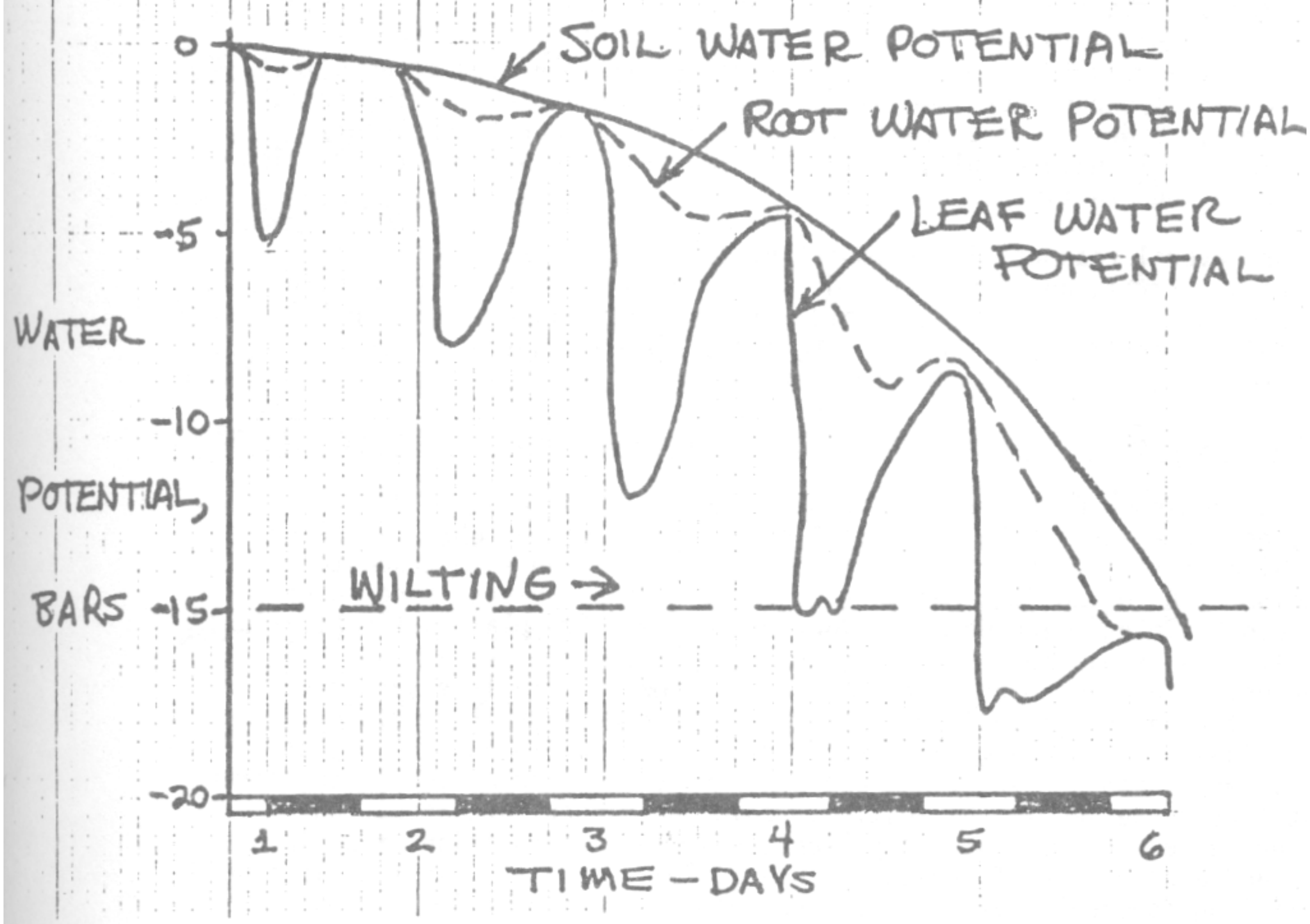


FIGURE 3
SOIL WATER Ψ
VERSUS
SOIL WATER
CONTENT
SOIL
WATER
POTENTIAL
(Ψ),
BARS
-14
-12
-10
-8
-6
-4
-2
0
0
0.1
0.2
0.3
0.4
CLAY
SANDY
LOAM
SAND
GRAVIMETRIC SOIL WATER CONTENT
GRAMS OF WATER PER GRAM OF SOIL

FIGURE 4- RELATION OF LEAF WATER POTENTIAL TO SOIL WATER POTENTIAL



Secondly, the water shortages this past summer vividly showed that unlimited water is no longer available to many tree nurseries. I believe I mentioned this problem last year when we discussed the western nursery situation at Manhattan, Kansas (McDonald, 1977). Tourney and Korstian observed, even in the 1930's, that tree nurserymen habitually over-water their seedlings (Tourney and Korstian, 1942). Certainly, in the past, most of us could say "why not?". With plentiful water, well drained soils, cheap fertilizer, and all the negative things that happen to seedlings if they dry out, why not be super-safe and use more than enough water? Well, as you know, a couple of things have changed. Fertilizer is more expensive. Can we afford to flush fertilizer down the drain with excess irrigation now? Do we have the extra water to waste? Finally, moves are underway to more closely monitor the pollution of streams and aquifers by agricultural pursuits (Blackman et al., 1977). Because most tree nurseries experience some overland flow off the place during irrigation and storms, as well as the usual sub-surface flows, our tree nursery operations will, undoubtedly, be scrutinized from the non-point pollution our irrigation practices.

So, for several reasons, it is important to monitor irrigation on tree nurseries. First, and foremost, to assure the physiological well-being of the crop, and, secondly, to avoid water and fertilizer waste and pollution. With this perspective on the subject, let's see what western tree nurserymen are doing regarding irrigation control.

B. How are western tree nurserymen monitoring seedling irrigation?

Data Collection - Over the past couple of years, I have visited most of the tree nurseries in the west, so I had a vague idea of what was being done along these lines. Last winter, however, I began some graduate training at Colorado State University. One of the courses, concerning tree ecophysiology, included considerable emphasis on plant-water relations as well as a requirement for a term paper. It seemed like a good opportunity to examine, in a little detail, how western tree nurserymen are monitoring irrigation. Dr. Pat Reid, the course instructor, agreed to the idea. Consequently, I developed a questionnaire on the subject that covered both bare-root and container nurseries and mailed it to thirty - eight tree nurseries in the west. I would guess there are about 100 tree nurseries in the west, at present, based on a tabulation of 88 in 1975, and a high rate of growth (McDonald, 1977, op cit). If this is true, the mailing covered about forty percent of the industry. I received about thirty responses, so the sampling intensity is around thirty percent, I would like to take a minute here to thank all those who took the trouble to fill out the questionnaire and mail it back. I hope you find the results interesting.

The profiles of responding nurseries are provided iii figures 5 and 6. Figure 5 shows the ownership categories of the nurseries and the average size, in terms of annual production. Figure 6 provides the general size ranges the nurseries are in. Most of the bare-root nurseries are in the 2 and 10 million tree annual production range, Most container nurseries produce less than 500,000 trees per year.

FIGURE 5 – OWNERSHIP OF RESPONDING NURSERIES

	NUMBER	%
RESEARCH ORGANIZATION	2	8
PRIVATE	5	18
INDUSTRIAL	1	4
ASSOCIATION	1	4
STATE	9	33
FEDERAL	9	33
TOTALS	27	100

AVERAGE NURSERY SIZE: (ANNUAL PROD.)

BARE-ROOT – 6,100,000
CONTAINER – 594,000

FIGURE 6 - TYPE NURSERY AND SIZE OF PRODUCTION

SIZE ↓	BAREROOT		CONTAINER	
	NUMBER	%	NUMBER	%
0-500m	2	7%	13	81%
500m to 2,000m	3	23%	2	13%
2,000m 10,000m	7	54%	1	6%
10,000m plus	2	16%	0	0
TOTALS	14	—	16	—

The questionnaire included a number of questions about methods and guidelines used in irrigation monitoring at these nurseries. These questions were separated into portions for base-root seedling culture and containerized seedling culture. Question categories were included for the most common methods of irrigation monitoring in each case. I won't go into more detail about the questionnaire here because of time constraints. A blank copy is included in the appendix of this paper and will be in the proceedings.

Results and Analysis - As I said earlier, the data collected was divided into bare-root and containerized portions. Within each of these the data was broken down by "methods" and "guides or rules" sections. "Methods" refers to how the monitoring is physically done, "guides" refers to how observations are interpreted. Let's discuss the bare-root data first. Figure 7 shows the principle methods used and their relative frequency of use in the sampled nurseries. Note that 15 nurseries (40 percent) reported they based judgement about irrigation needs on visual and tactile observations. In a few cases, there was reference to looking at the plants, but primarily the dampness of the soil was what was observed. As far as guides or rules go regarding this method, two-thirds (66%) of the nurserymen said they observed "general soil dampness", a quarter (25%) said it was time to irrigate when a cohesive "ball of soil" could no longer be formed in the hand, and about 10 percent said if they did not see dampness on the soil surface in the early morning they irrigated.

Five (14%) of the bare-root nurseries employ a "pressure bomb," or, more precisely, a "pressure equilibration device." I think most of you are familiar with this method. For those of you who aren't, a needle, leaf, or shoot is sealed in a pressure chamber with the cut surface protruding, as shown in Figure 8. Pressure is applied to the shoot until xylem'sap appears at the cut surface. The pressure required to force water from the leaf cells into the xylem is regarded as equal to the water potential of the leaf cells. There was some variation in the responses regarding guides for using the pressure bomb. A couple of nurserymen said they began to irrigate at around -15 atmospheres tension and a couple at -5 atmospheres tension. What's the right answer? Well, it could be either one. With a pressure bomb the internal water stress of the plant is being measured. This varies during the day because of the normal lag of absorbtion behind transpiration. This variation is illustrated in Figure 9 (Evans and Reid, 1976). For conifer seedlings a general rule might be a maximum of -12 to -14 bars or atmospheres (1 atmosphere = .987 bars) if taken about noon. Pre-dawn is the best time to take xylem pressure potential readings, but there's little hope anyone in this group will do that! Also, such readings on very hot, sunny days or very cold, wet ones will not correlate well with trends established on average days. The rules used at any tree nursery regarding xylem potential maxima should be appropriate for the species being grown and your growth and development objectives. Many plant processes are affected by even mild water stresses, with cell growth the most sensitive (Hsaio et al., 1976). The question really becomes how minimal you can really deep internal plant tension and still be operationally practical, avoid disease and drainage problems, and fertilizer waste?

Returning to the monitoring methods used, four (11%) of the nurseries used tensiometers. Direct field measurements of the matric, or capillary,

FIGURE #7 - IRRIGATION MONITORING METHODS USED AT BAREROOT NURSERIES

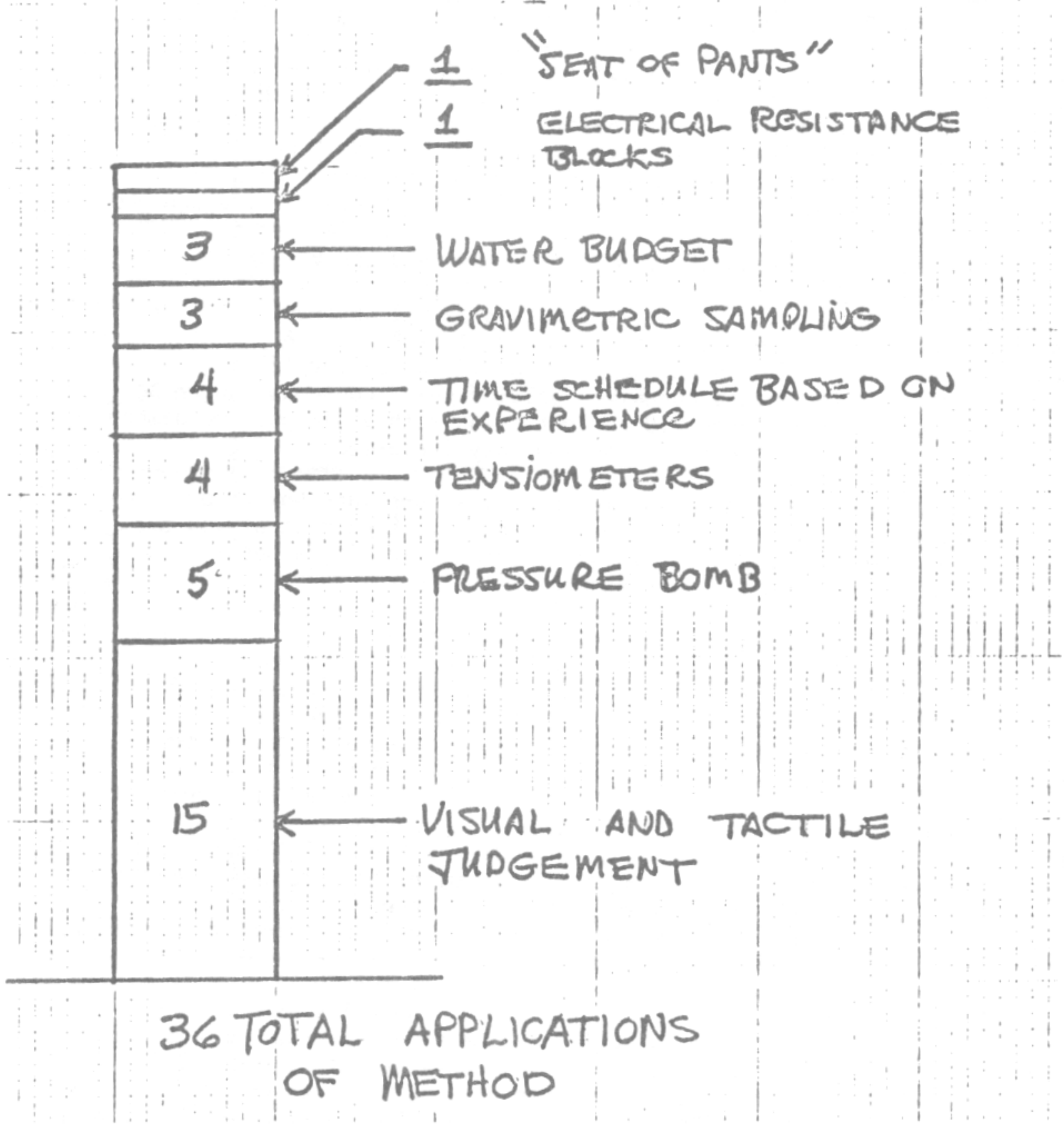
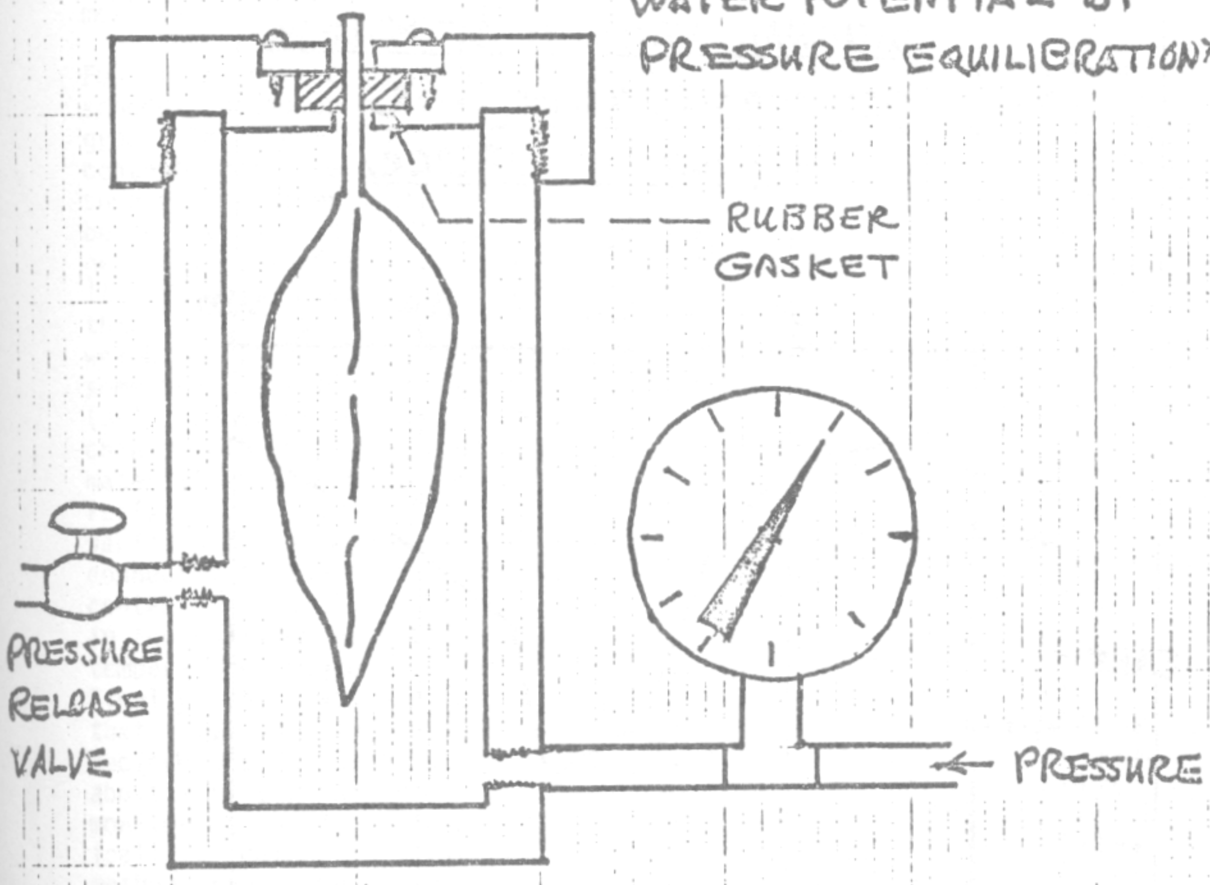


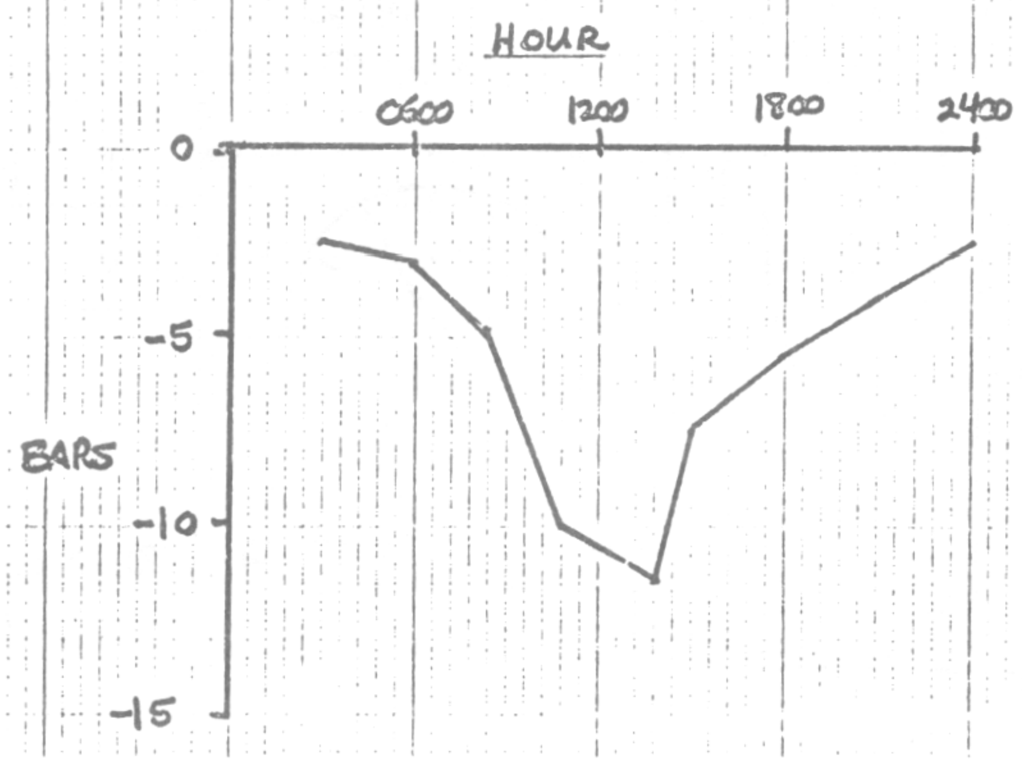
FIGURE 8 - CROSS SECTION OF A PRESSURE CHAMBER USED TO MEASURE WATER POTENTIAL BY PRESSURE EQUILIBRATION*



* FROM: KAUFMAN, 1962

FIGURE 9

DIURNAL PATTERN OF XYLEM PRESSURE POTENTIAL FOR ENGELMANN SPRUCE



potential of a soil can only be made with tensiometers. Figure 10 is a diagram of a tensiometer. They consist of a porous cup filled with water which is buried in the soil and connected to a manometer or vacuum gauge. The guage registers the pressure drop on the water in the porous cup which is in equilibrium with the matric potential of the water in the soil. It works well in wet soils, but when matric potential drops to -0.8 bar, air begins to enter the porous cup and the tensiometer becomes useless. The negative pressure units read from the tensiometer can be calibrated for a given soil for easy conversion to percentage water content. The instrument is quite useful for measuring soil water potentials where most rapid plant growth occurs.

Four (11%) of the questioned nurserymen relied on an irrigation time schedule based on experience at their nursery and with the species they grow. Three nurserymen (8%) gravimetrically ascertained the soil moisture content from time to time. This is the standard method used to calibrate some of the other methods. It's well to remember soil water content can be deceiving. The important thing is how hard the trees have to work to get water out of the soil. For soil moisture content to be meaningful, it must be related to soil matric potential. Gravimetric samples are weighed, then dried in an oven at about 105°C until the weight becomes constant. The weight difference is considered water. Three (8%) of the nurseries employed some type of water budgeting method (consumptive use). Only one nursery (3%) used electrical resistance blocks. The water content of these blocks changes with soil moisture content. The blocks are made of some porous material like gypsum, plaster of paris, or fiberglass. The electrical resistance to conductivity between two electrodes, buried in these blocks varies with the amount of water. The readings on the resistance bridge connected to these electrodes can be converted to an index of soil moisture content. Using these blocks presents some problems if there is much salt in the soil, or with temperature-induced changes in resistance when temperature changes. Figure 11 is a diagram of a resistance block. Finally, there was one fellow, probably the only honest one of the bunch, that said, although he observed the state of soil moisture, he mostly decided when to water by "flying by the seat of his pants". Like him, about half the nurserymen relied on two or more methods of moisture monitoring, as shown in Figure 12. A few used a second method periodically to calibrate their primary method. Of those who used only one method, the prime method was visual and tactile examination.

Since soil texture is important in irrigation, I also asked what type of soil texture the nurseries had. Figure 13 provides this information. As you would expect, most of the nurseries are on well-drained loams. Those on the heavier soils tend to be hardwood nurseries.

What about the nurseries growing containerized trees? Figure 14 shows the application of various irrigation monitoring methods at those responding to the questionnaire. Far and away the most frequently used method was visual and tactile examination of the medium in the container. The second most popular method was weighing the container to see how much the weight had decreased from a field or "container" capacity. If this weight had decreased more than a certain amount the containers are watered. This is a good method to prevent containers from drying out, especially when the trees are small. The pressure bomb was used some, but, of course, its use was limited to situations where there was enough foliage for sampling.

FIGURE 10: TENSIOMETER

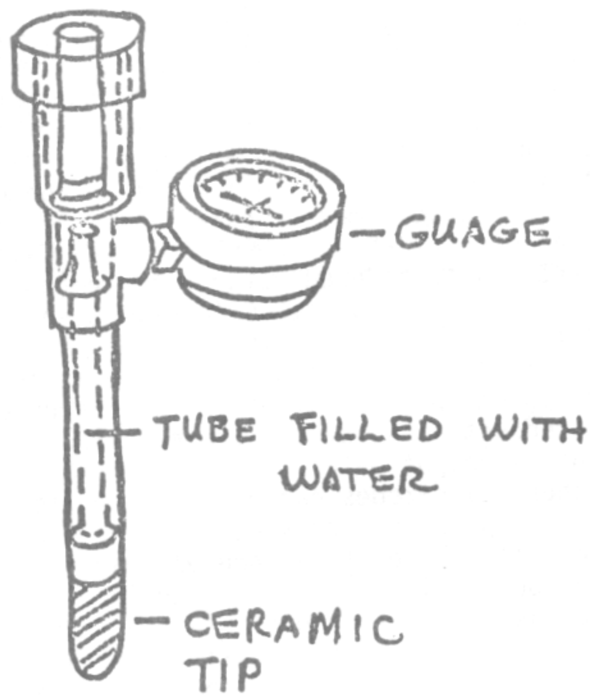
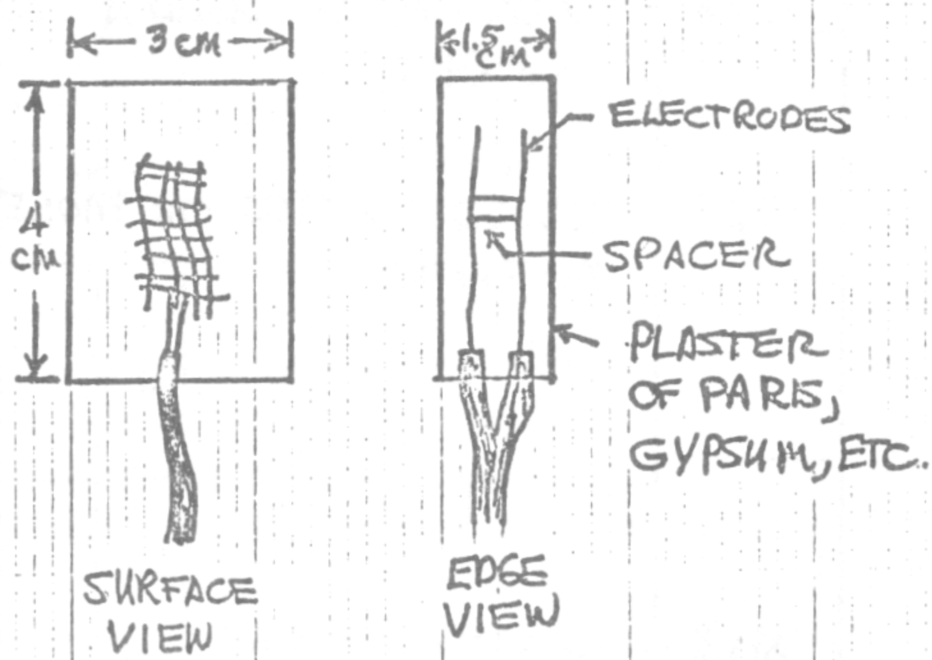


FIGURE 11: SURFACE AND EDGE VIEWS OF AN ELECTRICAL RESISTANCE BLOCK*



* FROM BOUYOUCOUS, 1954

FIGURE 12 – NURSERYMAN RELIANCE ON MONITERING METHODS (BAREROOT NURSERIES)

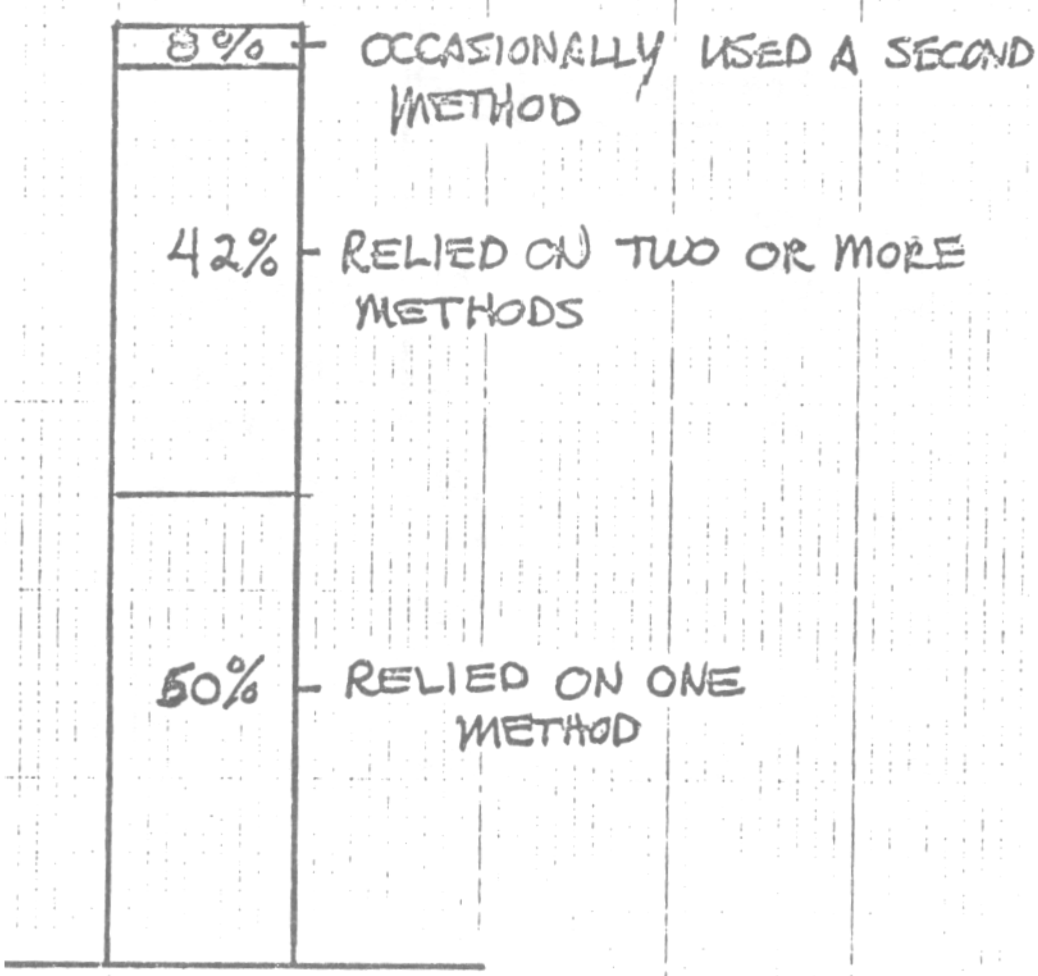


Figure 13 - NURSERY SOIL TEXTURES

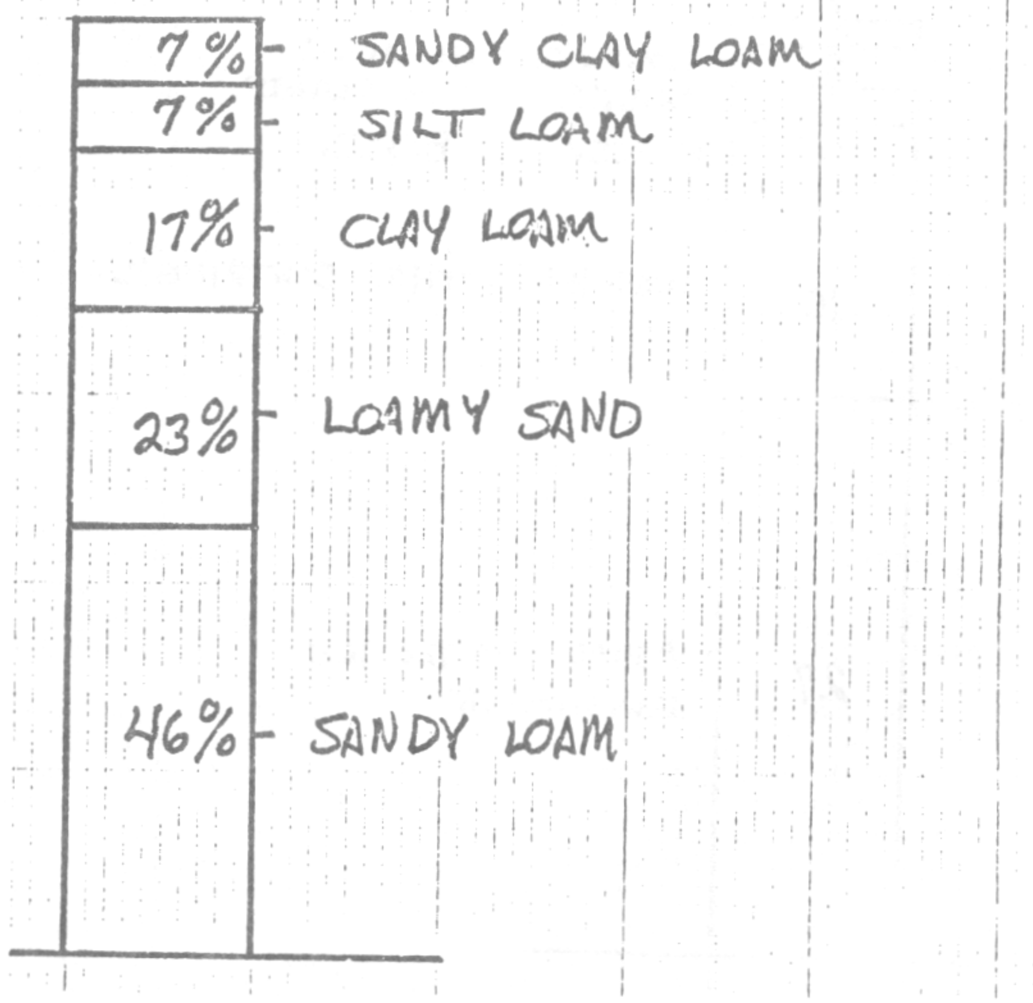
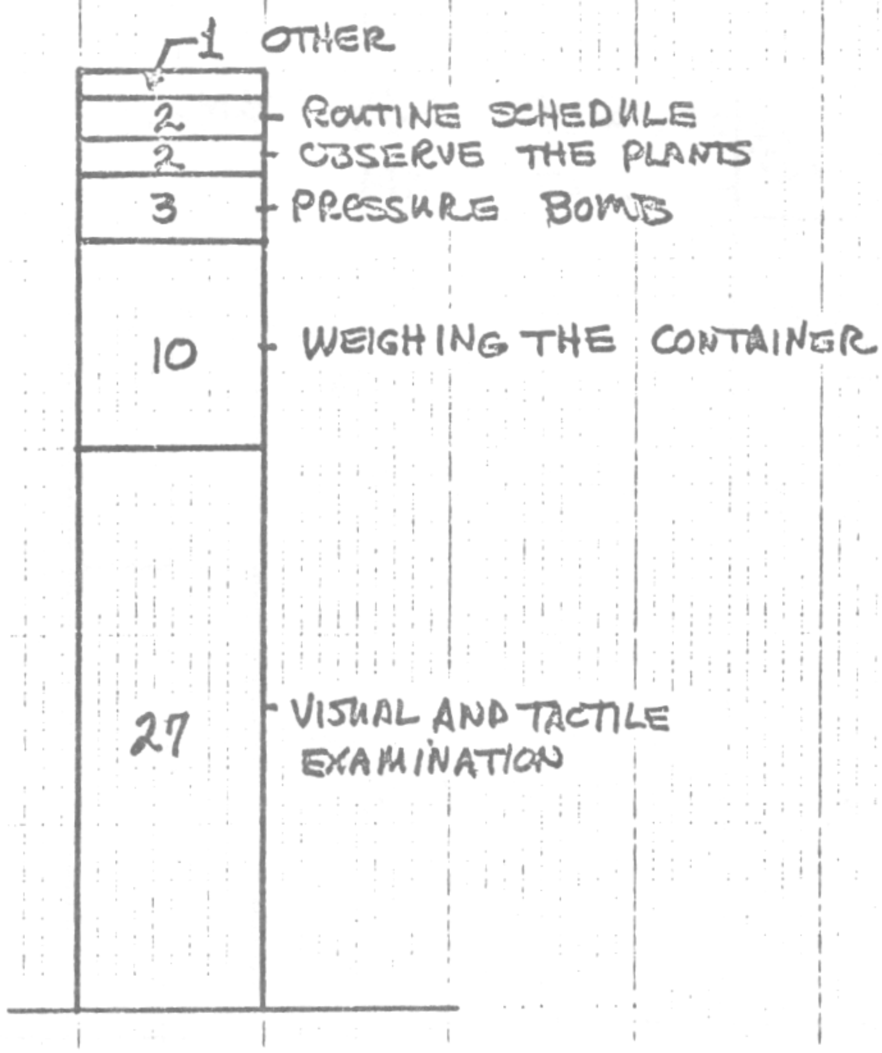


FIGURE 14: IRRIGATION MONITERING METHODS IN CONTAINER NURSERIES



Other methods such as irrigating on a routine schedule or "observing" the plants were used only in a couple of instances.

Only one-third of the container nurserymen correlated two or more monitoring methods. About half altered guidelines or methods as the crop grew in size. Eighty percent of those contacted were using a 1:1 peatvermiculite mixture as a growing medium. The rest were using mixtures of these components in similar blend.

Responses regarding rules or guidelines for irrigating were somewhat muddled as were bare-root responses on the same subject. Most decisions to irrigate involving visual and tactile observations were based on some subjective determination of the degree of dryness of the growing medium. A few hardwood nurserymen looked for wilt. Most using the weighing method irrigated when the weight of the moisture in the container decreases 10 to 31 percent. Those using the pressure bomb began irrigation at -12 to -20 atmospheres tension.

C. Is what's being done good enough?

However western tree nurserymen are monitoring irrigation requirements, what is being done works. This is evidenced by the production of around 300,000,000 tree seedlings each year in the west. The real question about these irrigation procedures is: are the methods and guides as good as they should be? Are we wasting water and fertilizer? Are we growing the best possible trees? Well, from this angle there's always room for improvement, so let's talk about what's being done and what might be done, in general terms.

As you see in the data, visual and tactile subjective observations and interpretations of soil or growing medium moisture conditions are, by a large margin, the most commonly used monitoring methods. I think this is just as it should be. There's no substitute for personal observation and judgement, based on experience, in nursery operations. The problems with the visual and tactile approach are easy to isolate, however:

1. Their Subjective Nature - Since the observations are not based on the indications -6-f a quantifiable mechanical or chemical procedure, there is always the problem of personal bias. This only means that no two people see things exactly alike. What may seem moist to one may seem dry to another. How precise can such observations be? One rule of thumb, put forth by some soil physicists, goes like this: "When the water in the soil glistens, the soil is wetter than field capacity. When it is possible to mold a ball of soil, it has a soil moisture tension of less than one (1) atmosphere. When the soil has a light color it is drier than the hygroscopic point. At the wilting point, the soil is crumbly, feels slightly moist, and has a dark color (though somewhat lighter than at one atmosphere tension)" (Kohnke, 1968). Another, more detailed version of this is provided in Figure 15. Anyway, the old idea of irrigation when you can no longer mold a ball of soil is not too bad, but it will certainly vary from soil to soil. Certainly it would be a good idea to calibrate your eye with some gravimetric samples or, better yet, a tensiometer. If you land on a strange nursery, you should do this at the start. For the container nurseryman, the first problem is getting to the part of the medium he wants to look at. Some containers can be opened, but most can't.

Figure 15

Availabe soil moisture remaining	Feel or appearance of soil			
	Coarse texture	Moderately coarse texture	Medium texture	Fine and very fine texture
0 to 25 percent.....	Dry, loose, single grained, flows through fingers.	Dry, loose, flows through fingers.	Powdery dry, sometimes slightly crusted by easily broken down into powdery condition.	Hard, baked, cracked, sometimes has loose crumbs on surface.
25 to 50 percent....	Appears to be dry, will not form a ball with pressure.[1]	Appears to be dry, will not form a ball.[1]	Somewhat crumbly but holds together from pressure.	Somewhat pliable, will ball under pressure.[1]
50 to 75 percent....	Appears to be dry, will not form a ball with pressure.	Tends to ball under pressure but seldom holds together.	Forms a ball somewhat plastic, will sometimes stick slightly with pressure.	Forms a ball, ribbons out between thumb and forefinger.
75 percent to field capacity (100 percent).	Tends to stick together slightly, sometimes forms a very weak ball under pressure.	Forms weak ball, breaks easily, will not stick.	Forms a ball, is very pliable, sticks readily if relatively high in clay.	Easily ribbons out between fingers, has slick feeling.
At field capacity	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.

[1]Ball is formed by squeezing a handful of soil very firmly.

* FROM SWANSON, 1978

Goodwin and Tinus recommend keeping the growing medium at, or near, field capacity (about -.3 bars) (Goodwin, 1975. Tinus, 1970). If water can't be squeezed-out of the mix, water. These guides are easy to say, but hard to do in practice. The idea is to keep the medium really moist without inhibiting sufficient aeration. The weighing method, discussed a little later, helps solve the problem, and supplements the educated eyeball and finger method.

2. Who does the visual-tactile check - The other major problem with the widely employed visual-tactile method concerns who does the checking? It's no secret that, in many cases, the nurseryman seldom gets to the field to do this checking, because of the press of other work. Is the fellow at your nursery who does it routinely really experienced, observant, and alert enough to methodically make the needed visual and tactile checks without supervision? For those of you who answer this question negatively, please wait till the end of this talk before leaving for home. If you answer yes, what are you going to do when you lose old reliable?

I've brought these points up to indicate a couple of the weaknesses of the visual-tactile method. It has some strength too: (1) there's no reliance on mechanical equipment that can fail or go out or adjustment, and (2) it means a man must go and look at the soil and the plants, consider the weather, and evaluate the need for irrigation. Abbott and Fitch reported in the Journal of Forestry last May that, of 99 nurseries checked nationwide, nearly all determine irrigating schedules by visual observations of soil dryness (Abbott and Fitch, 1977). Very few nurseries reported the use of instruments to measure soil moisture. All 99 of those nurseries produced bare-root seedlings, primarily. In summary regarding the visual and tactile approach to irrigation monitoring, no one should feel backward or archaic about using it; it is the standard of the industry. On the other hand, it is subjective and its precision is limited. Results can vary from person to person depending on experience and conscientiousness. I think it should always be accompanied by a mechanical method to (1) calibrate the irrigator's eye, (2) assure continuity if you lose your expert, and (3) provide a quantifiable measurement.

A number of nurseries, bare-root and container, are using the pressure bomb to measure internal plant water tension. Right now, it is probably the only practical field instrument for doing it. It does have a number of disadvantages: (1) time of day and the weather when the reading is taken are important, (2) it requires a careful, skilled operator, and (3) there must be enough foliage to get a sample. As was shown in Figure 4 earlier, illustrating the relationship between leaf, root, and soil water potentials, the leaf potential is variable during the day. The only times it really levels-out is at night and around noon. At night, or in the early morning, it is likely to equal the soil water potential.
At noon it is some higher value indicating the peak internal plant stress as absorbtion lags behind transpiration. At that point it can reach some threshold level that can serve as a signal to irrigate. What this level is can be debated. Scholander found sap pressures in a damp forest to range from -4 to -5 atmospheres, a figure that might be used as a startingpoint (Scholander et al., 1965). My guess, based on discussions with people who should know, would be -12 to -14 atmospheres at mid-day for hare-root seedlings. Figure 16 provides some data on loblolly pine seedling.. This may mean the data was generated under more humid conditions than are usual in the wet; similar to greenhouse humidities. Under such

FIGURE 16 - COMPARISON OF ROOT AND NEEDLE WATER POTENTIAL WITH DECREASING SOIL WATER POTENTIALS FOR LOBLOLLY PINE SEEDLINGS AT 11:30 AM.* (ATMOSPHERES)

SOIL WATER Ψ	ROOT WATER Ψ	LEAF WATER Ψ
-1	-4	-4
-4	-5	-9
-8	-8	-13
-12	-12	-14
-16	-16	-18

*FROM KAUFMAN, M.R., 1967. WATER RELATIONS OF PINE SEEDLINGS IN RELATION TO ROOT AND SHOOT GROWTH. PLANT PHYSIOL. 43: 281-288 conditions, it looks like -8 to -10 atmospheres might be a reasonable threshold. In any event, I suggest you talk to those with operational experience in conditions similar to yours. The pressure bomb does give direct readings of internal plane moisture stress, not inferences about plant stress from soil moisture contents or tensions. One other note of caution. There is a divergence between xylem pressure potentials, measured with the pressure bomb, and actual leaf water potentials in some hardwoods, but the two are generally close in conifers (Kaufman, 1968). In the container nursery, the pressure bomb should be a particularly valuable tool to prevent the trees from getting too dry; especially after they are larger and tree weight confounds the weighing procedure.

The methods of weighing the containers was used by a number of container nurseries and is a useful and practical method. The practice consists of weighing a container, seeded and filled with medium, then subtracting that weight from the weight of the same container with the medium at field capacity. The difference in weight is the water in the medium. When the wet weight declines to some predetermined percentage of the wet weight, the crop is irrigated. It is known the medium should be kept near field capacity.

A curve, for a given growing medium, to describe the relationship between medium. weight, as related to soil moisture content; and the tension required to pull the water out, can be developed by a soils lab using the pressure plate and pressure membrane techniques. The weighing procedure can be simplified by placing a representative container on a weighing device that electrically turns on the water when the weight of the container falls below a certain point (White and Shaw, 1966). Jerry Walters, who is at the Pacific Southwest Station in Hawaii, uses this method. Of course, as the trees get larger and heavier, the weight method becomes less accurate. I suggest phasing-in use of the pressure bomb, as the trees get larger.

Tensiometers were in use at a few of the base-root nurseries sampled. To properly use a tensiometer, you should have a soil moisture desorbtion curve for your nursery's soils, similar to the ones in Figure 17. These curves can be prepared by a soils lab; just be sure the sample(s) you send them are representative. The tensiometer is an excellent measuring instrument for moist soils, but is useful, as mentioned earlier, to only about -0.8 bars. However, note that in a sandy loom, as shown in figure 17, the range in soil moisture tension from 0 to -0.8 bars covers about 80 percent of the water available in the soil from 0 to -4 bars. The instrument really covers the prime irrigating range for nurseries. If you should want to grow drier than that, it will be necessary to use electrical resistance blocks or gravimetrical sampling. The resistance blocks are sensitive over a range from -0.5 to -15 bars of matric potential, so they work best in dry soil. The electrical resistance is easily calibrated against the available soil moisture content by the gravimetric method and plotting the resultant curve.

The gravimetric method (weighing, then drying and re-weighing the soil) normally takes too long for everyday use. It is very useful for calibration of other methods.

Tensiometers and electrical resistance blocks are generally too large to be useful in forest tree seedling containers.

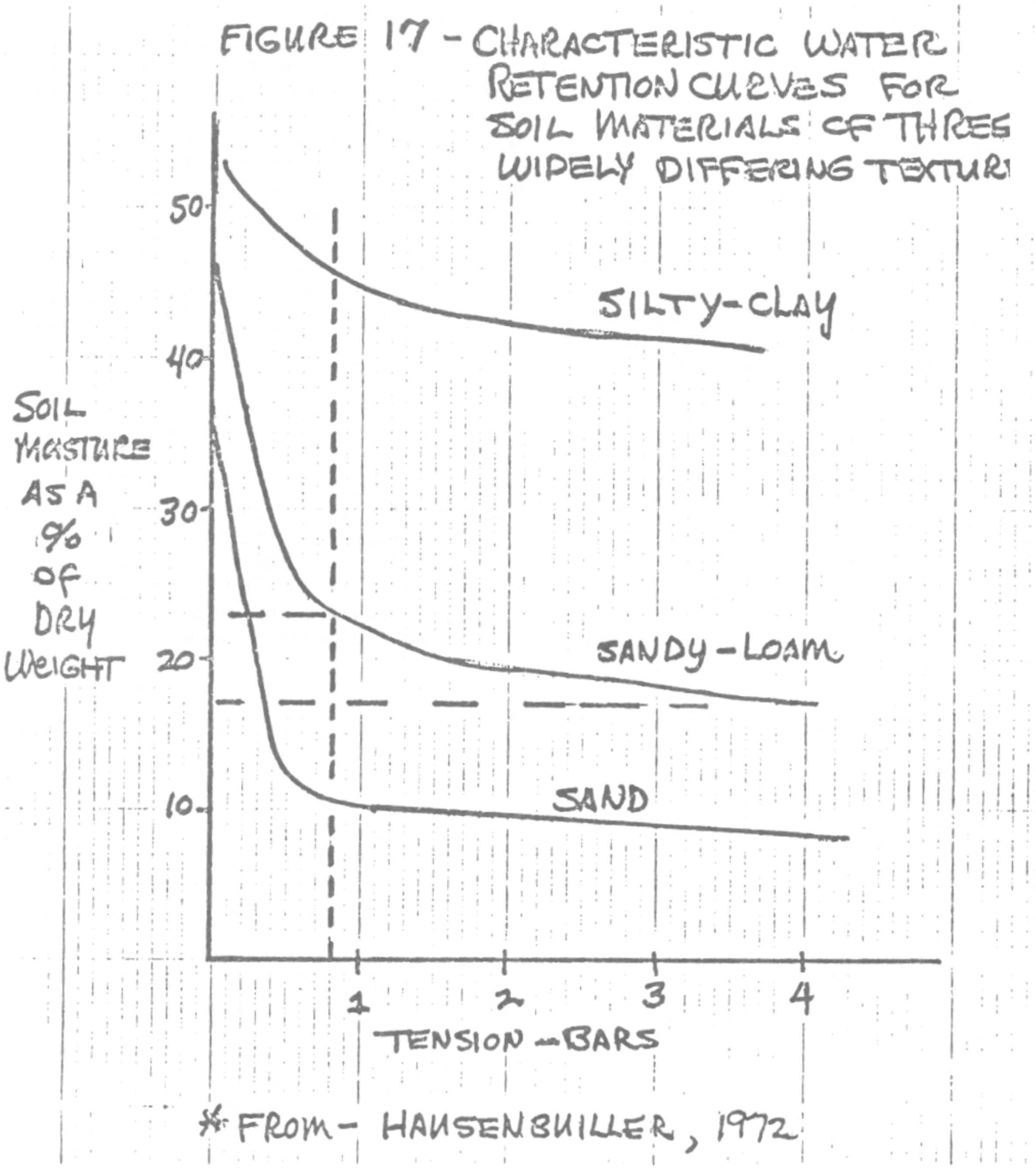


FIGURE 17 – CHARACTERISTIC WATER RETENTION CURVES FOR SOIL MATERIALS OF THREE WIDELY DIFFERING TEXTURES

A couple of nurseries reported they irrigated according to a "time schedule" or "water budget". The term "water budget" really refers to calculation of consumption use. This is the water lost to evaporation and transpiration. This varies with a great number of factors. The use rates for most agricultural crops have been worked-out, so good consumptive use indexes exist for most agricultural areas. For tree nurseries I see little opportunity for practical application of this method. We should he more precise. On the other hand, a time schedule based on observation and experience can be useful. It can work reasonably well if coordinated with frequent soil moisture inspections, but it can be wasteful in cool, cloudy weather. It really is only a poor substitute for proper observation and instrumentation.

<u>Summary</u>

In summary, for bare-root nurseries, visual and tactile soil moisture monitoring is hard to beat when coupled with experience, judgment, and conscientiousness. However, I do think every nursery should employ some kind of quantifiable method indicating available water in the soil or plant internal stress. This will aid the irrigator's judgment and calibrate his eyes and fingers. Tensiometers would be a good choice, or, perhaps electrical resistance blocks if drier conditions will be encountered. From the data gathered on the questionnaire, it looks a lot of you are doing something along these lines.

In the container nurseries, the weighing method is a good choice to supplement visual and tactile observations while the trees are small. Later, after the trees are larger, a switch to the pressure bomb would give the nurseryman considerable peace of mind.

In the questionnaire, I also asked a couple of accessory questions, One was: Is there a need for better irrigation guidelines? Ninety three (93%) of the respondents said yes. I also asked if there was a need for better irrigation monitoring equipment. About eighty percent (80%) said yes, both in bare-root and in container nurseries. I asked if a short course or workshop on the subject would be worthwhile. Again, about eighty-five (85%) said yes.

Well, when I got into this subject, I felt I was ignorant about many of its facets. Now that I have dug into it further, I'm sure of it. It appears to me the first thing to do is read up on the subject in the textbooks. A few good ones like Dr. Paul Kramer's book, are listed in the references of this paper. Probably the next thing to do is use the experts we have available to us. Soil physicists and agronomists at the state universities are usually willing to help. Frank Morby, from Medford, mentioned in his response that the Bureau of Reclamation may be willing to help. As far as a workshop goes, its a question expression of interest and determination of who would sponsor and direct it.

Its been a pleasure talking to you, and, again, I want to thank those of you who filled out and returned the questionnaire for me.

References Cited

Abbott, H.G., and D.S. Fitch. 1977. Forest nursery practices in the United States. Jour. For., Mar., pp. 141-145.

Blackman, W.C., C.G. Wills, and A.C. Ceinecker. 1977. PL 92-500 vs. pollution by irrigation return flow. Jour. Irrig. and Drainage Div., Proc. A.S.C.E., Vol. 103, No. IR-2, Dev. pp207-220.

Evans, A.K „ and C.P.P. Reid. 1976. Moisture stress patterns in mature Enjlemann spruce and quaking aspen during snowmelt in midsummer. In Steinhoff, H.W., and J.D. Ives (Eds.). Ecological impacts of snowpack augmentation in the San Juan mountains, Colorado. San Juan Ecology Project, Final Rpt., Colo. St. University Publ., Ft Collins.

Goodwin, O.C. 1975. Greenhouse container seedling production manual. No. Carolina For. Note No. 19, Raleigh-.

Hausenbuiller, R.L. 1972. Soil science, principles and practices. Wm. C. Brown Co., Dubuque, Iowa. 483 pp.

Hsaio, T.C. E. Acevedo, E. Fereres, and D.W. Henderson. 1976. Stress metabolism: water stress, growth, and asmatic adjustment. Phil. Trans. R. Soc., London. B. 273 (479-500).

Kaufman, M.R. 1968. Evaluation of the pressure chamber for estimating plant water potential of forest tree species. For. Sci.

Kohnle, H. 1968. Soil_ physics. McGraw-Hill, N.Y. 218 pp.

Kramer, P.J. 1969. Plant and soil water relationships; a modern synthesis. McGraw-Hill. N.Y., Second Ed,, 390 pp.

Leopold, C.A., and P.E. Kriedman. 1975. Plant growth and development. McGraw-Hill. N.Y., 452 pp.

lastalerz, J.W. 1877. The greenhouse environment. John Wiley and Sons. N.Y. 607 pp.

Scholander, P.F., st al. 1965. Sap pressure in vascular plants. Science 16(339).

Swanson, B.T. 1978. Guide for judainj how much moisture is available for crops. From Horticulture 321, Nursery Production and Management, Colo. St. Univer., Ft. Collings.

Tinus, R.W. 1970. Growiny_seedlinys in controlled_enci_ron ments. West For. Conserv. Assoc., West Refor. Coord. Comm. Proc., pp 34-37.

Toumey, J.W., and C.F. Korstian. 1142. Seedinc_ and_ulantinj in the practice of forestry. 3rd ed., John Wiley and Sons,-N.Y. 520 pp.

dhite, J.W., and M.D. Shaw. 1966. An automatic pot plant irrigation controller. Hort. Sct. 1P98-99.