RESPONSE OF A YELLOW-POPLAR SWAMP ECOTYPE TO SOIL MOISTURE

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Abstract. Pot testing of yellow-poplar may be a rapid method of identifying the variability of progeny from mature trees. One-year-old seedlings of a swamp ecotype of yellow-poplar (*Liriodendron tulipifera* L.) were grown in 37-liter cans under gravimetrically controlled soil moisture tensions for 7 weeks. Dry matter production of roots, stems and leaves increased as soil moisture increased. Root/shoot ratio did not vary. The number of leaves per seedling increased fourfold as soil moisture tension decreased from 15 atm to saturation. Differences between the diameters of the root collar and 30 cm above the root collar increased as soil moisture increased. Height growth during the 7 weeks of treatment increased as moisture increased. Seedlings grown under near saturated conditions lost their leaves 11 days after water was withheld. Seedlings grown at 0.1 and 15 atm retained their leaves 45 and 70 days respectively after water was withheld.

Additional keywords: Dry matter production, plant water potential, *Liriodendron tulipifera* L.

Large-scale progeny tests to assess the growth potential of hardwoods are time-consuming, difficult and expensive (Farmer et al. 1967, Kellison 1970, and Thor 1975). Attempts to assess variations in performance in different environments in field progeny tests greatly increase the costs. To overcome these limitations of progeny testing, we initiated a yellow-poplar (Liriodendron tulipifera L.) selection and testing program in 1970 which uses vegetative propagules of selected trees under defined environmental stresses. We feel that ramets grown under specified induced stresses, in large containers, can be used to estimate performance in different environments in relatively short studies. This procedure would save both money and time in field progeny tests.

The problem, of course, is to design a pot study whose results are truly indicative of long-term field performance. If we can do so, progeny from selected trees can be given this brief test before they are introduced into seed orchards. The relationship between moisture stress in the plant and soil will be a key variable. In previous tests we observed responses of upland yellow-poplars to various soil moisture regimes (Kormanik and Schultz, 1975). In the study described here we observed responses to moisture stress by the coastal plain ecotype of yellow-poplar described by Kellison (1970). Thus, we have now observed the full range in yellow-poplar responses and are prepared to specify some of the conditions for our pot tests.

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Soil moisture was selected for the test because of both the site requirements of this swamp ecotype (Kellison, 1970) and our continuing interest in identifying different hardwood clonal lines which perform well on a broad range of site conditions.

The soil moisture tensions were gravimetrically induced in pot soil mixtures. Although it is not possible to continuously maintain a given soil moisture tension in a potted soil mixture, we feel that growing seedlings under drying cycles to specific levels of soil moisture tensions before rewatering approximate the conditions found on natural sites.

METHODS

Yellow-poplar swamp ecotype seedlings were planted in 37-liter cans filled with a 1:1:1 mixture of a forest loam, sand and peat. The 1-0 seedlings had been grown from a mixed seedlot collected in the Dismal Swamp of Virginia. Large cans were used to provide sufficient rooting medium for root growth comparisons. The seedlings were planted in April and allowed 21/2 months to become established. During this time all pots were regularly watered and fertilized.

A soil moisture tension curve was developed for the soil mixture (Richards, 1965). Because of the site adaptability of the swamp ecotype soil moisture treatments were assigned at 15 and 0.1 atmospheres and near pot saturation. The levels corresponded to moisture contents of 3, 14 and 30 percent ovendry soil weight for the dry, moist and wet treatments. Moisture levels were gravimetrically controlled by allowing the soil to dry to the prescribed moisture level and resaturating it. The large pots minimized the need for frequent rewatering, thus subjecting seedlings to long periods of developing stress. As the study was carried out in a lathe house, all pots were covered with Styrofoam to exclude rain.

Moisture treatments were started in July and continued for 7 weeks. The graded seedlings were randomly assigned a moisture treatment and each treatment was replicated seven times. Each pot was randomly assigned a position in the lathe house. During the treatment period, saturated pots of the wet treatment were watered daily. The pots at the moist and dry treatments were watered approximately every 5 and 20 to 30 days, respectively. During the treatment period heights were measured weekly and all dead leaves were collected from each seedling and dried.

The day before harvesting, water potentials of trees at their maximum prescribed soil moisture treatment tensions were monitored by the pressure-bomb method (Scholander et al., 1965). Leaf water potentials were measured every two hours over a 16 hour period starting at 7 a.m. and ending 11 p.m. Both the day prior to and the day of monitoring were clear, warm and dry with temperatures around 26° C and relative humidities between 50 and 60 percent.

On the day of harvest, seedlings from five replications were removed from the pots, root collar diameter, diameter 30 cm above the root collar, total height

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[2] Seeds were collected by Robert D. Heeren, Project Leader, Hardwood Silviculture Management, Union Camp Corporation, Franklin, Virginia.

and number of leaves per seedling were measured. Dry weights of all seedling parts were obtained by drying the plant material at 72° C to constant weight.

Two of the seven replications of seedlings were allowed to dry until their leaves began to drop. Soil in these pots was saturated the day after water potential monitoring and the seedlings were harvested at the end of their leaf drop period.

Differences between treatment means for the measured growth variables were tested by analysis of variance and Duncan's Multiple Range Test (Steele and Torrie, 1960).

RESULTS AND DISCUSSION

Significant differences in the dry weights of the roots, stems and leaves were found between seedlings grown for only 7 weeks at the different moisture levels (Figure 1, Table 1). Total and root weights of the seedlings grown at the wet moisture level were four times greater than those of seedlings grown at the dry treatment. Total leaf weight over the same range showed a tenfold difference while the root/shoot ratio of the seedlings showed no significant differences. These data generally agree with those reported elsewhere (Pope and Madgwick, 1974, Kormanik and Schultz, 1975). Root weights of this swamp ecotype decreased as the soil became drier. Progeny of trees exhibiting this response probably would not be suitable for planting over a wide variety of sites. The ability to produce consistently large root systems over broad ranges of soil moisture conditions is an attribute required of seedlings used in broad scale planting programs. In a previous study, consistently large root systems were produced by clonal material selected from dry upland sites and typical yellow-poplar cove sites and grown in pots over a similar soil moisture range (Kormanik and Schultz 1975). In one upland and one cove clone, oven-dry root weights varied less than 6 grams between ramets grown under drying cycles of 1 atm and 15 atm of soil moisture tension. In three other clones ovendry root weights varied over 52 grams over the same soil moisture range. The swamp ecotype showed a 75 gram difference in ovendry root weights between seedlings grown at saturation and 15 atm of soil moisture tension. This ecotype is very sensitive to changes in soil moisture conditions. The large difference in root production response of these genetically different yellow-poplar strains suggests that root mass production ability under varying soil moisture regimes is an excellent selection criteria.

The large differences in leaf weight were the result of both new growth and senescence of old leaves. During the first dry-down cycle seedlings subjected to the dry treatment lost many of their large lower leaves. These leaves were subsequently replaced by fewer and generally smaller ones. The dry weights of the fallen leaves are reflected in the leaf weight for each treatment. The difference in the number of leaves per seedling showed large increases not only between the dry and moist treatment levels but also between the moist and wet levels (Table 2). This large increase in leaf number suggests again that this ecotype of yellow-poplar is very sensitive to soil moisture stress.

Table 1.--Means of yellow-poplar swamp ecotype growth variables for seedlings grown at soil moisture levels of 3, 14 and 30% ovendry weight

Soil Moisture Level %	Dry weights (grams)				Root/Shoot Ratio
	Total	Root	Stem	Leaf	
3 (dry)	60.0	24.1	29.4	6.5	0.65
14 (moist)	188.3	77.6	71.1	39.6	0.70
30 (wet)	240.5	98.8	81.9	59.8	0.71

Means grouped by lines are not significantly different at the 5% level. All other means are significantly different from one another at least at the 5% level.

In an attempt to identify whether the swamp ecotype responded to wet sites by increased butt swelling, the diameters at the root collar and 30 cm above the root collar were compared. As can be seen in Table 2 the difference between the two measures did vary significantly between the dry and moist soil moisture levels. Although no anatomical analyses were attempted the data would suggest that this swamp ecotype has a tendency to develop butt swell as is common to swamp species.

Height growth in the seven week period also varied between the dry and moist treatment levels but showed little change between the moist and wet levels (Table 2).

Table 2.--Means of yellow-poplar swamp ecotype growth variables grown at soil moisture levels of 3, 14 and 30% ovendry weight

Soil Moisture Level %	Number of Leaves per Seedling	Root collar diameter cm	Diameter 30 cm above root collar	Difference in diameter cm	Height growth in 7 wks. cm
3 (dry)	36	1.84	1.21	0.63	17.2
14 (moist)	95	2.59	1.48	1.11	32.8
30 (wet)	153	2.79	1.59	1.20	37.6

Means grouped by lines are not significantly different at the 5% level. All other means are significantly different from one another at least at the 5% level.

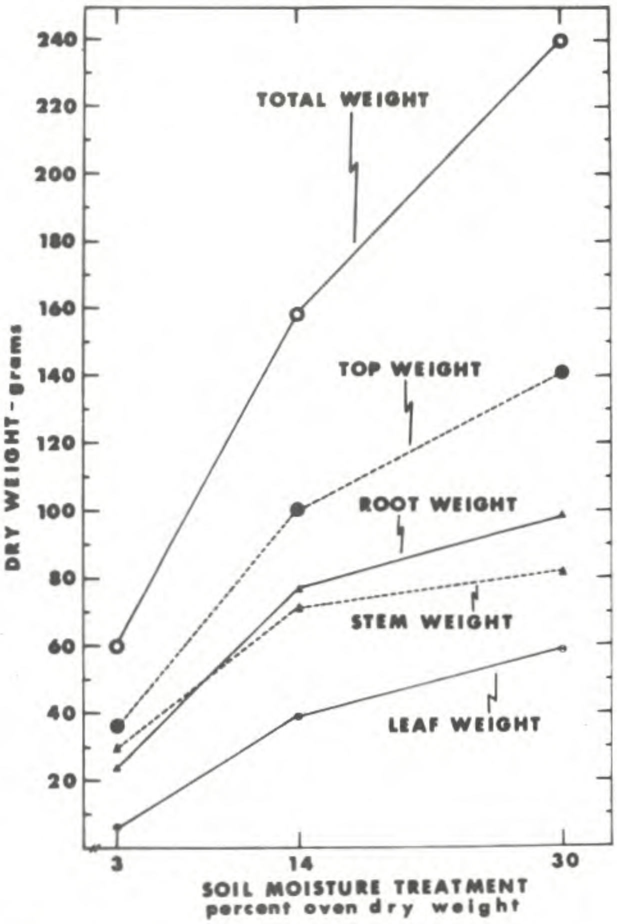

Fig. 1--Mean dry weights of yellow poplar seedlings grown at 3 soil moisture levels.

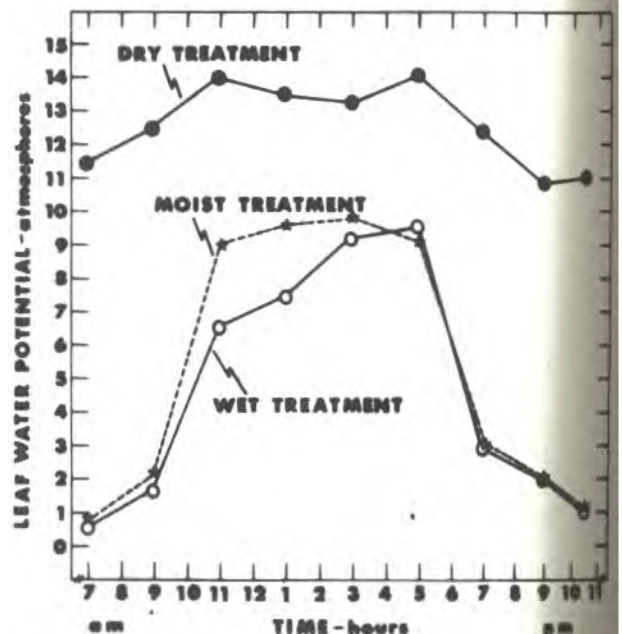

Fig. 2--Mean leaf water potentials for seedlings of yellow-poplar grown at 3 soil moisture levels.

The results of the internal moisture stress measurements (Figure 2) clearly show the direct effect of soil moisture deficit on the water status in the seedlings. Both the wet and moist treatments showed the daily transpirational lag which is responsible for midday moisture deficits. From Figure 2, the effect of available water on the transpirational lag can be clearly seen in the dry treatment. At the 3% soil moisture level the low available water resulted in almost no midday deficit, suggesting that these seedlings were growing near the threshold of permanent wilting. Thus, as these tensions developed in the dry-down cycle of the dry treatment, growth of the seedlings was severely curtailed. The relationship of a small root system and the high leaf-water potentials of trees grown under stress seem closely correlated. Seedlings with small root systems showed poor growth because they developed high leaf-water potentials during the day and were unable to regain sufficient turgor during the night.

Although not tested, it is assumed that the previously described dry upland clonal selections, with the consistently large root systems would have shown less leaf-moisture stress under the low soil moisture treatments. An extensive field comparison of leaf-water potentials outplanted swamp ecotype seedlings and dry site upland seedlings is presently under way. It may well be that the most direct method for comparing site adaptability is to compare leaf-water potentials of selected genotypes grown under controlled soil moisture conditions.

At the end of the investigation described above, two seedlings from each treatment were watered to saturation, set aside, and no further watering given them. Leaves on those trees grown previously under the wet treatment (daily watering) began to brown by the 8th day. By the 11th day, most of the leaves on these trees had died and the apical buds showed signs of desiccation. In contrast, those seedlings previously grown for seven weeks under both the moist and dry treatments showed little browning of leaves until 45 and 70 days, respectively. The trees at these two levels had previously lost their succulent leaves when the watering treatments were first initiated. Apparently, the leaves formed while growing under treatment stress were tolerant of renewed drying cycles as evidenced by the fact that these leaves were not shed during the duration of the investigation. Although these smaller, later developed leaves were tolerant to moisture stress, growth of these seedlings was significantly reduced.

The response of the swamp ecotype in this experiment and results from previous studies indicates that yellow-poplar genotypes can perform over a broad range of soil moisture site conditions. The moisture status of the soil and plant are one of the most critical limiting factors in seedling survival and tree growth. Thus selections for growth responses to soil moisture should be made. We feel that pot testing can provide a quick test of this adaptability.

For successful use of the pot testing method, the technique must be adapted to the species being tested. Earlier trials with smaller pots and thus limited soil volume led to some root binding with yellow-poplar. The more frequent watering of these smaller pots led to increased leaching and some nutrient deficiencies. With a fast growing species such as yellow-poplar, a pot size of at least 30 liters is necessary. This provides both the larger soil volume needed for accurate root mass comparisons and the longer drying cycles needed for extended stress on growth processes. At least three levels of treatment from soil saturation to 15 atmospheres of tension should be used in soil moisture tests. At present we feel that comparisons of ovendry weight of leaves, stems and roots are necessary to identify the distribution of biomass between selections. We also feel that a measure of internal water potential at critical stages in the drying cycle will provide a non-destructive selection parameter.

Pot testing can be used as an early selection method for identifying specific site adaptability between selections. It could be used not only for controlled soil moisture tests but for soil composition, fertility, temperature and other environmental factor tests. This pot pretesting could aid in providing early selection data for use in tree improvement programs.

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