LOBLOLLY SEEDLING GENOTYPIC XYLEM PRESSURE POTENTIAL RESPONSES TO CUTTING PRACTICES IN THE NURSERY

K.K. Kissee, R.J. Newton, and L. Carroll[1/]

Abstract.--Xylem pressure potential was reduced to a greater degree and at a greater rate immediately following undercutting and lateral root-pruning than occurred one day prior to these treatments. Early season undercutting and top-pruning appear to have no effect on the seedlings' response to later undercutting and lateral root-pruning treatments relative to water stress. However, genotypic differences in response to undercutting and lateral root-pruning relative to water stress were observed. Drought resistant seedlings wilted at a lower xylem pressure potential than did select seedlings when observed over the same time period.

Additional keywords: water stress, drought resistance, undercut, top-prune

Loblolly pine (Pinus taeda L.) is a major timber species in the southern United States and, in many cases, regeneration of this species involves the planting of nursery-grown, bareroot seedlings. To obtain the morphological characteristics most beneficial for survival and growth following outplanting, nursery managers plant seed from both select (or superior) and drought resistant families and, in addition, apply various cultural treatments to seedlings in the nursery. The cultural treatments most often performed include top-pruning, undercutting and lateral root-pruning. The physiological effects of nursery practices on select and drought resistant loblolly pine seedlings are not well understood and nursery managers desire more information in this area in order to synchronize the cultural treatments to best benefit the seedlings (Johnson and others 1982). The purpose of this study was to determine if undercutting and/or top-pruning had any long-term effects on diurnal xylem pressure potential on select and drought resistant loblolly pine seedlings.

MATERIALS AND METHODS

The study was conducted in the Champion International Corporation Nursery near Livingston, TX during the summer and fall of 1984. In late April, eight nursery seedbeds 158 m long were sown with loblolly pine seed from trees selected for superior growth. Eight additional seedbeds were sown with seed from trees selected for drought resistance. Approximately 12 weeks later the seedlings in four of the seedbeds of each genotype were wrenched and undercut and two weeks later (14 weeks following planting) the seedlings in the

---

1/ Graduate Assistant and Associate Professor, Department of Forest Science and the Texas Agricultural Experiment Station, Texas A & M University, College Station, TX; and Nursery Supervisor, Champion International Corporation, Livingston, TX.

remaining eight beds were top-pruned. The seedlings in all the study beds were undercut on September 12 and lateral root-pruned on October 17.

Xylem pressure potentials were measured from stems using the Scholander pressure chamber (Scholander and others 1965). On September 11 (9-11) and October 16 (10-16), the days prior to cutting, diurnal xylem pressure potential curves were generated by measuring xylem pressure potential every three hours beginning at 5:00 am and ending when the plants had begun to recover from the maximum deficit for the day. Three seedlings from each study seedbed were selected at random for each time period (12 seedlings per treatment, 48 seedlings total). Whole seedlings were excavated, placed in air tight bags and placed on ice until measurements were taken. The seedlings were cut at the root collar just prior to being placed in the pressure chamber. Measurements were begun as soon as all the seedlings from one time period had been collected.

On September 12 (9-12) and October 17 (10-17), xylem pressure potential was determined at pre-dawn (5:00 am) as described above. The seedlings were undercut or laterally root-pruned in the morning and then seedlings were excavated every 0.5 to 1.5 hours until wilting had occurred. Sample seedlings were then irrigated for 0.5 hour and one additional set of samples was taken to demonstrate that recovery had begun. Seedlings from all the time periods following cutting were placed in air-tight bags and then placed on ice until xylem pressure potential could be measured. These measurements were performed the evening on the day of cutting.

Maximum deficit in xylem pressure potential was determined by subtracting the pre-dawn xylem pressure potential from the lowest xylem pressure potential measurement. Paired t-tests were used to determine statistical differences between treatments using pre-dawn (base) xylem pressure potential and the maximum deficit in xylem pressure potential.

RESULTS

Figure 1 shows the diurnal xylem pressure potential mean values and curves that were generated on September 11 and 12, before and after the second undercut. Figure 2 shows diurnal mean values and curves generated on October 16 and 17, before and after lateral root pruning. These curves show that immediately following cutting xylem pressure potential decreased rapidly and then continued to decrease slowly until wilting occurred. The change in the rate of decrease in xylem pressure potential probably occurs when the stomata close and transpiration decreases. The curves also demonstrate that seedlings recovery begins quickly upon re-watering.

The base xylem pressure potential was not significantly different between September 11 and 12 and October 16 (Table 1). However, the base xylem pressure potential was higher on October 17 than on the other days. This was due to irrigation late on October 16. Base xylem pressure potential was not affected by genotype (Table 2) or early cutting treatments (Table 3).

The maximum deficit in xylem pressure potential was significantly greater on September 11 than on September 12 and was significantly greater on October 17 than on October 16 (Table 1). These results suggest that cutting of the roots will affect the water relations of loblolly pine seedlings immediately following the cut.

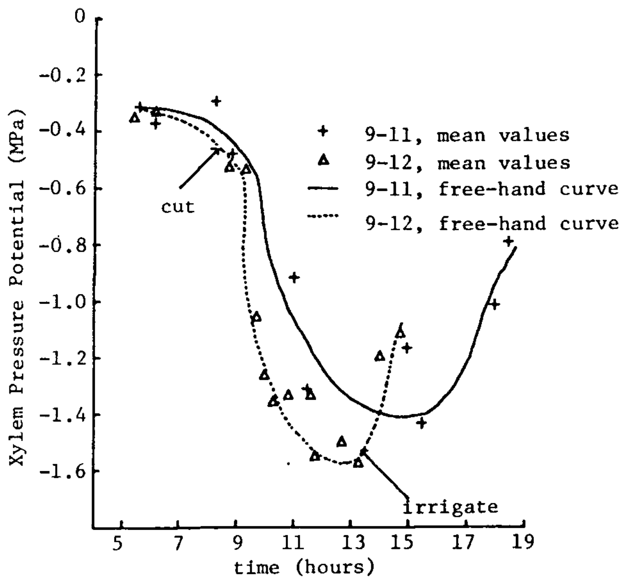

Figure 1.--Diurnal xylem pressure potential curves the day prior to undercutting and the day cutting was performed.

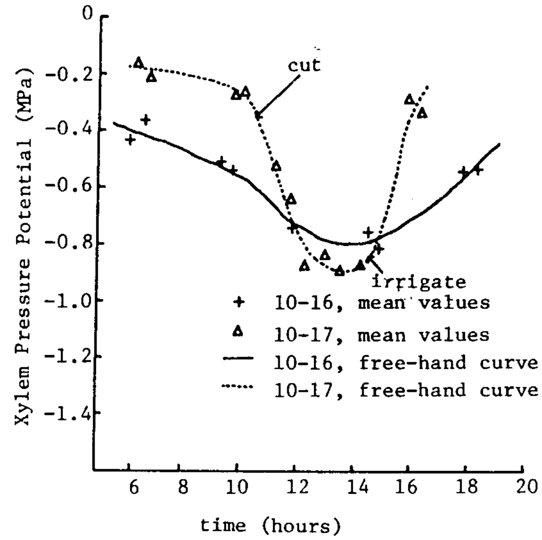

Figure 2.--Diurnal xylem pressure potential curves the day prior to lateral root-pruning and the day cutting was performed.

Table 1.--Base xylem pressure potential (BXPP) and maximum deficit in xylem pressure potential (MDXPP) determined the day prior to cutting (9-11, 10-16) and the day cutting was performed (9-12, 10-17).

	9-11	9-12	10-16	10-17
	MPa			
BXPP	-0.35a*	-0.34a	-0.40a	-0.12b
MDXPP	0.98b	1.31a	0.44c	0.81b

*different letters within a row designate significant differences at the 0.05 level of significance using paired t-test.

The maximum deficit in xylem pressure potential on September 11 was also greater than on October 16 and the deficit on September 12 was greater than on October 17. These data reflect seasonal fluctuations in water use. Wilting occurred following both types of root cutting; however, seedlings that were undercut wilted at a greater maximum deficit than did lateral root-pruned seedlings. This could be attributed to the ability of the plant to withstand greater water stress earlier in the year or it may be that the late undercut (September 12) reduced the ability of the plants to withstand future water stress.

Table 2.--Base xylem pressure potential (BXPP) and maximum deficit in xylem pressure potential (MDXPP) determined the day prior to cutting (9-11, 10-16) and the day cutting was performed for drought resistant and select loblolly pine seedlings.

	9-11		9-12		10-16		10-17	
	BXPP	MDXPP	BXPP	MDXPP	BXPP	MDXPP	BXPP	MDXPP
	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - MPa - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -
Drought	-0.38a*	1.08a	-0.33a	1.43a	-0.36a	0.49a	-0.21a	0.80a
Select	-0.31a	0.88b	-0.35a	1.20b	-0.44a	0.39b	-0.16a	0.82a

*different letters within a column designate significant differences at the 0.05 level of significance using paired t-tests.

Table 3.--Base xylem pressure potential (BXPP) and maximum deficit in xylem pressure potential (MDXPP) determined the day prior to cutting (9-11, 10-16) and the day late undercutting or lateral root-pruning was performed for seedlings that were top-pruned or undercut early in the growing season.

	9-11		9-12		10-16		10-17	
	BXPP	MDXPP	BXPP	MDXPP	BXPP	MDXPP	BXPP	MDXPP
	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - MPa - -	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -
Undercut	-0.34a*	0.99a	-0.33a	1.25a	-0.44a	0.45a	-0.18a	0.85a
Top-prune	-0.35a	0.96a	-0.36a	1.37a	-0.37a	0.43a	-0.19a	0.77a

*different letters within a column designate significant differences at the 0.05 level of significance using paired t-tests.

The maximum deficit in xylem pressure potential was greater for drought resistant than for select seedlings on all day considered except October 17 (Table 2). Perhaps drought resistant seedlings are able to withstand large decreases in xylem pressure potential before avoidance mechanisms take over and transpiration decreases. On October 17, the deficit was not significantly different between the two genotypes. This may be due to normal changes in the seedlings occurring late in the growing season, perhaps drought resistant seedlings are more susceptable to water stress late in the growing season.

The early treatments (undercut and top-prune) had no effect on the maximum deficit in xylem pressure potential on any of the four days under consideration (Table 3). This suggests that early treatments do not affect the water relations of the plants for long time periods.

DISCUSSION

Shortly following root cutting, xylem pressure potential in the stems of loblolly pine seedlings begins to decrease rapidly. This period of rapid decline is followed by a period during which xylem pressure potential continues to decrease but at a lower rate until wilting occurs. These results suggest that the seedlings maintained relatively high transpiration rates and high resistance to water uptake in the roots immediately following cutting. The root resistance seems to have remained high; however, the stomata probably closed shortly after the stress was applied, reducing transpiration rates, which resulted in a change in the rate of decrease in xylem pressure potential. Since xylem pressure potential increased rapidly following re-watering, the resistance to water uptake in the roots was probably decreased during this period while the stomata remained closed.

The maximum deficit in xylem pressure potential apparently changes throughout the growing season. In September, the maximum deficit was 0.98 MPa while in October, the deficit was 0.44 MPa. Perhaps later in the year transpiration rates have decreased and the plant maintains higher xylem pressure potential throughout the day than earlier in the growing season. Wilting occurred at 1.31 MPa in September and 0.81 MPa in October. This suggests that late in the year plants are unable to maintain turgor during high water stress conditions. This may be due to higher root resistance to water uptake because of suberization of roots prior to the onset of winter. Since the seedlings had been undercut twice when they were subjected to the lateral root-pruning treatment in October, perhaps the late undercutting reduced the ability of the seedlings to adjust to future stress; however this seems unlikely since the earlier cutting treatments had no long term effects.

Drought resistant seedlings had a lower maximum deficit in xylem pressure potential than select seedlings on all days considered except on October 17. This suggests that drought resistant seedlings were able to maintain open stomata under greater degrees of water stress than were select seedlings. On October 17 there was no significant difference in the maximum deficit in xylem pressure potential between select and drought resistant seedlings. Perhaps late in the season, the seedlings of both genotypes were "hardening-off" and neither could maintain turgor at low water potentials. This would not be unlikely, since the parent trees would not be subjected to water stress late in the growing season and there would be no reason for them to have become adapted to this condition.

Undercutting and top-pruning early in the growing season had no effect on the maximum deficit in xylem pressure potential before or after later undercutting or lateral root-pruning. This might be expected since all the seedlings had been subjected to one or the other type of cutting stress. Perhaps if some seedlings had not been cut early in the season, they would not have been able to adapt to the stress as well as those that did. While it has been suggested that top-pruning is detrimental to loblolly pine seedlings (Barnett and others 1984, Hennessey and Dougherty 1984), it does not seem to affect the ability of the seedlings to respond to water stress following cutting later in the season.

CONCLUSIONS

Based on diurnal fluctuations in xylem pressure potential, top-pruning loblolly pine seedlings early in the growing season does not affect the manner in which seedlings respond relative to water relations later in the season than does undercutting seedlings. Drought resistant seedlings reach a lower deficit than select seedlings during the same time period, suggesting that drought resistant seedlings transpire at lower water potentials than do select seedlings. Late in the growing season, loblolly pine seedlings are not able to maintain transpiration at as great a water deficit as earlier in the season. This study did not determine for what time period water relations are affected following cutting. Cutting practices may also affect osmotic adjustment, photosynthesis, and carbohydrate metabolism. More research is needed concerning the physiological effects of nursery cultural practices on the physiology of loblolly pine seedlings.

LITERATURE CITED

Barnett, J.P., T.E. Campbell, and P.M. Dougherty. 1984. Seedling establishment -- artificial methods. In Proceedings of the symposium on the loblolly pine ecosystem. Western Region. March 20-22, 1984. Jackson, MS.

Hennessey, T.C., and P.M. Dougherty. 1984. Characterization of the internal water relations of loblolly pine seedlings in response to nursery cultural treatments: Implications for reforestation success. In Seedling physiology and reforestation success (M.L. Duryea and G.N. Brown, eds), p 225-243. Martinus Nyhoff/DR W. Junk Publishers, Dordrecht, The Netherlands.

Johnson, J.D., D.L. Bramlett, R.M. Burns, T.A, Dierauf, S.E. McDonald, and J.M. Stone. 1982. Pine seedling production in the south: A problem analysis. Sch For Wdlf Resourc, Virginia Polytechnic Institute and State University. Publ No. FWS-82.

Scholander, P.F., H.T. Hammel, E.D. Bradstreet, and E.A. Hemmingsen. 1965. Sap pressure in vascular plants. Science 148: 339-346.