WATER RELATIONS AND GAS EXCHANGE OF LOBLOLLY PINE SEEDLINGS UNDER DIFFERENT CULTURAL PRACTICES ON POORLY DRAINED SITES IN ARKANSAS

Mohd S. Rahman, Michael G. Messina, and Richard F. Fisher[1]

Abstract—Substantial forest acreage in the south-central U.S. is seasonally water-logged due to an underlying fragipan. Severely restricted drainage in the non-growing season leads to a reduced subsoil zone, which restricts root respiration. The same sites may also be subjected to summer drought. These climatic and edaphic problems may result in low seedling survival and reduced growth. To address these issues, we established ten research sites in southern Arkansas. Six sites in an incomplete factorial design were established in 1999, each with four bedded treatments: 1) control (no subsequent treatment), 2) fertilized during the first two years after planting, 3) complete weed control until canopy closure, and 4) complete weed control and continuous fertilization as per foliar analysis; and two non-bedded treatments: 1) control and 2) fertilization and complete weed control in the first year. Water relations data (diurnal water potential, stomatal conductance, and transpiration) and net CO_2 assimilation were collected during the 1999 and 2000 growing seasons. This paper will include data from the 2000 growing season. Results to date show improved water relations and gas exchange from intensive culture.

INTRODUCTION

There is a substantial acreage of seasonally wet, somewhat poorly drained sites in the Western Gulf. These sites experience standing water through much of the winter due to an underlying fragipan. This results in an anaerobic atmosphere for roots and subsequent poor seedling survival. The condition may also assist in nutrient leaching loss to the subsoil fragipan. The sites also experience summer drought which may contribute to reduced growth. Mechanical site preparation and early cultural treatment can affect pine growth on flatwoods (Lauer and Glover 1998, Shiver and Rheney 1990). Therefore, our research objectives was to test the efficacy of several cultural practices for ameliorating adverse site conditions.

MATERIALS AND METHODS

The research was designed to investigate three treatment factors: mechanical site preparation, fertilization and chemical vegetation control. Treatments tested in an incomplete factorial design were: two levels of mechanical site preparation (no preparation, and bedded and ripped), three levels of chemical vegetation control (no control and chemical control during the first year, and complete vegetation control until canopy closure), and three levels of fertilization (none, fertilization during the first year, and continuous fertilization until desired nutrient foliar concentration was achieved). Six of the 18 possible treatment combinations were established at each of six sites in southern Arkansas:

— Bedding control (BED-N)
— Bedding + complete chemical vegetation control (BED-CV)
— Bedding + continuous fertilization (BED-F)
— Bedding + complete chemical vegetation control + continuous fertilization (BED-CVF)
— Flatplanting control (FP-N)
— Flatplanting + chemical vegetation control in the first year + fertilization in the first year (FP-VF)

Spacing was uniform in any site, but varied among sites to 1.8-2.4 meters between trees on the row/bed and 3.3-4.0 meters between rows/beds. All sites were planted with loblolly pine (*Pinus taeda* L.) in January 1999. A whole plot was 13 rows X 18 trees, of which the central 7 rows X 10 trees were used for measurement giving a three-row buffer on each side and a four-tree buffer on each end. The whole plot covered an area of about 0.40 hectare.

Mechanical Site Preparation

All sites were initially prepared by shearing and burning, followed by a combination plow with a ripping tine and bedding disks, except for the non-bedded plots.

Fertilization

Fertilized plots were treated in a broadcast manner with 280 kilograms per hectare of diammonium phosphate, 140 kilograms per hectare of potassium chloride, and 112

[1]Graduate Student, Professor,Department of Forest Science, Texas A&M University, College Station, TX 77843-2135; Temple-Inland Forest Products Corporation, P.O. Drawer N, Diboll, TX 7594, respectively.

Citation for proceedings: Outcalt, Kenneth W., ed. 2002. Proceedings of the eleventh biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–48. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 622 p.

Table 1—Soil volumetric moisture content (cm³ cm⁻³) of six treatments, bedded (BED) and flatplanted (FP), treated with fertilizer alone (F), complete vegetation control (CV), complete vegetation control and continuous fertilization (CVF), vegetation control and fertilization during year of planting (VF), and control or check (N). Numbers followed by the same letter within columns are not statistically different (alpha = 0.05)

Site Prep	Treatment	June 8	August 18
FP	N	6.9 c	4.9 c
FP	VF	9.8 a	8.0 a
BED	N	6.7 c	4.1 d
BED	F	6.2 c	4.1 d
BED	CV	10.3 a	7.1 b
BED	CVF	8.2 b	5.5 c

kilograms per hectare of a mix of calcium, magnesium, boron, and manganese.

Chemical Vegetation Control

All plots to be treated with herbicide were sprayed with glyphosate and sulfometuron in 1999 and imazapyr and sulfometuron in 2000. Herbicides were applied with backpack sprayers at recommended rates. To ensure a complete vegetation control, plots were resprayed as necessary.

Data Collection

Data were collected throughout the 1999 and 2000 growing seasons. Volumetric soil moisture content was determined using time-domain reflectometry during sampling sessions for water relations at three different locations within each plot at all measurement hours. Diurnal water potential data were collected using a pressure bomb apparatus on three seedlings per plot at 0900, 1200, 1500 and 1800 hours. The same seedlings were used for all measurement hours and also for other measurements such as stomatal conductance, transpiration and vapor pressure deficit, which were measured using a LiCor 6200. In addition, net CO_2 assimilation rate, intercellular CO_2 concentration and incoming irradiance were measured using a LiCor 6250 for the same seedlings concurrent with the other measurements.

RESULTS AND DISCUSSION

Data will be presented from one of the six sites measured, that being located near Crossett. The soil series there is a Calloway silt loam, a fine-silty, mixed, active, thermic Aquic Fragiudalf. The depth of the subsoil fragipan ranges between 50 and 60 centimeters. Data were collected on two 2000 sampling sessions, once at the beginning of the summer (June 8) and again at the end of the summer (August 18). Air temperatures, averaged throughout the day, for these two sampling sessions were 34.8 and 35.1 °C, respectively. Cumulative precipitation for the 14 days preceding June 8 was 6.68 centimeters of which 5.41 centimeters fell in the previous seven days. There was no

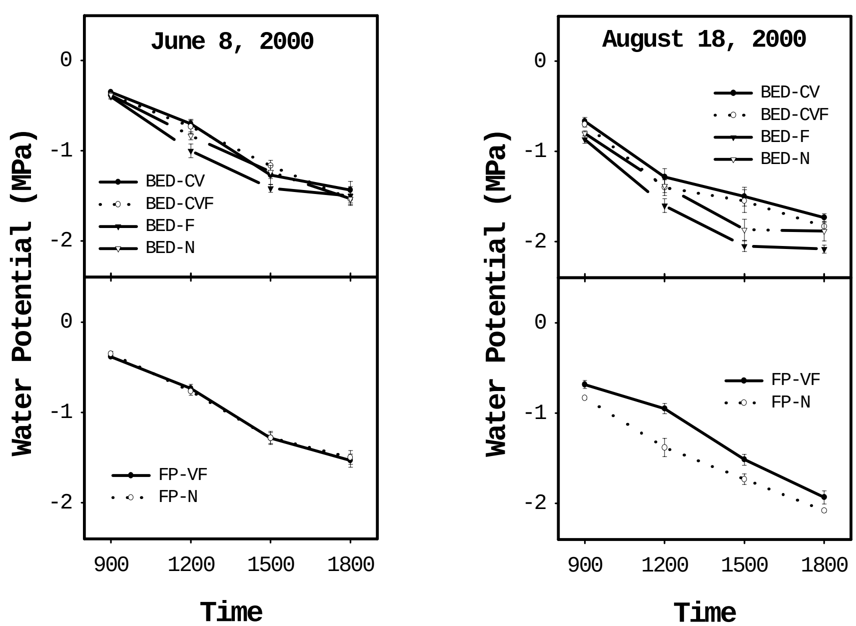

Figure 1—Needle water potential of loblolly pine seedlings during two sampling sessions from four different treatments on bedded plots: control (BED-N), continuous fertilization (BED-F), complete vegetation control (BED-CVF), and complete vegetation control and continuous fertilization (BED-CVF); and two flat-planted plots: control (FP-N) and fertilization and weed control in year of planting (FP-VF). Vertical bars indicate one standard error on each side of symbol.

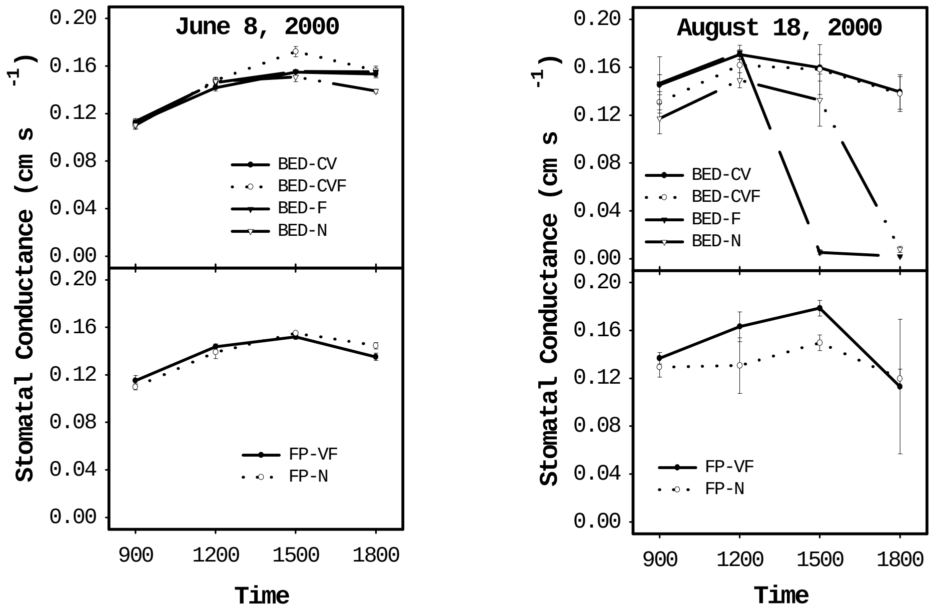

Figure 2—Stomatal conductance of loblolly pine seedlings during two sampling sessions from four different treatments on bedded plots: control (BED-N), continuous fertilization (BED-F), complete vegetation control (BED-CVF), and complete vegetation control and continuous fertilization (BED-CVF); and two flat-planted plots: control (FP-N) and fertilization and weed control in year of planting (FP-VF). Vertical bars indicate one standard error on each side of symbol.

rainfall in the four days immediately preceding data collection. There was no rainfall recorded in the 14 days preceding the August 18 sampling session.

Volumetric Soil Moisture Content

Soil volumetric moisture content was higher for all plots with chemical vegetation control (table 1). There was more water available on June 8 for all treatments than on August 18, reflecting prolonged drought as summer progressed. Bedding decreased soil water availability in summer as there was less water available in the bedded treatments than in flatplanted treatments. For example, soil volumetric moisture content on August 18 for the flatplanted-continuous vegetation control-fertilized treatment was 8.0 percent, whereas for the same treatment on a bedded plot is was only 5.5 percent. Although bedding can enhance early seedling survival, it can also decrease soil water availability during summer drought from enhanced subsoil drainage. Fertilization also affected soil volumetric moisture content when combined with certain site preparation and herbicide treatments (table 1). On bedded treatments, fertilized plots had lower volumetric soil moisture contents when competing vegetation was controlled on both sampling dates (BED-CV vs. BED-CVF). However, the combination of complete vegetation control and fertilization increased soil moisture content on flat-planted plots (FP-N vs. FP-VF). Fertilization alone did not affect soil moisture content on bedded plots (BED-N vs. BED-F). These results seem counterintuitive in that fertilization without competition control would be expected to promote prolific herbaceous plant growth with a consequential decrease in soil moisture. Herbicide application would be expected to diminish this effect. However, the opposite results were observed for which no clear explanation can be offered.

Needle Water Potential

Needle water potential on June 8 was comparable for BED and FP treatments (figure 1). Even though the BED-F treatment had lower water potential at 1200 and 1500 hours compared to the other treatments, it showed comparable water potential at 1800 hours. Needle water potential in the early morning was very high for all treatments and decrease throughout the day linearly, but never went below –1.8 MPa. However, there was a strong treatment difference in needle water potential on August 18. Seedlings from all treatments showed a lower water potential compared to June, starting with a lower early water potential and decreasing to as low as –2.1 MPa at the end of the day, thereby reflecting a moderate to severe water stress (Fitter and Hay 1987, Seiler and Johnson 1988). Seedlings from plots treated with herbicide showed higher water potential indicating that improved plant water relations were obtained from chemical vegetation control by means of increased soil water availability (figure 1).

Stomatal Conductance

Stomatal conductance did not vary between flatplanted plots during the June sampling session (figure 2). On bedded plots, all treatments started to conduct water in a comparable manner early in the day, but seedlings in the BED-N treatment conducted less by the end of the day. Stomatal conductance for all treatments, bedded and flatplanted, increased to a maximum at 1500 hours and then decreased at 1800 hours. There was a strong treatment effect on August 18 on stomatal conductance for all treatments (figure 2). Seedling stomatal conductance for the FP-VF plot was higher for 1200 and 1500 hours than the FP-N. However, the lower stomatal conductance at 1800 hours for FP-VF was due to one sample which

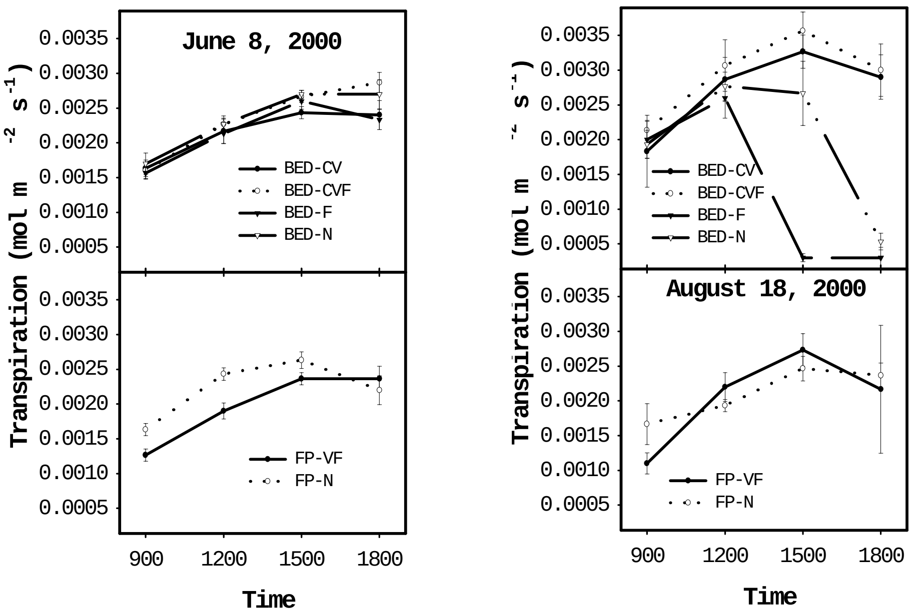

Figure 3—Transpiration of loblolly pine seedlings during two sampling sessions from four different treatments on bedded plots: control (BED-N), continuous fertilization (BED-F), complete vegetation control (BED-CVF), and complete vegetation control and continuous fertilization (BED-CVF); and two flat-planted plots: control (FP-N) and fertilization and weed control in year of planting (FP-VF). Vertical bars indicate one standard error on each side of symbol.

showed stomatal conductance as low as zero presumably due to stomatal closure, resulting in a high standard error for that treatment at that hour. Stomatal conductance for the BED-F ceased after 1500 hours and for BED-N at 1800 hours. Seedlings with water potential lower than –1.8 MPa ceased stomatal conductance.

Transpiration

Transpiration was similar among bedded treatments for most hours on June 8, although there was a treatment difference at 1500 and 1800 hours with BED-CVF transpiring most water (figure 3). Transpiration for the FP-N treatment was significantly (alpha=0.05) higher than for FP-VF until 1500 hours after which it was comparable. Transpiration did not vary between flat-planted treatments on August 18. However, transpiration followed a pattern similar to that for stomatal conductance for bedded treatments on August 18 (compare figures 2 and 3), reflecting that transpiration was controlled by stomatal behavior for this sampling session during this time of severe drought.

Net Photosynthesis

Net CO_2 assimilation rate (i.e., photosynthesis) did not vary between flatplanted plots on June 8, although it varied slightly within the bedded plots with fertilized plots being higher than the N and CV (figure 4). Photosynthesis was strongly affected by stomatal behavior on August 18 when treatments with no stomatal conductance showed no net CO_2 assimilation; BED-FP after 1500 hours and BED-N after 1800 hours (compare figures 2 and 4).

CONCLUSIONS

There was a strong influence of treatments on seedling water relations and photosynthesis. This was more obvious in the late summer after a droughty summer. Chemical vegetation control played a key role in maintaining improved seedling water relations. However, fertilization helped to enhance net CO_2 assimilation and at a time of severe water stress, there was a continuing CO_2 assimilation due to reduced competition from chemical vegetation control. Even though bedding did result in decreased soil water availability later in the growing season, comparable water relations between seedlings on bedded and flatplanted sites suggest increased root growth in seedlings on bedded plots.

ACKNOWLEDGMENTS

We thank the following for financial support: International Paper Company, Potlatch Corporation, The Timber Company, Oak Ridge National Laboratory, and the Department of Energy. We also thank the following scientists for intellectual contributions to study design and maintenance: Nick Chappell, Marshall Jacobson, Conner Fristoe, Chuck Hollis and Mark Hebert.

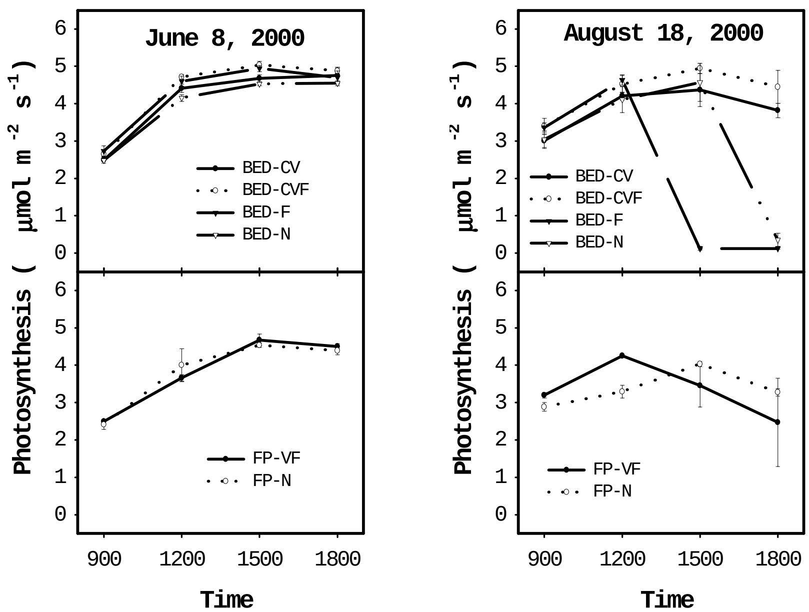

Figure 4—Net CO_2 assimilation (photosynthesis) of loblolly pine seedlings during two sampling sessions from four different treatments on bedded plots: control (BED-N), continuous fertilization (BED-F), complete vegetation control (BED-CVF), and complete vegetation control and continuous fertilization (BED-CVF); and two flat-planted plots: control (FP-N) and fertilization and weed control in year of planting (FP-VF). Vertical bars indicate one standard error on each side of symbol.

REFERENCES

Fitter, A. H.; R. K. M. Hay. 1987. Environmental physiology of plants. 2d Ed. San Diego, CA: Academic Press.

Lauer, D.K.; G.R. Glover. 1998. Early pine response to control of herbaceous and shrub vegetation in the flatwoods. Southern Journal Applied Forestry. 15(4): 201-208.

Seiler, J.R.; J.D. Johnson. 1988. Physiological and morphological responses of three half-sib families of loblolly pine to water-stress conditioning. Forest Science. 34(2): 487-495.

Shiver, B. D.; J. W. Rheney. 1990. Site-preparation method and early cultural treatments affect growth of flatwoods slash pine plantations. Southern Journal of Applied Forestry. 14(4): 183-188.