United States
Department of
Agriculture

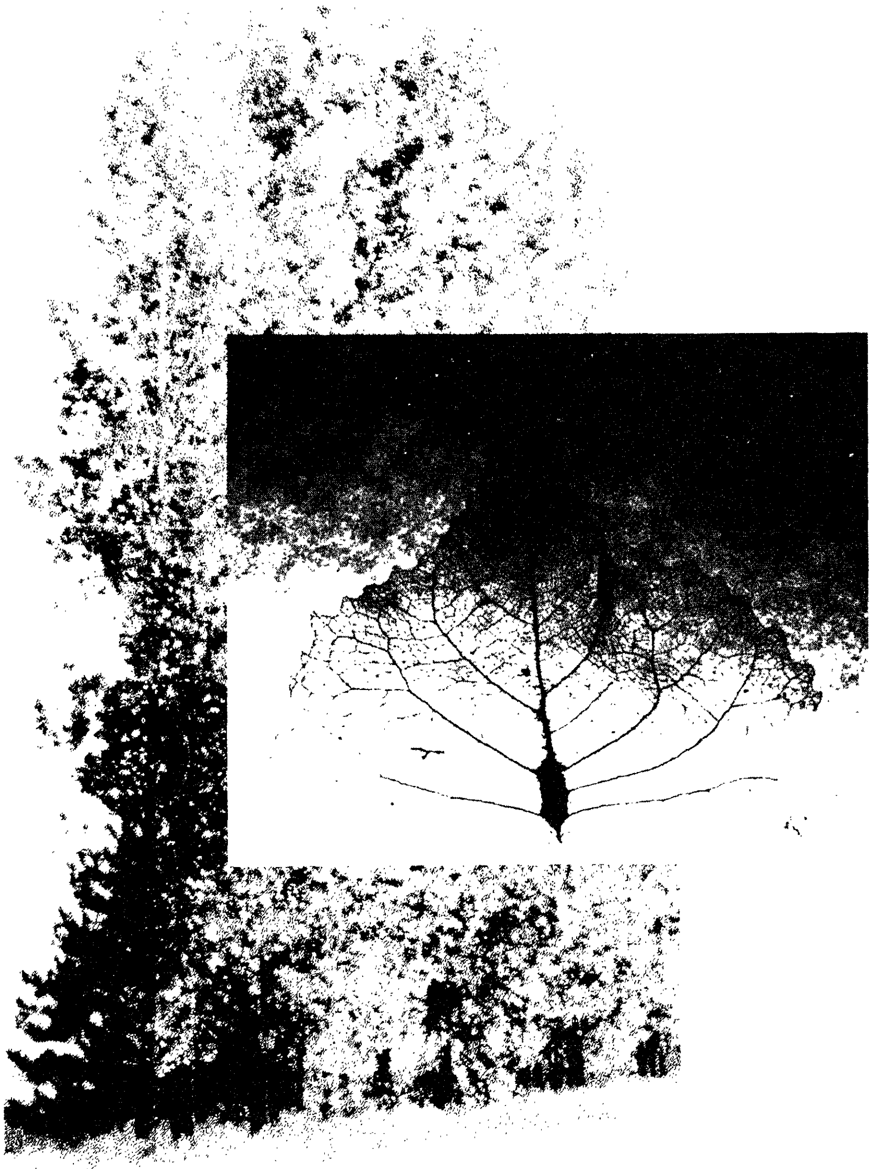
Forest
Service

North Central
Forest Experiment
Station

Research
Paper NC-311

Seasonal Variation In Hybrid Poplar Tolerance to Glyphosate

Daniel Netzer and Edward Hansen



This research is partially funded by the Department of Energy under interagency agreement DE-A105-800R20763.

North Central Forest Experiment Station
Forest Service—U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108
Manuscript approved for publication December 10, 1992
1992

Seasonal Variation In Hybrid Poplar Tolerance To Glyphosate

Daniel Netzer and Edward Hansen

Short rotation intensive culture (SRIC) of hybrid poplars uses genetically improved stock, together with agronomic cultural practices of site preparation, weed control, fertilization, and in some instances irrigation, to grow large amounts of biomass fiber or fuel (Hansen *et al.* 1983). Weeds compete strongly for water, light, and nutrients in newly established hybrid poplar plantations, and weed control is essential for fast early tree growth and consequent high yields. Weeds can be controlled with a combination of cultivation and herbicides. Cultivation, however, is difficult or impossible during wet weather and can cause mechanical damage to stems and shallow roots of hybrid poplars. Herbicides also have shortcomings. Some herbicides are difficult to apply in windy conditions and often do not work well in very dry or wet conditions. Weeds reinvade, and few herbicides can be applied during the growing season without damaging actively growing hybrid poplars (Netzer and Noste 1978).

One herbicide that might provide weed control during the growing season is glyphosate, a broad-spectrum foliar applied herbicide that is rapidly inactivated by soil contact (Sprankle 1975 a, b; Akinyemiju *et al.* 1982). It has been used to control actively growing perennial weeds in early spring and late fall when hybrid poplars are dormant (Netzer and Hansen 1983). However, young poplars are sensitive to glyphosate applied during the growing season to control reinvading weeds (Danfield *et al.* 1983). Recent observations of directed glyphosate applications at low rates of 1.1 kilograms active ingredients per hectare (kg ai/ha) during the growing season have indicated possible tolerance of 4- to 5-year-old hybrid poplars to the herbicide (Wendell Johnson, personal communication). This raises the possibility that glyphosate may be applied in older plantations during part of the summer without undue damage to the trees. We investigated how glyphosate applied at different times throughout the growing season affects 3- and 4-year-old hybrid poplar plantations and hybrid poplar stump sprouts (coppice stoolbeds).

METHODS

Hybrid Poplar Plantations

Herbicide trials were conducted in two field plantations near Ashland, WI. Each plantation contained nine contiguous 0.4 ha blocks, each block consisting of a single randomly assigned hybrid poplar clone (table 1). One plantation was established in 1987 and the other was established in 1988, both with trees planted at a 2.4 x 2.4 m spacing. Herbicide treatments were applied throughout the summer of 1990 when the plantations were in their third or fourth growing season. Before the study, weeds had been controlled by a combination of chemical and mechanical measures.

Treatments were randomly assigned to tree rows in each of the two plantations and were oriented so that they crossed all of the clonal blocks. Glyphosate (RoundUp)[1] was applied with flat fan nozzles at a constant 0.50 m height, with no attempt to shield the lower branches or base of the trees. It was applied at 1.1 kg ai/ha on both sides of a single row of trees across the entire plantation. A different row was randomly selected for each treatment every 2 weeks. Rows on either side of the treated rows were left as buffers.

Daniel Netzer is a Forester and **Edward Hansen** is a Silviculturist with the North Central Forest Experiment Station in Rhinelander, Wisconsin.

[1] *Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

Table 1.—*Hybrid poplar clones tested for growing-season tolerance to glyphosate during summer 1990*

Clone	Parentage	Year planted
NE 387	P.candicans x P.berolinensis	1987 & 1988
NE 54	P.candicans x P.berolinensis	1987 & 1988
NE 308	P.charkowiensis x P.incrassata	1987 & 1988
NE 299	P.betulifolia x P.trichocarpa	1987
NE 19	P.charkowiensis x P.caudina	1988
DN 17	P.deltoides x P.nigra	1987 & 1988
DN 34	P.deltoides x P.nigra	1987 & 1988
DN 182	P.deltoides x P.nigra	1987 & 1988
Siouxland	P.deltoides x P.nigra *	1987 & 1988
NC 5260	P.tristis x P.balsamifera	1987 & 1988
NE 54	P.candicans x P.berolinensis	1984 ***
NE 20	P.charkowiensis x P.caudina	1987 ***
NE 387	P.candicans x P.berolinensis	1987 ***
DN **	P.deltoides x P.nigra	1987 ***

* nigra parentage not confirmed
** (DN clonal numbers include 126, 128-130, 132-135, 137-139, 141-145, 147-151, 159-161)
*** stoolbed study

Lower leaf mortality and weed control were evaluated 2 weeks after each herbicide application. "Lower leaf" was defined as the tree canopy from the ground level to a height of 5 feet. Herbicide damage to lower leaves was rated using a five-point system as follows: 0=100 percent leaf area dead, 1=Ca 85 percent, 2=Ca 50 percent, 3=Ca 30 percent, 4=Ca 10 percent, 5=normal leaf (Akinyemiju 1980). Weed control was rated by estimating percent ground covered by weed species. The hybrid poplar clones were pooled into two parentage groups for analysis: the Northeast (NE) clones, and the *P. deltoides* x *P. nigra* (DN) clones plus Siouxland. In the 3-year-old plantation, the blocks of the two parentage groups were adequately intermixed to allow analysis of parentage differences of growth response to herbicide application date. In the 4-year-old plantation, however, the parentage groups were clumped and did not permit a statistical test of parentage differences.

Seasonal height growth was measured in the fall of 1990 (the treatment year) and again in the fall of 1991. Fall height growth measurements represent the combined seasonal growth before and after herbicide application. Herbicide-treated trees were compared with untreated controls to determine growth gain or loss. Differences in height growth from the untreated controls represent the combined effects of potential growth loss from herbicide damage and potential growth gain from weed control. Both maximum negative herbicide effects and maximum positive weed control effects (if either occurred) were anticipated from early to midseason treatments because of the longer impact on the growing season. Late season spray dates would not have much opportunity to impact growth that season, but might have significant carryover effects to the next year. Consequently, fall growth measurements were taken again in 1991 to assess damage not observed in 1990 from the late summer spray dates.

Coppice Stoolbeds

The stoolbed herbicide trials were conducted at the Harshaw Forestry Research Farm, 15 km west of Rhinelander, WI. The stools were spaced at 1 x 1 m and harvested annually for cuttings. The NE54 clonal stoolbed was planted in 1984 in a block separate from the other stoolbeds and had the oldest stumps (table 1). The NE20 and NE387 clones were planted nearby in adjacent blocks in 1987. The DN stoolbeds were planted in 1987 in small 30-tree plots at another location at Harshaw Farm. The area contained 30 of these small plots, each with a different DN clone. Because no single DN clone had enough stools to be treated on more than two spray dates, all DN clones were pooled for treatment and analysis. The NE20 and NE387 clones occupied a large enough area to allow two replications of herbicide treatments in each, but there was only enough area for one replication in the NE54 and DN clonal blocks.

Treatment dates were assigned consecutively to rows across the stoolbeds to avoid random assignment of widely separated spray dates to adjacent rows, which could cause treatment bias from possible herbicide drift damage. An unsprayed control row was left after the last fall spray date. The stoolbed coppice was treated at the same 2-week intervals as the plantation treatments. Glyphosate was applied over the top of the actively growing stools with a N_2-powered small-plot sprayer equipped with flat fan nozzles. Shoot height growth and stool mortality were measured at the end of the growing season. Height growth, lower leaf damage, and weed control were analyzed by ANOVA, linear regression, and "t" tests; differences were tested for significance at $p = 0.05$ for both the field plantations and the coppice stoolbeds.

RESULTS

Hybrid Poplar Plantations

Glyphosate applied in 3-year-old plantations in early May significantly increased seasonal height growth (fig. 1). Herbicide applied June 7 or later did not significantly affect height growth of DN clones but did depress growth of NE clones, especially during the June 18-July 17 period. Growth differences between the two clonal parentage groups for the June 7 to July 17 spray dates were significant; the NE clones grew significantly less than the DN clones. Herbicide applied July 30 or later did not significantly affect height growth of either the two parentage groups in relation to the unsprayed controls. However, 1991 growth of NE clones treated after June 18, 1990, was less than the control (fig. 2). The DN clones, on the other hand, grew equal to or greater than the controls for all spray dates except August 14.

Unlike in 3-year-old plantations, glyphosate application in 4-year-old trees did not reduce growth. In fact, seasonal height growth significantly increased with glyphosate applications before July 2 (fig. 3). Linear regression analysis of all 4-year-old clones pooled showed a significant relation of increased height growth with earlier spray dates. There were no residual growth differences the next year.

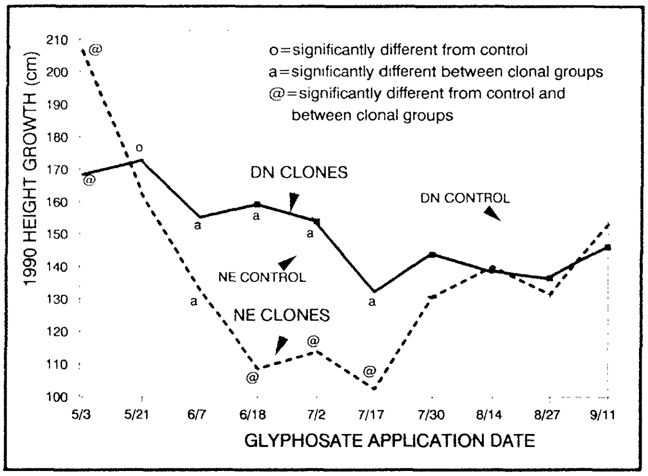


Figure 1.—*Hybrid poplar height growth related to date of glyphosate application during the third growing season (1990). Height growth is average of four DN clones and four NE clones.*

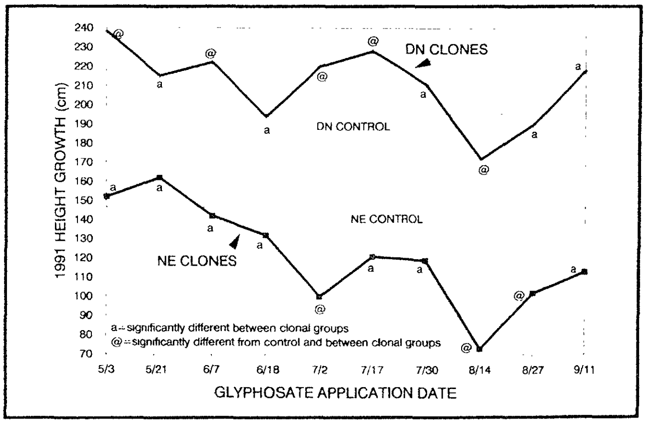


Figure 2.—*Hybrid poplar height growth during 1991, 1 year after glyphosate application. Plantation established 1988, glyphosate applied during 1990.*

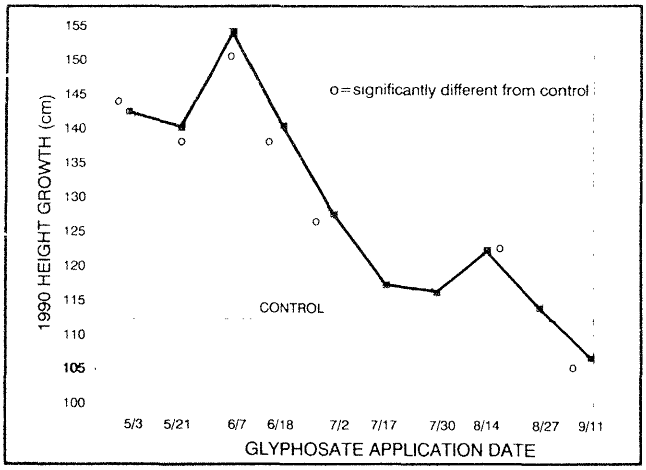


Figure 3.—*Hybrid poplar height growth related to date of glyphosate application during the fourth growing season. Height is average of nine of the clones in table 1.*

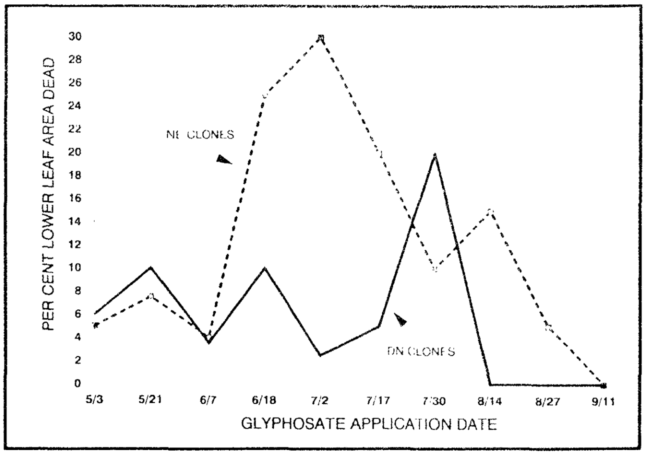


Figure 5.—*Leaf damage of NE vs. DN clones on 3-year-old hybrid poplars, related to glyphosate application date.*

Nearly all weeds died during the 2 weeks following each glyphosate application in both 3- and 4-year-old plantations. Weeds reinvaded the rows treated in May; ground coverage ranged from 20 to 50 percent from June through the rest of the season. Weeds included various annuals and perennials, predominated by ragweed (*Ambrosia artemisiifolia* L.).

Herbicide damage to lower leaves was difficult to separate from shading and drought effects. Lower leaf mortality associated with early and late spray dates was light, but was greater from midseason applications in both plantations (fig. 4). There was increased leaf mortality in the 4-year-old plantation associated with the July 17 and July 30 spray dates. NE clones tended to have greater leaf mortality than DN clones in the 3-year-old plantation (fig. 5), but not in the 4-year-old plantation (fig. 6).

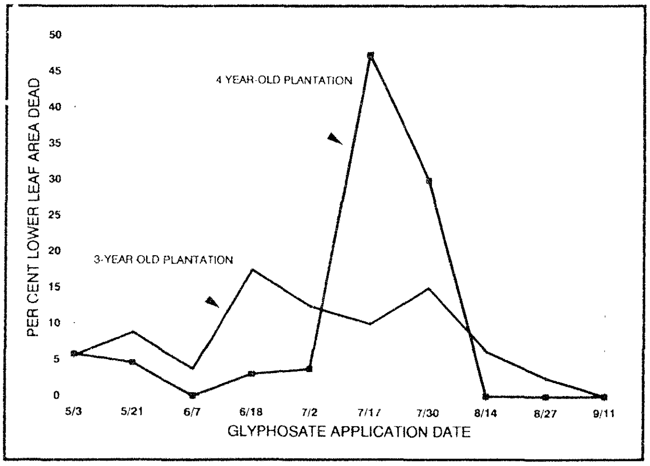


Figure 4.—*Hybrid poplar leaf damage related to glyphosate application date.*

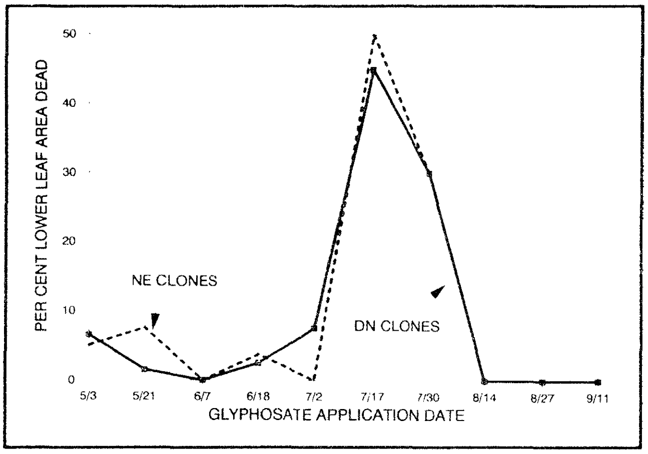


Figure 6.—*Leaf damage to NE vs. DN clones on 4-year-old trees, related to glyphosate application date.*

Coppice Stoolbeds

Stoolbed coppice growth of the DN clones was significantly greater than the unsprayed control for the two earliest spray dates of May 8 and May 21, but significantly reduced for the June 4 through August 31 application (fig. 7). Growth of NE clones, on the other hand, did not respond to early season herbicide applications and was significantly reduced from the June 21 through September 7 treatments. Significant growth loss occurred 2 weeks later (June 21 vs. June 4) for the NE clones than for the DN clones. Height growth in figure 7 is the average growth of the live stools plus the dead stools in a treatment with dead stools assigned a value of zero. DN stool mortality ranged from 50 to 100 percent from the June 4 through August 31 applications; the NE clones did not have substantial mortality until the July 6 spray date (fig. 8).

DISCUSSION AND CONCLUSIONS

Hybrid Poplar Plantations

The depressed growth of the 3-year-old NE clones treated from June 18 through July 17 (fig. 1) coincides with high leaf mortality (fig. 5). The DN clones did not show such a response. Crown architecture may have been one factor in these differences. The NE clones had more lower branches and more leaves near the ground than the DN clones at this age and thus were more exposed to the herbicide. Spray dates earlier than June 18 did not cause as much leaf mortality or growth loss, consistent with earlier findings that glyphosate used in 1-year-old hybrid poplars did not cause significant injury until later in June (Danfield *et al.* 1983). The continued reduced growth of these NE clones over the subsequent year suggests they had substantial herbicide damage (fig. 2).

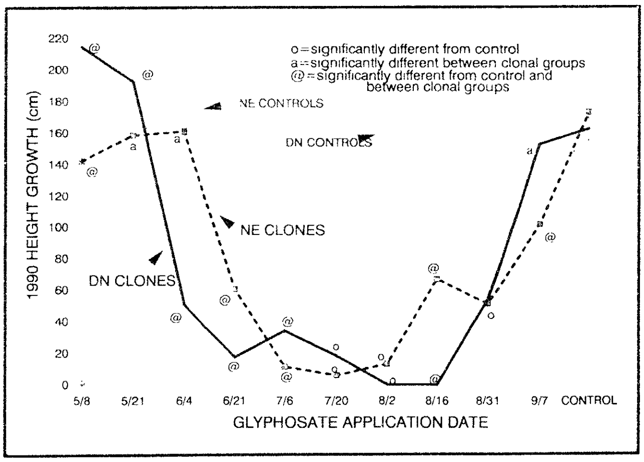


Figure 7.—*Hybrid poplar stoolbed coppice height growth for the growing season, related to date of glyphosate application.*

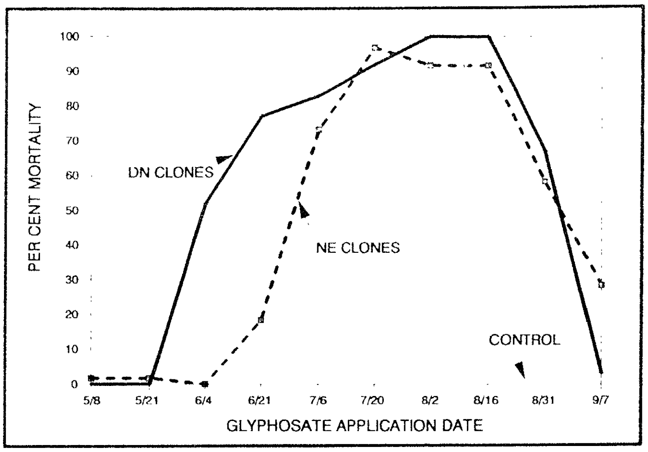


Figure 8.—*Hybrid poplar stoolbed mortality related to date of glyphosate overspray during growing season.*

Glyphosate applied in the 4-year-old plantation throughout the growing season seems to benefit tree growth (fig. 3). The earlier spray dates produced the greatest growth response because of their longer impact on the growing season. As spray dates progressed through the summer, a shorter period of weed control limited subsequent tree growth. The lack of any reduced growth in the subsequent year indicates there was no undetected herbicide damage during the treatment year. The greater lower leaf mortality associated with the July 17 and July 30 spray dates (fig. 4) coincided with canopy closure. Because this increase in leaf mortality was not associated with any growth depression for either year, we suggest that competition for light and/or water by the rapidly closing canopy, rather than herbicide injury, led to the observed leaf mortality. Lower leaf mortality was negligible for spray dates earlier and later than July 17 and July 30. The absence of a similar pulse in lower leaf mortality in the 3-year-old plantation during July of the year before canopy closure supports our contention.

Weed control to reduce competition for nutrients and moisture may not be necessary if these resources are sufficient. However, site resources are usually limited and, weed control is essential under most conditions. For example, precipitation for the Ashland plantations from May to August during this study period was 18 cm (7.15 inches) below normal (National Oceanic and Atmospheric Administration 1990). Under such conditions, competition for moisture by weeds can be critical and will result in tree growth loss, if not mortality. Because it is impossible to predict summer moisture conditions, invading weeds must be controlled throughout the season by glyphosate or other measures.

Plantations of 4-year-old hybrid poplars planted at a 2.4 x 2.4 m spacing can be treated with glyphosate with minimal negative effects. As trees get older, there are fewer lower branches with functional leaves, and less damage is likely from direct contact or spray drift. However, 3-year-old plantations of some clones at this spacing are sensitive to glyphosate from mid-June through the rest of the growing season because of their large number of functional leaves near the ground. The key to safe midseason glyphosate application seems to be the absence of tree foliage in the spray zone.

Coppice Stoolbeds

Glyphosate can be safely applied in stoolbeds in early season until the end of May. It can also be applied over dormant sprouts in the fall with no harmful effects on survival and growth of cuttings made from these sprouts (Akinyemiju *et al.* 1982). Differences by clone as well as age in this study indicate that midseason application of unshielded sprays (June through August) may cause high growth loss or mortality. Small local trials should be conducted before glyphosate is used extensively during this period. Stoolbeds to be killed for removal can be treated with 1.1 kg ai/ha from mid-July through mid-August with much success (fig. 8).

The slightly greater tolerance of the NE vs. the DN clones to glyphosate oversprays in the stoolbeds (figs. 7 and 8) suggests that NE clones may be more resistant to direct contact of glyphosate. We interpret this as "physiological tolerance." In contrast, the NE clones in the 3-year-old plantation were damaged more than the DN clones by glyphosate underspray (fig. 5). We attribute this difference to crown architecture rather than differential clonal tolerance to glyphosate. This we term "morphological tolerance." Clones such as the NE group have many live lower branches and leaves exposed to potential contact with glyphosate as compared to DN clones that have less foliated lower crowns. However, when glyphosate is sprayed directly over small trees such as in coppice stoolbeds, herbicide can easily contact almost all foliage regardless of clone. In such instances, the NE clones appear to be at least as, if not somewhat more, tolerant to glyphosate than the DN clones.

This study confirms earlier work by Netzer and Hansen (1983) suggesting that significant gains can be made in tree growth from weed control through properly timed glyphosate applications. However, in younger (1- to 3-year-old) established plantations and stoolbeds care must be taken to apply glyphosate during the dormant "safe" periods defined here and in previous studies (Netzer and Hansen 1983, Danfield *et al.* 1983, Akinyemiju *et al.* 1982). Glyphosate may be safely applied throughout the growing season in older (4-year-old and older) hybrid poplar plantations if the trees do not have actively growing crowns in the spray zone.

LITERATURE CITED

Akinyemiju, O.A. 1980. **Differential effects of simazine and diuron on survival, growth and physiology of *Populus* clones.** East Lansing, MI: Michigan State University. Ph.D. dissertation. 102 p.

Akinyemiju, O.A.; Isebrands, J.G.; Nelson, N.D.; Dickman, D.I. 1982. **Use of glyphosate in the establishment of *Populus* in short rotation intensive culture.** In: Proceedings, 19th annual meeting North American Poplar Council; 1982 July 20-22; Rhinelander, WI: 161-169.

Danfield, William; Martishus, James; Hansen, Edward. 1983. **Application date affects herbicide tolerance of hybrid poplars.** Res. Note NC-301. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 4 p.

Hansen, Edward; Moore, Lincoln; Netzer, Daniel; Ostry, Michael; Phipps, Howard; Zavitkovski, Jaroslav. 1983. **Establishing intensively cultured hybrid poplar plantations for fuel and fiber.** Gen. Tech. Rep. NC-78. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 24 p.

National Oceanic and Atmospheric Administration. 1990. **Climatological data Wisconsin May-August 1990.** Asheville, NC: National Climatic Data Center. Vol. 95, Number 6-8.

Netzer, Daniel; Hansen, Edward. 1983. **Controlling weeds in poplars by dormant season glyphosate overspray.** In: Proceedings, North Central weed control conference; 1983 December 6-8; Columbus, OH. Champaign, IL: North Central Weed Science Society: 141-142.

Netzer, Daniel; Noste, Nonan. 1978. **Herbicide trials in intensively cultured *Populus* in northern Wisconsin.** Res. Note NC-235. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 4 p.

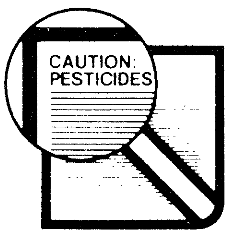
Sprankle, P.; Meggitt, W.F.; Penner, D. 1975a. **Rapid inactivation of glyphosate in soil.** Weed Science. 23: 224-228.

Sprankle, P.; Meggitt, W.F.; Penner, D. 1975b. **Absorption, mobility, and microbial degradation of glyphosate in soil.** Weed Science. 23: 229-234.

PESTICIDE PRECAUTIONARY STATEMENT

This publication reports research involving pesticides. Mention of trade names does not constitute endorsement of the product by the USDA Forest Service. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.



*U.S.GPO:1993-756-551/60274

Netzer, Daniel; Hansen, Edward.
1992. **Seasonal variation in hybrid poplar tolerance to glyphosate.** Res. Pap. NC-311. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.

Reports that glyphosate applied during April or May in hybrid poplar plantations usually results in tree growth increases and that later summer applications often result in tree damage, growth loss, or mortality. Introduces the concept of "physiological" and "morphological" herbicide tolerance.

KEY WORDS: Intensive culture, weed control, herbicide, growing season, clonal variation, short-rotation.