USE OF THE PLANT MOISTURE STRESS METER

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Plant moisture stress (PMS) is a measure of the internal water status of plants. A simple device called a plant moisture stress meter can be used to measure moisture stress in seedlings and trees. The meter has also proved valuable for checking PMS of seedlings throughout lifting, sorting, packing, storing, transporting, and planting operations. Nursery managers can use these measurments to help determine watering schedules.

PLANT MOISTURE STRESS

The woody tissues of plants -- tracheids in conifers and vessels in hardwoods -- have two functions. They provide rigidity or strength and through them water and nutrients are conducted up the plant (Mirov 1967; Brown, Panshin, and Forsaith 1949; Salisbury and Ross 1978). Tracheids are small, short, pointed fibers which range in length from 3 to 8 mm (USDA 1974:2-4); vessels are generally longer. In pines, resin canals are intermingled with the tracheids.

The water columns in tracheids and vessels are under tension (stress) most of the time because a plant cannot take in water through its roots faster than it is transpired from stems and leaves. If these water columns are broken by cutting a branch or by decapitating a seedling, the water withdraws from the cut up and down the tracheids or vessels. The distance the water withdraws is proportional to the tension (stress) the water columns were under. Thus, if a plant is under slight moisture stress there is almost no withdrawal of the water columns. However, when the water columns are under tension, the water withdraws more than in plants under low moisture stress.

A PMS meter is a simple and accurate device which directly measures moisture stress in plants (Scholander et. al. 1965; Waring and Cleary 1967). It gives a reliable measurement of both the moisture stress the plant is under and the water potential of the plant at the time the sample is taken. Plants sampled in the predawn hours give a close approximation of soil moisture; therefore, with a PMS meter you can get a quick approximation of the soil moisture stress.

The PMS meter records moisture stress in bars of tension; one bar (or atmosphere) equals 14.7 pounds per square inch. For all practical purposes the PMS reading is always a negative value but the negative sign is rarely written when reporting the values -- it is always assumed. A higher number of bars indicates high stress and a lower number indicates lower stress.

Many seedling physiological functions are affected by PMS. For example, Brix (1979) showed that photosynthesis rates in Douglas-fir, western hemlock, white spruce, and lodgepole pine dropped to below 50 percent when the PMS exceeded 15 bars. Therefore, to keep seedlings in a desirable moisture regime may require watering them when the predawn readings exceed 5 bars. This, coupled with a mid-day light watering, could keep the plants vigorously growing throughout most of the day.

Excellent reviews and descriptions of water relationships in plants are found in Bonner and Galston (1959), Meyer et. al. (1960), Cleary (1970), Ritchie and Hinckley (1975), Kramer (1969), Levitt (1969:87-96), and Slatyer (1967). Nursery managers and silviculturists should read these books and papers so they have a better understanding of seedling growth and survival in relation to water requirements.

Moisture stress in seedlings can be determined by various methods, but the PMS meter is the "most foolproof [and] ... the best field tool for plant moisture stress monitoring" (McDonald and Running, 1979).

METHODS FOR MEASURING PMS

Moisture stress can be measured in needles, leaves, branches, or the tops of seedlings (minus the roots). The following techniques for measuring moisture stress in conifer seedlings can be modified for use on almost any plant.

After you have properly set up the PMS meter and gone through the required safety checks, you can begin measuring seedlings. Cut the tap root of the seedling at or below the first major lateral root. Carefully slice and scrape off the bark and phloem tissue up to the first green needles. This is best done by laying the seedling on a flat surface (such as your leg just above the knee) while you scrape. Do not sharply bend the stem; this could cause an embolism (air pocket in the water transporting tissue) which will result in an incorrect reading. After the entire xylem is exposed and smooth, sharpen the end of the root and shove it through the stopper (or use an insertion tool for small diameter samples or needle bundles).

Insert the stem through the stopper far enough to grasp the sharpened end; pull the sample until the base of the rubber stopper hits the bark tissue. Cut the stem off at a slight angle to the stem axis about 1.5 to 2.0 cm above the stopper. Use a single edge razor blade (unless you have an extremely sharp knife); make a single, smooth cut. Never make a second cut to get a smooth surface if your first cut was rough. Also, if the sample is improperly cut or sharply bent during preparation or insertion, discard it and start over. The reason for discarding the sample is that the water has already withdrawn from the first cut and the second cut eliminates part of the empty columns.

Seat the sample in the chamber lid, install the lid on the chamber, pressurize the chamber, and observe the cut end. Adjust the rate of gas flow into the chamber to about 1 bar every 15 seconds for plants under a stress of 1 to 14 bars and use a flow rate of 1 bar every 3 seconds for plants above 15 bars.

On pines, pitch-bubbles arise first from the cut surface; then a film of water appears which begins to "boil" if the gas flow continues to pressurize the chamber. Stop the gas flow and read the pressure gauge when the film of water forms on the cut surface. Practice is the only way to learn to differentiate between pitch and water bubbles on pines.

A sample of at least five seedlings is needed to get a reliable average measurement. If there is considerable variation, 10-15 samples are needed. A high variation may indicate you are sampling seedlings from different populations. For example, seedlings from different soil types or seedlings from recently watered versus dry sites will yield different PMS values.

Always work rapidly and prepare the samples in the shade (the shade from your body is sufficient). It should take less than one minute to prepare the sample and begin applying pressure.

To find out if the soil water supply is a limiting growth factor, measure the seedling or tree just before dawn. A daytime measurement does not give a true indication of the soil moisture stress; therefore, daytime readings should not be used to determine watering schedules. Take at least five samples from each of two or three parts of the bed. This proceedure will give you a good indication of the average PMS of the seedlings in the bed.

Measurement of established seedlings in plantations poses a special problem; silviculturists are reluctant to 'destructively sample' seedlings in the plantations. Thus, special study plots should be installed for this purpose. For example, one hundred or more seedlings planted at close spacing (0.5 meter) on north and south slopes could be destructively sampled periodically through the growing season. The effects of various treatments on moisture stress such as shading, mulching, planting dates, and watering could be studied.

In order to get accurate moisture stress readings, McDonald and Running (1979) give the following precautions for the use of a PMS meter:

1. Measure samples immediately after cutting (within 1 minute or sooner).

2. Increase chamber pressure slowly (ca. 3 psi/sec).

3. Keep sample size consistent (e.g., same diameter seedlings or twigs).

4. The cut end of the sample should not protrude more than 1 cm from the gasket.

Nursery managers and foresters can generate meaningful and valuable data with a PMS meter. However, if improper sampling techniques are used and if the samples are misread, doubtful or valueless data will result. For instance, if too few samples are taken a nursery manager may decide not to water when watering may be necessary. On the other hand, watering when not necessary can lead to root aeration problems that might stunt growth.

RECORDS

PMS measurements should be recorded and deposited in the nursery records or plantation files. The following should be recorded when applicable:

1. Operator and date.
2. Time of day at beginning and end of measurements.
3. Instrument used.

4. Climate.
   a. Cloud cover.
   b. Wind.
   c. Air temperature.
   d. Dry, wet bulb and relative humidity.
   e. Soil temperature (record the depth).
5. Seed source.
6. Where samples were taken from.
7. General comments.

TRAINING AND SAFETY

Do not allow your staff to operate the PMS meter unless they are trained by an experienced operator.

A PMS meter is commonly referred to as a "pressure bomb." Reference to the PMS meter as a "bomb" is discouraged as it evokes a pending disaster. Modern PMS meters are properly engineered for the high pressures used. However, as with all instruments using bottled gas under high pressure, you must carefully follow certain safety precautions.

Safety considerations are found in the manufacturer's PMS meter instruction sheet and have been further expanded by Cleary and Zaerr (1979). You should wear safety glasses through all these operations as it is possible liquids or plant parts could be ejected from the pressure chamber or hoses. In addition to the instructions provided by the manufacturer, the following checklist of operations is recommended:

SET-UP OF PMS METER

1. Visually check quick-disconnect fittings for dirt, insects, and other foreign objects. Clean if necessary. Check the valves on the tanks before connecting fittings. Never lubricate any of the gas line fittings.
2. Connect pressure gauge and hose to tank. Make certain fitting is completely seated.
3. Slowly open valve.
   a. Have gauge pointed away from you when opening valve.
   b. Flush out the hose with a burst of gas. Hold hose so it does not whip.
4. c. Close valve. NEVER force a valve and DO NOT over tighten. These valves are precision fittings that require only a snug turn to shut them off.
5. Remove lid from chamber.
6. Visually check lid and gasket.
7. Install lid with rubber stopper in the lid and close the chamber.
8. Check safety valve.
9. Open tank valve slowly and charge system. Listen for leaks.
10. Pressurize the chamber to about 10 atm and adjust rate valve.
11. Exhaust chamber.
12. Begin measurements.

SHUT DOWN OF PMS METER

1. Turn main valve (on tank) off.
2. Exhaust chamber.
3. Turn instrument valve to Chamber.
4. Open bleed valve or slowly open tank connection and drain pressure off the line.
5. When tank pressure gauge reads "0," disconnect couplings.

TO FILL SMALL TANK FROM LARGE TANK

1. After you have checked the valve and connectors, connect PMS meter's hose and pressure gauge to big tank.
2. Slowly open valve and tightly hold end of hose and flush line with short burst of gas.
3. Connect hose to small tank and check connectors for leaks.
4. Slowly open small tank valve.
5. Slowly open large tank valve to fill small tank.
6. When both tanks' pressure gauges are reading the same pressure, small tank is full.
7. Close large tank valve.
8. Close small tank valve.
9. Exhaust pressure from line with bleed valve or "hand nut."
10. Remove PMS meter's hose from large tank.

As mentioned earlier, the PMS meter is often referred to as a "pressure bomb." This is an unfortunate nickname, because modern machines bought from reputable manufacturers are properly engineered for high-pressure gas. However, when using high pressure gas, there is always the possibility that a gas line, coupling, or gauge could fail.

The following are potential hazards:

1. Accidentally cutting a finger when preparing a sample.
2. Ejecting gas, liquid, or plant material from the stopper while pressurizing the system. Wear safety glasses.
3. Hose whiplash from improperly connecting the quick couplings.
4. System failure due to rapidly opening valve on tank.
5. Mechanical failure of hoses, pipes, couplings, connectors, or chamber (very unlikely).

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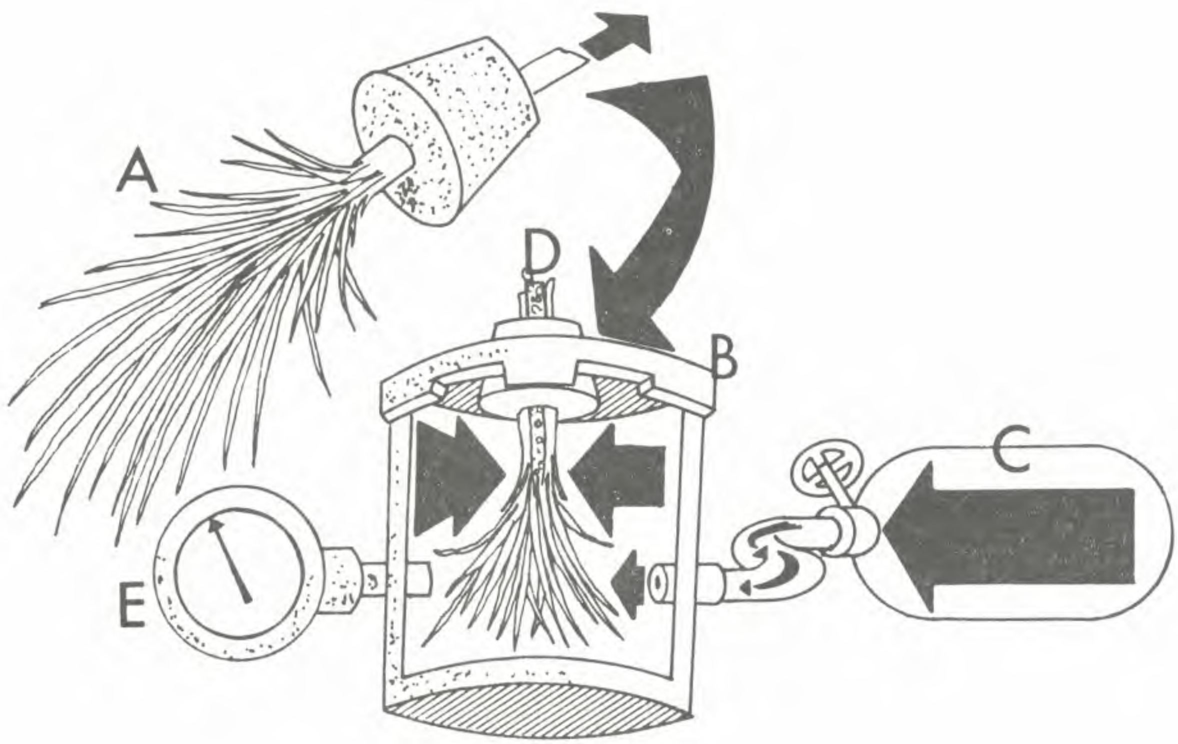

Figure 1 Measuring PMS with a pressure chamber. A, sample; B, pressure chamber; C, pressure tank; D, water forced back to cut surface; and E, pressure gauge.

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