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CULTIVATION OF FAST-GROWING HARDWOODS

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CULTIVATION OF FAST-GROWING HARDWOODS

Final Report

Prepared for

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ABSTRACT

Fast-growing hybrid poplar plantations can be a way to utilize idle land in New York State, providing a vegetative cover that is usable for a variety of end products, including wood energy. Additionally, these plantations can provide an alternative crop on lands that are not idle. In order to evaluate the utility of hybrid poplar in New York, the intensive culture of hybrid poplar has received in-depth study as part of the Fast-Growing Hardwood Program of the State University of New York College of Environmental Science and Forestry. Research has concentrated on soil-site relationships and specific clone attributes as expressed in short-rotation intensive culture systems. Specific studies and operations included establishing and maintaining a nursery/cutting orchard, installing clone-site trials in central and southern New York State and initiating studies of no-till site preparation, nutrient utilization efficiency, wood quality and soil solution chemistry. The nursery/cutting orchard was used to provide material for various research plantings and as a genotype repository. Clone-site trials results showed that hybrid poplar growth potential, as described by indices of growth and disease damage, were affected by clone type and was shown to be related to inherent soil-site conditions. No-till techniques were shown to be successful in establishing hybrid poplar in terms of survival and growth when compared to conventional clean tillage and/or no competition control, and can be considered for use on sites that are particularly prone to erosion. Nutrient use efficiency was significantly affected by clone type, and

should be a consideration when selecting clones for operational planting if fertilization is to be effectively and efficiently used. Wood quality differed among clones with site condition and tree age inferred as important factors. Soil solution chemistry was minimally affected by intensive cultural practices with no measured adverse effect on soil water quality. Generally, results of these studies showed that appropriate hybrid poplar clones grown in short-rotation intensively cultured systems can be used successfully in New York State if proper site conditions exist and appropriate establishment and maintenance techniques are used.

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EXECUTIVE SUMMARY

The Cultivation of Fast-Growing Hardwoods Program was established in 1983 to investigate cultural systems for the establishment, tending and harvesting of short-rotation hybrid poplar clones. Differential accumulation of biomass and nutrients among hybrid poplar clones grown in clone-site trials on three different sites were evaluated. Existing literature information on the culture of Populus was evaluated and summarized, and additional techniques developed, for the intensive culture of hybrid poplar in the Northeast. This included installing a nursery for the production of hybrid poplar clonal planting material.

Results of the literature search, and the knowledge gained through experience, have been presented at numerous workshops, seminars, presentation of invitational papers, and publications in refereed and popular journals. Every effort has been made, and continues to be made, to transfer technical experience and knowledge from the Fast-Growing Hardwood Program at the College of Environmental Science and Forestry to the public and private landowners.

Four main studies were completed as part of the overall project: three clone-site trials were established, two on high-quality agricultural soils in the Southern Tier of New York State and the other on upland soils in central New York State; the latter represents large acreages of land available for reforestation. These trials were used to evaluate growth potential of hybrid poplar. The response of hybrid poplar to no-till site preparation techniques was evaluated and biomass and

nutrient accumulation and removal in 3-year-old hybrid poplar grown in short-rotation systems were measured and related to long-term site nutritional status.

Results of the clone-site trials demonstrated that hybrid poplar can be successfully established in New York State using intensive management practices, including mechanical and chemical site preparation and chemical tending. Relative growth potential was shown to be related directly to individual clones (inherent growth rate and disease resistance) and responsive to inherent site conditions, primarily soil properties.

Results of the no-till trials demonstrated that the no-till techniques were successful in terms of hybrid poplar establishment and growth when compared to conventional clean tillage and/or no-competition control. Trees planted under no-till attain similar growth rates and survival as compared to conventional clean cultivation. Demonstrating success of no-till establishment of hybrid poplar may ultimately allow expansion of the hybrid poplar programs to sites with potentially erosive soils.

Biomass production and nutrient accumulation, as affected by clone type and time-of-harvest (leaf-on versus leaf-off), was shown to be collectively important for the evaluation of hybrid poplar clone-site relations, specifically with regard to the use of fertilization in intensive culture systems. Nutrient efficient clones can be grown to produce the same amount of biomass per unit of nutrient used, thereby reducing the total amount of nutrients removed from the site by harvesting. Leaf-on

harvests removed significantly more nutrients than leaf-off, indicating that dormant season harvest would be more site nutrient efficient.

In addition to these major research emphases other important aspects of establishment, maintenance and product recovery in intensively cultured hybrid poplar were explored. Deer browse was shown to have an impact on hybrid poplar establishment and growth. Soil and weather conditions were seen to be collectively important for the successful use of herbicides during establishment and tending. Preliminary wood quality analyses among clones and between sites indicated that the suitability of various hybrid poplar clones as substrate for bioconversion and usable energy products is dependent on both clone and site conditions. Soil solution chemistry was shown to be minimally affected by intensive cultural practices and that there was no measurable affect on soil water quality.

While project objectives and goals were accomplished there is still a considerable amount of research that should be done. Hybrid poplar can be established successfully and grown in New York State, but refinement and expansion of existing techniques to be applicable to a wide range of available sites, and development of fast-growing disease resistant clones and more efficient cultivation, establishment and harvesting methods are needed before this fast-growing hardwood system can be operationally employed. Larger scale pilot and operational trials are the next step in the research program, with efforts made to find markets for the products.

Section 1

INTRODUCTION

The "Cultivation of Fast-Growing Hardwoods" project (NYSERDA No. 548-RIER-BEA-83, SUNY Research Foundation No. 210-6306A) was initiated in April 1983. The goal of the project was to establish experimental plantations and initiate a program of research related to the culture and management of fast-growing hardwoods in New York State.

Populus clones were chosen as the first species to work with, and because the establishment of intensive cultured plantations of hybrid poplar varies by clone and site, techniques needed to be developed specific to the physiographic regions and soils of New York State. The current project addressed this need so as to make the culture and management of intensively cultured hybrid poplar feasible in New York.

OBJECTIVES

The objectives of the current project were as follows:

1. summarize existing literature concerning cultural methods, experimental yields and soil suitability from studies with fast-growing hardwoods and apply this information to site conditions in New York State;
2. establish a hybrid poplar stoolbed nursery at the Lafayette Experiment Station, a property of the State University of New York College of Environmental Science and Forestry near Syracuse, New York, to produce clonal material for support of experimental plantings and to act as a genotype repository;
3. develop cultural strategies and establish experimental plantations (clone-site trials) of selected hybrid poplar clones for demonstration and research purposes;
4. organize and conduct technical workshops to discuss the state-of-the-art regarding the establishment of fast-growing hardwood plantations for biomass production in the northeastern United States.

During Spring, 1983, a literature study was completed to analyze data concerned with biomass energy plantations using fast-growing hardwoods, specifically establishment and maintenance techniques and experimental yields of Populus. These data and information were summarized for use in establishment and maintenance of short-rotation intensively cultured (SRIC) hybrid poplar in New York State. SRIC systems include mechanical and chemical site preparation to create a competition-free

environment, genetically improved clonal trees propagated in dense plantations (500 to 15,000 stem ac^{-1}) through vegetative cuttings, maintenance of pest-free situations, and fertilization to mitigate possible losses of growth through nutritional stress.

In Spring of 1983 a hybrid poplar clonal nursery stool bed was established at the Lafayette Field Station, a property of the State University of New York, College of Environmental Science and Forestry (CESF). Clonal material was selected from stock available in Canada (Ontario Ministry of Natural Resources) and the U.S. (United States Forest Service), and from material already established by the CESF. The stool beds are currently being operationally maintained to provide clonal material for planting and to serve as a genotype repository.

Development of cultural strategies which would allow for the successful establishment and maintenance of hybrid poplar under various site conditions was the main goal of this project. Three plantations, 3.9 to 5.7 ha in size and with 4 to 10 clones each, were successfully established in the Southern Tier (Big Flacs) and Central (Heiberg Forest) New York State. These sites provided conditions similar to those on surrounding private, state and industrial ownerships. The soil at Big Flats are relatively productive, agricultural soils that lie on a major river flood plain. At Heiberg Forest, the soil is a Mardin channery silt loam (Typic Fragiochrept), occupied a sloping (3 to 15 %) catena of upland glaciated soil (Bath-Lordstown-Mardin-Volusia; over 1 million ha in central New York State). Both sites represent large physiographic regions and soil types that are extensively available for the intensive culture of hybrid poplar in the

northeastern United States.

Results of the literature search, and the knowledge gained through experience, have been presented at numerous workshops, seminars, presentation of invitational papers, and publications in refereed and popular journals (Appendix A1-1). Every effort has been made, and continues to be made, to transfer technical experience and knowledge from the Fast-Growing Hardwood Program at the College of Environmental Science and Forestry.

Trees in the clone-site trials at Heiberg Forest and Big Flats, which completed their fifth growing seasons, provided the general basis for this final report. Other research efforts concentrated on: 1.) evaluating biomass production, nutrient accumulation and time-of-harvest effects (leaf-on versus leaf-off) and determining their collective importance for measuring productivity for specific clones; 2.) evaluation of no-till site preparation techniques for establishing hybrid poplar plantations; 3.) analysis of wood quality among clones and between sites; and 4.) environmental monitoring of soil solution chemistry in clone-site trials after intensive site preparation and tending. To achieve these specific research objectives three graduate student programs were initiated. Two Master of Science programs were completed (Edmonds 1986; Ulzen-Appiah 1987) and a third is near completion with results having been presented at scientific meetings (McKittrick et al. 1986; Oyler et al. 1986). Ulzen-Appiah's work was completed in conjunction with the Fast Growing Forest Group of the Ministry of Natural Resources, Brockville, Ontario, Canada.

Section 2

ESTABLISHMENT AND MAINTENANCE OF THE LAFAYETTE HYBRID POPLAR CUTTING ORCHARD/NURSERY

The first step for successful clonal fast-growing hardwood programs is securing quality planting stock of known parentage and phenotypic character. Because hybrid poplar had received limited attention in New York State before the initiation of this research program, the existence of stock for outplanting in intensive culture systems was nearly non-existent. In order to provide reliable planting material for this and similar poplar programs, and to facilitate the maintenance of appropriate genetic material for New York State, a series of clonal hybrid poplar stool beds were established at the Lafayette Road Experiment Station, Lafayette, New York.

The nursery property is part of the State University of New York College of Environmental Science and Forestry (SUNY CESF), and is located approximately 4 km south of Syracuse, New York. It is the location of an extensive nursery operation for both conifer and hardwood production. Existing facilities (storage areas, greenhouses, irrigation system) and central location with regard to anticipated poplar plantation establishment sites made this site a good choice for a clonal hybrid poplar cutting orchard.

An existing set of clonal hybrid poplar stool beds, established in 1981 in conjunction with other research programs at the SUNY CESF, was expanded in 1983, 1986 and 1987 to provide planting material for research purposes of the "Cultivation of Fast-Growing Hardwoods" program. During late fall, 1982, material

was cut from existing stool beds for use as planting stock in the expanded cutting orchard area and stored at 0° C until planting. Site preparation for the new stool beds took place during the summer-fall 1982. The area was mowed during late summer to promote active regrowth of weed vegetation, followed one month later by an application of glyphosate at 2.2 kg a.i. ha⁻¹. After the vegetation died, the site was rototilled, raked smooth and capped with the pre-emergent herbicide simazine at 4.5 kg a.i. ha⁻¹. Unrooted 25-cm-long cuttings (from the 1981 stool bed) were planted in 49 tree blocks at 0.5 x 1.0 m spacing during May 1983. In May 1986, subsequent to the same site preparation procedures outlined for the 1983 planting, clonal material obtained from the Ontario Ministry of Natural Resources (OMNR) Fast Growing Forests program was planted at 0.5 x 1.0 m spacing in 28 tree clone blocks. At the same time, clonal blocks in the 1983 nursery area received matching "fill-in" plantings to replace mortality and the 1981 cutting orchard was removed. Three new clones were obtained from OMNR and added to the cutting orchard in May 1987.

A schematic map of the hybrid poplar clones grown in the nursery are shown in Figure 2-1. A list of these clones and associated parentages are presented in Table 2-1.

Approximately 500 cuttings were harvested from the beds each year during February-March, 1984-1988. Cuttings from 1985 were used, in part, to establish the 54 clone genetic selection field trial located in the St. Lawrence River Valley near Massena, New York ("Biotechnology and Genetic Selection of Fast-Growing Hardwoods" project, NYSERDA No. 757-RIER-IER-85, SUNY Research Foundation No. 210-6354A). Cuttings were also made available to

Figure 2-1. Hybrid poplar cutting orchard plot layout. The 1981 area was removed in 1986 after replanting some of the "best" clones in the adjacent block.

Table 2-1. Parentages of hybrid poplar clones included in the cutting orchard/nursery at Lafayette Experiment Station.

Clone	Parentage
D51	<u>Populus deltoides</u> x <u>P. nigra</u>
DN10	<u>P. euramericana</u> cv Robusta
DN16	<u>P. euramericana</u> cv Regenerata Batarde d' Hauterive
DN30	<u>P. euramericana</u> cv Canada Blanc
DN33	<u>P. euramericana</u> cv Virginia Nancy
DN34	<u>P. euramericana</u> cv Eugeni
DN38	<u>P. deltoides</u> cv Virginia x <u>P. cv Volga Poplar</u>
DN55	<u>P. deltoides</u> x <u>P. nigra</u>
DN70	<u>P. deltoides</u> x <u>P. nigra</u>
DN106	<u>P. deltoides</u> x <u>P. cv N1 + 2 mixed Pop 683-27</u>
DN125	<u>P. deltoides</u> x <u>N1 + 2 mixed Pop 694-28</u>
DTAC2	<u>P. angulata</u> x <u>P. x berolinensis</u>
GA88	<u>P. grandidentata</u> cv G321 x <u>P. alba</u> cv A321
JAC34	<u>P. maximowiczii</u> x <u>P. trichocarpa</u>
NE17	<u>P. nigra</u> var <u>charkowiensis</u> x <u>P. nigra</u> var <u>caudina</u>
NE19	<u>P. nigra</u> var <u>charkowiensis</u> x <u>P. nigra</u> var <u>caudina</u>
NE21	<u>P. nigra</u> var <u>charkowiensis</u> x <u>P. nigra</u> var <u>caudina</u>
NE27	<u>P. nigra</u> var <u>charkowiensis</u> x <u>P. x berolinensis</u>
NE49	<u>P. maximowiczii</u> x <u>P. x berolinensis</u>
NE54	<u>P. tacamahaca</u> var <u>candicans</u> x <u>P. x berolinensis</u>
NE279	<u>P. nigra</u> x <u>P. laurifolia</u>
NE280	<u>P. nigra</u> x <u>P. laurifolia</u>
NE292	<u>P. nigra</u> var <u>baatanicorum vitrum</u> x <u>P. trichocarpa</u>
NE293	<u>P. nigra</u> var <u>betulifolia</u> x <u>P. cv Volga Poplar</u>
NE308	<u>P. nigra</u> var <u>charkowiensis</u> x <u>P. incrassata</u>
NE309	<u>P. nigra</u> var <u>charkowiensis</u> x <u>P. nigra</u> var <u>caudina</u>
NE320	<u>P. nigra</u> var <u>charkowiensis</u> x <u>P. trichocarpa</u>
NE324	<u>P. tacamahaca</u> var <u>candicans</u> x <u>P. x berolinensis</u>
NE325	<u>P. tacamahaca</u> var <u>candicans</u> x <u>P. x berolinensis</u>
NE328	<u>P. tacamahaca</u> var <u>candicans</u> x <u>P. x berolinensis</u>
NE332	<u>P. simonii</u> x <u>P. x berolinensis</u>
NE343	<u>P. nigra</u> x <u>P. laurifolia</u>
NE380	<u>P. nigra</u> var <u>charkowiensis</u> x <u>P. nigra</u> var <u>caudina</u>
NM5	<u>P. nigra</u> x <u>P. maximowiczii</u> (cl. "Max-4")
NM6	<u>P. nigra</u> x <u>P. maximowiczii</u> (cl. "Max-5")

the landowners as part of the technology transfer program ("Technology Transfer Fast-Growing Hardwoods Program", NYSERDA No. 744-RIER-IER-85, SUNY Research Foundation No. 210-0803A). Numerous requests for planting material were received and cuttings of the "best" clones were distributed to growers in the Northeast (Appendix A2-1)

The nursery is being maintained, providing support for future experimental and operational hybrid poplar plantations and acting as a repository for some clones not available in Canada or elsewhere in the United States. Maintenance generally has included: combinations of mechanical (hand hoeing and rototilling) and chemical tending (application of glyphosate with shielded sprayers and wick applicators) to keep an 80 % weed-free environment; fertilization to maintain stool bed vigor; and yearly dormant season harvests to store viable cutting material for each successive growing season. Future plans call for rotating existing growing stock so as to keep the stools in vigorous condition.

Section 3

HYBRID POPLAR CLONE PERFORMANCE IN THREE CLONE-SITE TRIALS IN CENTRAL AND SOUTHERN NEW YORK

INTRODUCTION

An intensive culture system is necessary to establish and maintain hybrid poplar because survival and growth are reduced by competition with weeds (White 1985). Site preparation (plowing, disking, harrowing, herbicides), planting of vegetative shoots (cuttings), tending (competition control, pest management), and coppice regeneration at relatively short intervals (5 to 15 years) are common components to a successful fast-growing forest program.

Hybrid poplar plantations are established with unrooted dormant season vegetative cuttings. This permits relatively easy planting and maintenance of genetic integrity and planned diversity.

The ease of maintaining genetic integrity and high growth rates enables researchers to develop clones that are suited for specific sites and allow for optimum production under varying management regimes, product objectives, and pest problems. Differential sensitivity of hybrid poplar clones to soil conditions is important. Preferred soils are deep loams, sandy loams and well structured silt loams which are imperfectly to moderately well drained and have a pH between 6.5 and 8.5 (Table 3-1). An effective hybrid poplar program is based on the proper matching of clones with soil and other site (e.g. climate, geography) conditions. Additionally, disease resistance,

Table 3-1. Soil criteria for evaluating suitability of planting sites for hybrid poplar^{1/}.

Soil property	Suitability class		
	Preferred	Acceptable	Unacceptable
Texture	loams, sandy loams well structured clay and silt loams	loamy sands, clay loams, silt loams	coarse sands, clays, pans present
Bulk density	< 1.4 g cc ⁻¹	1.4 to 1.7 g cc ⁻¹	> 1.7 g cc ⁻¹
Structure	well developed spheroidal	amorphous or single grain	massive
Drainage	imperfect water table at 1-2 meters	moderately well	very poor or excessive prone to flooding
	no standing water during growing season		mottling to the surface
	no mottling to 0.6 meters		
Organic matter	> 3% especially in sandy soils	1 to 3 %	< 1%
pH	6.5 to 8.5	5.0 to 8.5	< 5.0 or > 8.5
Rooting	> 75 cm	45 to 75 cm	< 45 cm

^{1/} Adapted from Barkley (1983), Dickmann and Stuart (1983) and White (1985).

especially for leaf rust (Melampsora spp) and stem cankers (Septoria and Cryptosphaeria spp.) must be considered in the clone selection process.

Three hybrid poplar clone-site trials were used to test several clones for suitability and utility on known soil types in specific geographic/climate regions of central and southern New York State. These clones had been screened in genetic-selection and clone-site trials in Canada. Successful clones, which are those clones that were to be further tested in clone-site trials, achieved relatively high levels of survival and growth.

Clone-site trials are used to refine clone recommendations for specific site conditions; coupled with knowledge of region-wide soils and land-use patterns, these trials can provide managers with valuable information for expanded use of hybrid poplar. Because of the investment in breeding programs and plantation establishment and maintenance, it is vital that proper clone-site selections be made for operational plantations so that maximum benefits are achieved.

MATERIALS AND METHODS

Study Area Location and Description

The clone-site trials were located in the Chemung River valley and Tully valley uplands, in the Southern Tier and central region of New York State, respectively. The Southern Tier trials, hereafter referred to as Big Flats North or South, were established at the United States Department of Agriculture Soil Conservation Service's Big Flats Plant Materials Center, Corning, New York (42° 07' N, 76° 52' W). The North and South areas were

approximately 1 km apart and were 5.1 and 5.7 ha in size, respectively. The central trial was located on the State University of New York College of Environmental Science and Forestry's Sven O. Heiberg Memorial Forest, Tully, New York ($42^{\circ} 48' \text{ N}$, $76^{\circ} 03' \text{ W}$), and is referred to as the Heiberg Forest trial. It was 3.9 ha in total size.

Average monthly temperatures range from -6.1° C in December to 21.9° C in July at Big Flats, and -8.6° C in January to 18.6° C in July at Heiberg Forest. Annual precipitation is approximately 90-95 cm at both sites (Big Flats Plant Material Center 1984; NOAA 1985).

Soils at Big Flats are nearly level and lie on a major river flood plain; the North trial is at the furthest extent of that flood plain and the South trial is directly behind a river levy. The major soil series in the North trial was a Wallington silt loam (Aeric Fragiaquept) with minor inclusions of Howard gravelly silt loam (Glossoboric Hapludalf), Papakating silt loam (Typic Fluvaquent) and Hudson silt loam (Glossaquic Hapludalf). Tioga silt loam and Tioga fine sandy loam (Dystric Fluventic and Eutrochrept, respectively) were the major soil series in the south block, with a minor inclusion of Middlebury silt loam (Fluvaquentic Eutrochrept). The soil at Heiberg Forest, a Mardin channery silt loam (Typic Fragiochrept), occupied a sloping (3 to 15 %) catena of upland glaciated soil (Bath-Lordstown-Mardin-Volusia; over 1 million ha in central New York State), with minor inclusions of Lordstown and Volusia soils. Both sites represent large physiographic regions. The Heiberg site soil types are

extensively available for the intensive culture of hybrid poplar in the northeastern United States.

Site Preparation

Because mechanical access during the spring is limited, a fall site preparation is necessary, thus, both sites were prepared the fall prior to planting. Big Flats' sites were initially covered with a variety of vegetation including: 'KY-31' tall fescue (Festuca arundinacea), Pennlawn red fescue (Festuca rubra), perennial rye grass (Lolium perenne), 'Chemung' crownvetch (Coronilla varia), 'Lathco' flatpea (Lathyrus sylvestris), redtop (Agrostis gigantea), bluestem grass (Andropogon gerardi), goldenrod (Solidago spp.), milkweed (Asclepias syriaca), bindweed (Convolvulus sepium), and autumn olive (Elaeagnus umbellata). Site preparation was completed during fall 1983, with an initial application of glyphosate at 2.2 kg a.i. ha⁻¹ made during late September, 1983. In early October, 1983, the site was plowed to a depth of 25 to 30 cm and disked several times. Eptam 6E (EPTC, S-ethyl dipropylthiocarbamate) was applied at 10 kg a.i. ha⁻¹ and incorporated into the soil by disking. After disking, the site was cultipacked to smooth the surface and capped with 4.5 kg a.i. ha⁻¹ simazine.

Site preparation at Heiberg Forest was different than Big Flats, primarily in response to weed vegetation. The site was an old field occupied by a variety of herbaceous and woody plants; primarily goldenrod (Solidago spp.), apple (Malus spp.) and raspberry (Rubus spp.). Site preparation began during the summer 1983. After the large trees were pulled and removed, the area

was mowed August 1983 to promote active growth of weed vegetation, followed by an application of glyphosate at 2.2 kg a.i. ha⁻¹. The site was subsequently plowed, but weather conditions precluded finishing the site preparation during 1983. Site preparation was resumed during September 1984 with an initial application of glyphosate and dicamba at 2.2 and 0.3 kg a.i. ha⁻¹, respectively. In October, 1984, the site was plowed to a depth of 25 to 30 cm and disked several times. After disking, the site was cultipacked to smooth the surface and capped with simazine at 4.5 kg a.i. ha⁻¹.

Planting

Clones were chosen for planting based on field trial results in the Ontario Ministry of Natural Resources Fast Growing Forests program, considering study site soils. Primarily considered was soil drainage class, texture, fertility and pH (Tables 3-2 and 3-3).

Clones were assigned to each area in a completely randomized design, replicated three times. Plots in the North and South areas at Big Flats were 63 x 54 and 48 x 78 m, respectively. At Heiberg Forest plots were 36 x 36 m in size. Unrooted cuttings, 25 cm in length, were obtained from the Kemptville Nursery, Ministry of Natural Resources, Kemptville, Ontario, Canada. Cuttings were stored at -4^o C until planting and were carried by planters in plastic buckets in about 10 cm of water to prevent dehydration during planting. Cuttings were planted using a 2 cm diameter planting dibble at 3 X 3 m spacing flush with the top flush with the soil surface during April 1984 and 1985, at Big Flats and Heiberg Forest, respectively.

Table 3-2. Surface soil characteristics for the clone-site trials at Big Flats and Heiberg Forest, New York.

Soil property	Big Flats-North	Big Flats-South	Heiberg Forest
Textural class	clay loam	loam	silt loam
Organic matter (%)	3.5	2.1	7.8
Structural class	subangular, blocky and granular	granular	subangular, blocky
Drainage class	somewhat poorly	moderately well, well somewhat poorly	moderately well, somewhat poorly
Soil rooting depth (cm)	46	137	30-45
Depth to mottling (cm)	28	45	36
pH	5.6	6.6	5.3
CEC (meq 100 g ⁻¹)	19	10	22
N (%)	0.20	0.11	0.31
P (ppm)	8	47	10
K (ppm)	45	42	85
Ca (ppm)	976	877	744
Mg (ppm)	154	151	52
Na (ppm)	8	6	-

Standard laboratory procedures were used to analyze soil samples. Total N (macro-Kjeldahl), extractable P (Truog's method), exchangeable cations (2 N NH₄OAc; pH 7.0), organic matter (Walkley-Black wet oxidation), pH (1:2 soil:water paste; glass electrode) and soil texture (modified Bouyoucos hydrometer method) were determined for all samples (Truog 1930; Bickelhaupt and White 1982; Wilde et al. 1979). Phosphorus was measured colorimetrically (molybdate stannous chloride) and cations by atomic absorption spectrophotometry.

Table 3-3. Hybrid poplar clones grown at Big Flats and Heiberg Forest clone-site trials.

Clone	Parentage
<u>Big Flats-North:</u>	
AK41	<u>Populus alba</u> x <u>P. glandulosa</u>
DN1	<u>P. x euramericana</u> cv. Allenstein
JACN5	<u>P. Jackii</u> x <u>P. nigra</u>
NM1	<u>P. nigra</u> x <u>P. maximowiczii</u>
<u>Big Flats-South:</u>	
DN19	<u>P. x euramericana</u> cv. Blanc di Poitou
DN55	<u>P. deltoides</u> x <u>P. nigra</u>
DN70	<u>P. deltoides</u> x <u>P. nigra</u>
DTAC8	<u>P. deltoides</u> x <u>P. trichocarpa</u>
NM5	<u>P. nigra</u> x <u>P. maximowiczii</u> (cl. "Max4")
<u>Heiberg Forest:</u>	
DN2	<u>P. x euramericana</u> cv. Baden 431
DN30	<u>P. x euramericana</u> cv. Canada Blanc
DN33	<u>P. deltoides</u> cv. Virginia Nancy
DN106	<u>P. deltoides</u> x <u>P. N1+2 mixed Pop 683-27</u>
DN128	<u>P. deltoides</u> x <u>P. N1+2 mixed Pop 696-3</u>
DN149	<u>P. deltoides</u> x <u>P. N1+2 mixed Pop 696-26</u>
DN173	<u>P. x euramericana</u> (cl. Dorskamp)
DTAC7	<u>P. deltoides</u> x <u>P. trichocarpa</u>
JAC4	<u>P. tacamahaca</u> x <u>P. deltoides</u>
NM5	<u>P. nigra</u> x <u>P. maximowiczii</u> (cl. "Max 4")

Tending

Maintenance of a weed free environment is critical for the successful establishment and growth of hybrid poplar. Weed control measures were taken to maintain a weed free environment. Treatments and timing of tending operations are presented in Table 3-4.

It is important to point out that mechanical control of bind weed and nutsedge (Cyperus esculentus L.) on the south block of Big Flats appeared to have made the weed problems worse by promoting vegetative propagation. Disking reduced the effectiveness of the simazine cap allowing other weed species, primarily grasses, to successfully invade the area.

A necessary function of the tending and maintenance phase in hybrid poplar programs is the monitoring, identifying and controlling of potentially damaging agents. All plots were periodically monitored for insect, disease, herbicide, weather related and mammal damage.

Data Collection, Preparation and Analysis

At Big Flats, a 100 percent survey of survival was done in fall of 1984 and 1985. Survival and diameter at breast height outside bark (dbhob; 1.37 m) of the largest stem for each tree was recorded for the 36 center trees in the fall of 1986 and 1987. In 1988, all stems for each of the 36 center trees were measured for dbhob. At Heiberg Forest, the center 64 trees were measured for survival during the dormant seasons of 1985, 1986 and 1987 and for the center 36 trees in 1988 and 1989; dbhob of the largest stem for each tree was measured in 1987 and for all stems for each tree in 1988 and 1989 (see Appendix for data).

Table 3-4. Summary of tending treatments applied at Big Flats and Heiberg Forest during the first two growing seasons.

Treatment	Date	Site	Rate
			kg a.i. ha ⁻¹
<u>Big Flats:</u>			
Sethoxydim	5/84 6/84	North	0.5
Terbacil	6/84	North	3.0
Disking (5 cm deep)	8/84	South	
Glyphosate	9/84	Both	1.1
Glyphosate	5/85	North	1.1
Terbacil	6/85	South	1.1
Amitrole	8/85	North	2.2
Simazine	9/85	North	3.4
<u>Heiberg Forest:</u>			
Glyphosate (spot treat)	6/85		
Glyphosate	8/85		2.2
Simazine	8/85		2.2
Amitrole	8/85		1.1

NOTE -- reference to herbicides does not imply endorsement of any chemical or that they are registered for such use.

On each site every tree that was damaged by deer the first year was tallied. Second year deer damage was considered important, and tallied, if the damage appeared to limit height growth. If only the side branches were browsed the tree was not counted as damaged. Other mammal and insect damage was considered as nonlimiting to growth, and was not recorded for subsequent analysis.

Because stem and branch cankers can significantly affect productive capacity of hybrid poplar, a detailed assessment of canker (Septoria spp. and Cryptosphaeria spp.) infestation was made at both sites during the fall 1987 and 1988, and in 1989 at Heiberg Forest. The following rating scheme was utilized to evaluate the degree of canker damage (after Abrahamson et al. 1990): 0 -- no cankers observed; 1 -- one canker observed; 2 -- two or three cankers observed; 3 -- four or more cankers observed, or greater than one half of the stem girdled (regardless of the number of cankers).

Data Analyses

Fifth year survival, dbhob and canker incidence were examined for clone effects using analysis of variance with a completely randomized design model (Snedecor and Cochran 1980; $\alpha=0.05$). When main effects were significant, Duncan's Multiple Range Test was used to separate means ($\alpha=0.05$). Survival percentages were transformed using arc sine procedures to correct for a skewed probability distribution (Neter and Wasserman 1974). All statistical analyses were done using the SAS computer software system (SAS Institute, Inc. 1985).

Clone growth potential was evaluated using a technique proposed by Abrahamson et al. (1990), wherein growth potentials of hybrid poplar clones grown in a 3-year-old genetic-selection trial were compared using indices of canker severity and total growth (sum of dbhob² (cm²) for all living trees). A graphical evaluation of growth potential was done. Trees with relatively low canker severity and high total growth were considered as having the highest potential for biomass production.

RESULTS AND DISCUSSION

Survival And It's Contributory Factors

Except for the South trial at Big Flats, there was a significant clone effect on fifth year survival (Table 3-5). Average survival for all of the clones ranged from 47 to 97%, excluding AK41. The minor increase in survival after 1986 may be attributed to sampling, subsample measurements were used post-1986, compared to total survey pre-1987.

The poor survival of clone AK41, also observed in other hybrid poplar studies (Barkley et al. 1983; Hansen et al. 1983), can be attributed to the use of unrooted cuttings and the generally poor rooting capabilities of aspen clones. Because of its very low survival percentage clone AK41 was considered a failure and was not included in subsequent surveys or analyses.

In early June, 1985, the preemergent herbicide terbacil was applied at 1.1 kg a.i. ha⁻¹ to the South trial at Big Flats to help maintain weed control. Significant defoliation of all hybrid poplar clones was noted soon after treatment, and may have been due to a heavy rain event (6.1 cm in 45 min) which apparently

Table 3-5. Source table from comparing hybrid poplar clone effects on survival, diameter growth and canker severity; fifth growing season.

Source of variation	Degrees of freedom	Sum of squares	F-statistic	Observed significance level
<u>Test of survival</u>				
Heiberg Forest:				
Clone	9	5.999	9.99	<.01
Error	20	1.335		
Big Flats -- North:				
Clone	2	0.279	1.40	<.01
Error	6	0.597		
Big Flats -- South:				
Clone	4	0.664	2.19	0.14
Error	10			
<u>Test of diameter growth</u>				
Heiberg Forest:				
Clone	9	36.790	4.41	<.01
Error	20	18.532		
Big Flats -- North:				
Clone	2	58.429	23.65	<.01
Error	6	7.411		
Big Flats -- South:				
Clone	4	14.094	2.20	0.14
Error	10			
<u>Test of canker severity</u>				
Heiberg Forest:				
Clone	9	8.328	9.87	<.01
Error	20	1.874		
Big Flats -- North:				
Clone	2	1.748	10.15	0.01
Error	6	0.517		
Big Flats -- South:				
Clone	4	5.686	14.25	<.01
Error	10	0.998		

1/ Analysis of variance with a completely randomized design model (three replications) was used to test clone effects; alpha = 0.05, n=108.

Table 3-6. Survival percentages for the hybrid poplar clones grown at Big Flats and Heiberg Forest.

Clone	Survival percentage					
	1984	1985	1986	1987	1988	1989
<u>Heiberg Forest:</u>						
NM5	-	98	96	96	95	97 a
DN2	-	95	93	92	92	94 ab
DN30	-	94	94	93	90	89 abc
DN128	-	94	92	91	92	92 ab
DN106	-	86	84	84	84	85 bc
DN33	-	85	84	84	87	87 abc
DN149	-	79	74	74	72	74 c
DTAC7	-	72	71	70	76	75 c
JAC4	-	56	56	55	54	53 d
DN173	-	45	43	42	41	43 d
Average:	-	80	79	78	78	79
<u>Big Flats -- North:</u>						
DN1	92	90	80	92	93 a	-
NM1	89	87	87	93	93 a	-
JACN5	89	85	84	81	79 a	-
Average:	90	87	84	89	88	-
<u>Big Flats -- South:</u>						
NM5	76	74	73	72	69 a	-
DN19	68	66	63	69	69 a	-
DN70	63	61	59	56	55 a	-
DN55	58	57	56	47	47 a	-
DTAC8	48	46	45	49	48 a	-
AK41	22	-	-	-	-	-
Average:	63 ^{2/}	61	59	59	58	-

1/ Fifth year means within a clone-site trial area with the same letter are not statistically significantly different (Duncan, alpha=0.05).

2/ Clone AK41 was not included in this average. A hyphen designates that not measurements were taken.

caused the herbicide to leach into the poplar rooting zone. No mortality was attributed to this treatment and the trees were able to refoliate within a few weeks.

During July, 1985, a severe rain and hail storm passed over the Big Flats North Block, causing extensive defoliation and wounding to the poplar trees. Bark (~ 50 %) and some wood on the northwest side of each tree was severely shredded. Fifty percent defoliation was caused by the impact of hail. By August 1985, the trees had refoliated and callus tissue had begun to form over stem and branch lesions. Effects of the storm on tree growth were indiscernible (no control situation to compare tree growth) and trees seem to have fully recovered by Summer, 1986.

By late summer of the first growing season numerous trees had been browsed by deer in the north block at Big Flats and Heiberg Forest (Table 3-7). Big Flats' south block was not appreciably browsed, most likely because it was not located near wooded areas. Damage from deer browse was observed for all clones for the 2 years it was measured (Table 3-7) and appeared to have directly affected survival and growth at Heiberg Forest. The most impacted deer browse clone 2 years after planting was also the clone that had lowest survival.

Verch (1979) indicated that there is a deer browse preference for certain clones. From the current study data, the relationship between clone growth and deer browse preference and intensity can not be determined primarily because of the study design; i.e., some clones were located closer to favored deer areas making these trees more susceptible to browsing. Heavy deer browse occurred on clones along the edges of the plantations, especially in corners

Table 3-7. Percent of trees damaged by deer during the first and second growing seasons at the Big flats and Heiberg Forest clone-site trials.

Clone	Percent damage		
	1984	1985	1986
<u>Big Flats-North:</u>			
JACN5	57	22	-
DN1	63	13	-
NM1	40	1	-
AK41	21	-	-
<u>Heiberg:</u>			
DN106	-	95	1
DN173	-	90	44
DN33	-	80	12
DN2	-	77	2
DN30	-	77	1
DN128	-	77	10
DN149	-	75	6
DTAC7	-	58	1
NM5	-	56	1
JAC4	-	54	8

1/ First year after planting trees were recorded as damaged if any portion of the tree was browsed. Second year after planting trees were recorded as damaged if height growth was affected by browsing; side branch browsing was not recorded.

A hyphen indicates that the trees were not measured.

where other cover (surrounding mature forest) was accessible.

Diameter Growth

Total dbhob was significantly affected by clone, except in the South trial at Big Flats (Table 3-5 and 3-8). Mean annual increment at Big Flats-North, Big Flats-South and Heiberg Forest ranged from 2.5 to 5.6, 2.8 to 4.1 and 1.3 to 3.0 cm, respectively. These values were comparatively high at Big Flats and low to average at Heiberg Forest for young hybrid poplars in Eastern North America (Zsuffa et al. 1977; Dickmann and Stuart 1983).

Canker Incidence

There was a significant clone effect on canker incidence for all clone-site trials (Table 3-5 and 3-9). On Heiberg Forest, incidence appeared to increase over time, but on Big Flats North it decreased. This increase and decrease may be accounted for in measurement errors, which may have changed from year to year as technical personnel changed. Another possible explanation for the decrease in canker incidence is that the infected trees may have healed over some cankers. This has been observed in the field, with the ability to "heal" canker damage appearing to be clone and site specific, most likely related to growth rate. It appeared that the slower growing species were able to heal most effectively.

Comparison of NM5 Across Sites

Comparison of clones across sites is generally not possible because different clones were used for the different sites; the exception is clone NM5. In both the Heiberg Forest and Big Flats

Table 3-8. Diameter at breast height for the hybrid poplar clones at Big Flats and Heiberg Forest; fifth growing season.

Clone	Diameter at breast height ^{1/}
- - - - cm - - - -	
<u>Heiberg Forest:</u>	
NM5	15.5 a
DTAC7	14.2 ab
DN2	12.2 abc
DN30	11.4 abcd
DN106	10.9 abcd
DN128	10.9 abcd
DN149	9.7 bcde
JAC4	8.6 cde
DN33	6.9 de
DN173	6.1 e
<u>Big Flats -- North:</u>	
NM1	28.4 a
DN1	17.8 b
JACN5	13.0 b
<u>Big Flats -- South</u>	
NM5	20.3 a
DTAC8	17.8 ab
DN19	16.8 ab
DN55	14.2 ab
DN70	13.5 b

^{1/} Means within a clone-site trial area with the same letter are not significantly different (Duncan, alpha=0.05).

Table 3-9. Canker incidence for the hybrid poplar grown at Big Flats and Heiberg Forest.

Clone	Mean number of cankers per tree ^{1/}		
	1987	1988	1989
<u>Heiberg Forest</u>			
DTAC7	0.87	0.54	2.13 a
DN106	0.77	0.30	1.13 b
JACN	0.07	0.06	0.83 bc
DN173	0.07	0.05	0.59 bc
NM5	0.09	0.06	0.45 c
DN33	0.00	0.00	0.43 c
DN2	0.05	0.04	0.43 c
DN149	0.08	0.05	0.39 c
DN30	0.08	0.03	0.39 c
DN128	0.03	0.00	0.35 c
Average:	0.22	0.12	0.71
<u>Big Flats -- North</u>			
DN1	0.19	0.19 b	-
NM1	1.30	1.04 a	-
JACN5	0.78	0.03 b	-
Average:	0.76	0.42	
<u>Big Flats -- South</u>			
DN19	2.75	2.04 a	-
NM5	1.81	1.95 a	-
DN55	1.04	1.03 b	-
DTAC8	1.70	0.66 b	-
DN70	0.33	0.63 b	-
Average:	1.53	1.26	

^{1/} Means within a clone-site trial area with the same letter are not statistically significantly different (Duncan, alpha=0.05).

trials NM5 grew relatively well. However, in the Big Flats trial, where soil conditions were inherently better for the growth of hybrid poplar, NM5 outperformed the same clone grown under similar cultural systems but different soils and environment at Heiberg Forest (Figure 3-1).

There were important specific differences between Heiberg Forest and Big Flats in inherent soil conditions. Soil pH at Heiberg Forest was 5.3, below the preferred range of 6.5-8.5 for optimum hybrid poplar growth. Additionally, rooting depth was relatively shallow for hybrid poplar on the Mardin soil, 30 to 45 cm compared with a recommended depth of > 75 cm. Conversely, soil pH and rooting depth at Big Flats-North were 6.6 and 137 cm, respectively.

Intense soil erosion occurred at Heiberg Forest during the first year after planting. Sheet erosion, due to the sloping topography, exposed geographic position, soil physical properties, and the fact that the site was clean cultivated, caused the erosion problem. Soil loss, calculated using the Universal Soil Loss Equation (Dissmeyer et al. 1980), was estimated to have been 130 to 157 MT ha⁻¹ yr⁻¹ with losses of N, P and K estimated at ~ 445, 1 and 12 kg ha⁻¹. This loss in essential nutrients, especially N, could have impacted hybrid poplar growth at Heiberg Forest. Fertilization would have compensated for these erosional nutrition losses. A no-till program, where dead weed vegetation remains on site and no plowing is done during site preparation, could have been used to reduce erosional losses (McKittrick et al. 1986; Oyler et al. 1986).

Figure 3-1. Cumulative diameter growth (CD), mean annual increment (MAI) and current annual increment (CAI) for hybrid poplar clone NM5 grown in clone-site trials on two different sites.

Growth Potential

Accurate assessment of growth potential requires measures that collectively represent factors important and directly related to both present and future growth. The conjunctive use of canker severity and total growth indices incorporates numerous important factors, including survival and growth, and provide a measure of relative growth potential that is indicative of future productive capacity.

Figure 3-2 depicts canker severity index versus total growth index and shows relative growth potential of the hybrid poplar clones within each clone site trial. Clones NM1 and DTAC8 had the greatest growth and lowest canker severity for the North and South clone-site trials at Big Flats; for Heiberg Forest it was clone NM5. These clones are judged as having the greatest potential for future growth and are conditionally recommended for further testing and limited operational planting.

Interpretations of the growth potential ratings need to be qualified. Because all recommended clones had relatively high incidence of canker, these clones can be only conditionally recommended for planting with rotations kept at a length (5 to 10 years or less) that would minimize production losses through canker related problems (e.g., stem and branch breakage). While it may be possible to obtain relatively high production using clones with moderately high canker incidence, it is likely that coppiced second and third rotation plantations will have even higher incidence of canker disease and concurrent lower productivity. Additionally, inclusion of these clones in operational plantation may provide an canker infection source for

Figure 3-2. Relative growth potential of hybrid poplar clones grown in three clone-site trials.

adjacent hybrid poplar. Breeding programs that develop clones resistance to stem and branch cankers provide the best solution.

CONCLUSIONS

Results of these clone-site trials demonstrate that hybrid poplar can be successfully established and maintained in New York State, and other areas in the northeastern United States with similar climate and physiography. Intensive management practices are needed, including mechanical and chemical site preparation and tending. Relative growth potential was shown to be related directly to individual clones, primarily responsiveness to site conditions.

While study objectives were met, there is still much research that needs to be done, including refinement and expansion of existing techniques, development of efficient and effective cultural tools (e.g., fertilization), planting and harvesting mechanics, further development of disease resistant clones and exploration of markets for the wood products are needed before the fast-growing hardwood system can be operationally employed. However, as research continues, we currently have the knowledge to begin using this system.

Section 4

RESPONSE OF HYBRID POPLAR TO NO-TILL SITE PREPARATION

INTRODUCTION

The initial site preparation practice of clean cultivation has been used to successfully establish hybrid poplar in short-rotation plantations. However, this practice may not be practical for some sites, especially those that are potentially erosive due to sloping topography and soil condition. For example, approximately 160 MT ha⁻¹ of soil was lost the first year after planting hybrid poplar on a Mardin silt loam soil with 13 % slope that was clean cultivated and maintained weed-free (80 %) in central New York (Section 3). No-till site preparation techniques may have reduced this erosion without a loss in production.

No-till is the practice of using herbicides to solely control weeds during site preparation and maintenance operations. The objective of no-till is to keep site disturbance to a minimum allowing organic matter to stay on the surface of the site. Surface organic matter is a major factor in reducing soil erosion potential.

Most studies with no-till techniques have been done with traditional agronomic crops. Therefore, there is little evidence regarding the response of hybrid poplar to no-till site preparation. The objective of the current study was to compare hybrid poplar growth under clean cultivated, no-till and live sod (control) site preparation so as to determine if the no-till technique is a viable option for the intensive culture of hybrid poplar in New York State.

MATERIALS AND METHODS

Study Area

The study area was located in the Chemung River Valley in the Southern Tier of New York State, at the United States Department of Agriculture Soil Conservation Service's Big Flats Plant Materials Center, Corning, New York ($42^{\circ} 07' N$, $76^{\circ} 52' W$). This site was described in Section 3.

The soil type was a Tioga silt loam (Dystric Fluventic Eutrochrept) (Pearson et al. 1973). The area was under sod for at least five years prior to planting with the principal grasses including red fescue (Festuca rubra L.), tall fescue (Festuca arundinacea Schreb.) and quackgrass (Agropyron repens L.).

Experimental Treatments

Three site preparation treatments were used: clean cultivated, no-till, and live sod (control). These treatments were randomly applied (two replicates) in two separate areas. Each area was considered as an individual experiment and differs by the clone type used.

Site preparation treatments were completed in May 1984. The no-till plots were treated using a hand sprayer with simazine and paraquat at 2.2 kg a.i. and 2.3 l ha^{-1} , respectively. Cultivated plots were plowed, disked once and capped with 1.7 kg a.i. ha^{-1} of simazine. Live sod control plots received no site preparation.

Planting

Unrooted 25-cm-long cuttings of hybrid poplar clones DN55 and DN70 (Populus deltoides x P. nigra for both clones) were planted during the period May 24-June 14, 1984, flush with the soil surface at 1 X 1 m spacings. The outside border row, considered a buffer that was not to be included in subsequent measurements, was planted with DN70 for all plots. Plot size was 8 X 9 m.

Tending

Weed control in clean cultivated and no-till plots was done in 1984 using a rope wick application of glyphosate at 0.5 kg a.i. ha⁻¹ and a mechanically sprayed application of sethoxydim at 0.2 kg a.i. ha⁻¹. During the spring, 1985, advance weed vegetation was cut by hand to promote growth, and sprayed during June with glyphosate at 1.1 kg a.i. ha⁻¹. Cultivated plots were rototilled in mid-June. An additional treatment of simazine at 0.5 kg a.i. ha⁻¹ was applied to both no-till and cultivated plots. Regrowth of difficult-to-control weeds, particularly nutsedge, was treated with an application of terbacil at 2.5 kg a.i. ha⁻¹ during mid-July on the cultivated plots. This application of terbacil caused damage (defoliation, stunting) to the trees. Severe thunderstorms (61 mm in 45 min) immediately followed the terbacil application and apparently carried the herbicide into the rooting zone. Immediate apparent damage to trees (leaf wilt) on the cultivated plots prevented the use of terbacil in the no-till areas. The trees survived the herbicide damage, but cultivated DN70 failed to grow in height for the

remainder of the 1985 season.

During the 1984, 1985 and 1986 dormant season all multiple stem trees were cut at ground level except for one main stem from each stool. This was done to concentrate growth on one stem only.

Field Measurements

The center 30 trees of each plot were measured for survival and total height growth during late September-early October, 1984, 1985 and 1986. Additionally, diameter at 10 cm above groundline was measured during late-September-early October in both 1985 and 1986. Measurement data is provided in Appendix A4-1 through A4-6.

Statistical Procedures

Analysis of variance for a completely randomized design was used to test the effect of site preparation technique on survival, height, diameter and volume growth for each of the clones (Snedecor and Cochran 1980). Survival percentages were transformed to stabilize the variances using an arcsin transformation procedure (Neter and Wasserman 1974). Volume was calculated as a cone: $V = 3.1416 * r^2 * ht / 3$; where V is the volume (cm^3), r is the radius of the base of the tree (cm), and ht is height of the total stem (cm). When main effects were significant, means were separated using Duncan's Multiple Range Test ($\alpha=0.05$; Chew 1976). All statistical analyses were done using the SAS (SAS Institute, Inc. 1985) computer software system.

RESULTS AND DISCUSSION

Survival and Height, Diameter and Volume Growth

Survival percentages for the two clones are presented in Table 4-1. Trees growing in cultivated and no-till site preparation had good survival (>90 %) for the four-year study period; live sod treated DN70 trees did not. Only 12 % of DN70 trees survived until the third year after planting. The importance of weed control in successful growth of hybrid poplar was clearly demonstrated by these results.

Height and diameter growth for clones DN55 and DN70 during the four-year study period is shown in Figure 4-1 and Table 4-2, respectively. Cultivated and no-till trees had significantly greater height and diameter growth than trees planted in live sod. After three years growth, trees on the no-till treatment had significantly greater height growth than trees on the cultivated plots. It should be noted that interpretations of these results are complicated by the herbicide-induced tree damage on cultivated plots that occurred during July 1985. While growth rates of these trees were altered, results as a function of site preparation technique are still strikingly apparent and interpretations of these can be validly made.

Table 4-3 shows volume produced on a measurement plot area (0.003 ha) basis for both clones. Clone DN55 showed no significant difference between cultivated and no-till treatments for the 1986 measurement period. Live sod plots had significantly less volume than cultivated and no-till. For clone DN70, estimates of volume appear biased by the herbicide damage to

cultivated plot trees. Even so, the live sod trees are smaller than both the cultivated and no-till trees.

Table 4-1. Three-year survival for two hybrid poplar clones grown under different site preparation and tending programs.^{1/}

Clone ^{2/}	Year	Cultivated	No-till	Live sod
- - - - - % - - - - -				
DN55	1984	100a	87 ^a	92ab
	1985	100a	87 ^b	92ab
	1986	100a	87b	78b
DN70	1984	100a	93b	40c
	1985	100a	93b	40c
	1986	93a	90a	12b

^{1/} Means within a year, within a clone, with the same letter are not significantly different (Duncan's; alpha=0.05).

^{2/} Clones DN55 and DN70 are both Populus deltoides x P. nigra crosses.

Table 4-2. Second- and third-year mean total diameter growth (10 cm above groundline) for two hybrid poplar clones grown under different site preparation and tending programs.^{1/}

Clone ^{2/}	Year	Cultivated	No-till	Live sod
		- - - - - cm - - - - -		
DN55	1985	3.3a	2.8a	0.5b
	1986	5.3a	5.4a	1.0b
DN70	1985	2.6a	3.4a	0.3b
	1986	4.7b	5.7a	0.7b

^{1/} Means within a year, within a clone, with the same letter are not significantly different (Duncan's; alpha=0.05).

^{2/} Clones DN55 and DN70 are both Populus deltoides x P. nigra crosses.

Table 4-3. Third-year plot volume estimates for two hybrid poplar clones grown under different site preparation and tending programs.^{1/}

Clone ^{2/}	Cultivated	No-till	Live sod
	- - - - - cm ³ plot ⁻¹ - - - - -		
DN55	106740a	104234a	981b
DN70	61515ab	122401a	48b

1/ Means within a clone with the same letter are not significantly different (Duncan's; alpha=0.05). Plot size =0.003 ha.

2/ Clones DN55 and DN70 are both Populus deltoides x P. nigra crosses.

Figure 4-1. Yearly total mean height for two clones grown under different site preparation and tending programs. Bars within a clone, within a year, with the same letter are not significantly different ($\alpha=0.05$, Duncan's).

Section 5

NUTRIENT ACCUMULATION AND UTILIZATION EFFICIENCY IN MINI-ROTATION HYBRID POPLAR PLANTATIONS

INTRODUCTION

Mini-rotation forestry, as defined by the Fast Growing Forests Program, Ontario Ministry of Natural Resources, is the application of agronomic crop production practices to the culture of fast-growing hardwoods, primarily from the genera Populus and Salix. Plantations are established at 35,000 trees ha⁻¹ and coppice production is harvested every two to five years. Expected maximum productivity from mini-rotation forestry with hybrid poplar is 16.0 oven dry tonnes ha⁻¹ yr⁻¹ (Raitanen 1980). Because of the large amount of biomass produced, the nutrients removed during harvesting may lead to eventual nutrient depletion, even on the most fertile sites (Boyle and Ek 1972; White 1974).

The objectives of the study were to estimate biomass and nutrient accumulation, distribution and nutrient utilization efficiency, and site nutrient depletion from harvesting three-year-old hybrid poplar. To accomplish these objectives, three hybrid poplar clones growing in a short-rotation system were harvested during "foliage on" and foliage off" periods and analyzed for biomass, nutrient accumulation, within tree nutrient transfer and cycling, and nutrient utilization efficiency (Ulzen-Appiah 1987).

METHODS AND MATERIALS

Study Area

The study was located near Brockville, Ontario in the Edwardsburg Land Assembly, on field trial sites of the Fast Growing Forest Group of the Ministry of Natural Resources, Ontario, Canada. The soil was a Guelph series developed on low-lime, stone-free, sandy outwash materials of variable moisture relations.

Site preparation

Site preparation was completed during the period June 28-July 14, 1980. The area was plowed and doubled-disked to incorporate Eptam (EPTC, S-ethyl dipropylthiocaramate) at 8.8 kg a.i. ha⁻¹. After leveling the site with a midwestern harrow, a simazine cap was applied at 4.0 kg a.i. ha⁻¹ to prevent weed reinvasion.

Planting

The following hybrid poplar clones were used for the study: DN70 (Populus deltoides X P. nigra); DTAC2 (P. angulata X berolinensis); and NM6 (P. nigra X P. Maximowiczii). Unrooted 25-cm-long cuttings were planted flush with the soil surface during April 1981, at a spacing of 1.0 X 0.3 m; a total of 35,864 trees ha⁻¹. Study plantations were 0.05, 0.06, and 0.20 ha in size for clones DN70, NM6, and DTAC2, respectively.

Tending

First-year tending was done to provide an 80% weed-free environment. This involved the shielded application of glyphosate at 2.2 kg a.i. ha⁻¹ during July and August 1981, and terbacil at 1.0 kg a.i. ha⁻¹ during September and October 1981, to all areas of weed growth.

Field Sampling

The plantations were sampled in late August and November, 1983, corresponding to "foliage on" and "foliage off" harvests, respectively. Total tree sampling procedures were employed on four 3 x 3 m randomized plots established within each plantation. Six trees were sampled for nutrient concentration determinations. These trees were systematically selected, severed at groundline, measured for total height and basal diameter outside bark, separated into component parts and bagged. All remaining trees on each plot were severed at the groundline, measured for total height and basal diameter, separated into component parts and bagged for biomass estimation.

Two soil pits were randomly located and constructed in each subplot (n=8 for a clone). Representative soil samples were taken from the 0-15 and 15-30 cm depth zone. These samples were placed in paper bags and allowed to air dry. Bulk density samples were taken using a metal core sampling cylinder.

Field measurement data is presented in the Appendix.

Laboratory Analysis

All tissue samples were oven-dried (60° C) to constant weight, weighed, and ground to pass through a 1 mm stainless steel sieve. Nitrogen was determined by macro-Kjeldahl method. Subsamples of ground material were dry ashed at 470° C, with the ash taken up in dilute HCL. Aliquots of these solutions were used to colorimetrically determine P concentration and K, Ca, and Mg concentrations were determined by atomic absorption spectrophotometry (Wilde et al. 1979; Bickelhaupt and White 1982).

Soil samples were air-dried, sieved to pass through a 2 mm sieve and subsampled for moisture content determination. Total soil N (macro-Kjeldahl), extractable P (Troug 1930), exchangeable K, Ca, Mg (1N NH_4OAc ; pH 7.0), soil texture (modified Bouyoucos hydrometer method), uncorrected bulk density, pH (1:2 soil:water paste, glass electrode), and percent organic matter (dry oxidation) were determined and expressed on a dry weight basis (Wilde et al. 1979; Bickelhaupt and White 1982).

Statistical Analyses

Component part nutrient concentrations were weighted by component biomass so as to minimize the influence that tree size had on nutrient concentrations over time. Calculation of nutrient content was done by multiplying tree component dry mass by element concentration. Area estimates of element content were done by summing the individual tree component contents and dividing by the measurement area.

The effect of clone type and sampling period on tree height,

basal diameter, aboveground biomass, and component part nutrient concentration and content were tested using analysis of variance with a completely randomized design ($\alpha=0.05$) (Snedecor and Cochran 1980). If effects were significant, Scheffe's method was used to separate means (Chew 1976).

RESULTS AND DISCUSSION

Growth and Biomass Production

Soil physical and chemical properties within the rooting zone of each plantation indicated that the clones occupied similar sites in terms of fertility and potential productivity (Tables 5-1).

Three years after planting, tree height and basal diameter were significantly different among the hybrid poplar clones (Table 5-2). Clone NM6 was taller and had larger basal diameters than clones DTAC2 and DN70. Mean annual height and basal diameter growth for the "best" performing clone, NM6, were 1.5 m and 11 mm, respectively, which compared favorably with mean annual height and diameter increases of 1 to 2 m and 10 to 30 mm, respectively, reported by Zsuffa et al. (1977) for hybrid poplars in eastern Ontario.

Total and component biomass differed significantly among clones in August and November (Table 5-2). Total aboveground biomass harvested in August was 5, 13, and 25 oven dry (od) MT ha⁻¹ for clones DN70, DTAC2, and NM6, respectively. Clone DN70 had a greater proportion of total biomass in foliage and branches compared to clones DTAC2 and NM6. Clones DTAC2 and NM6 had

Table 5-1. Mean soil properties of plots supporting plantations of hybrid poplar clones in eastern Ontario, Canada.

	Clone		
	DN70	DTAC2	NM6
Texture	loam to sandy loam	sandy loam	sandy loam to loamy sand
Structure	weak to moderate	moderate	moderate
Bulk density	1.34	1.38	1.32
Drainage	imperfect to moderately well	imperfect	imperfect
Organic matter (%)	5.4	5.0	5.7
pH	6.7	7.1	6.6
CEC (meq)	16.3	15.6	14.2
N (kg ha ⁻¹)	6262	6598	6765
P (kg ha ⁻¹)	188	282	112
K (kg ha ⁻¹)	976	583	505
Ca (kg ha ⁻¹)	26773	47164	23345
Mg (kg ha ⁻¹)	6412	2547	4526

Table 5-2. Mean total height, basal diameter, and component dry biomass of 3-year-old hybrid polar clones grown in a mini-rotation system.

Variable ^{1/}	Clone		
	DN70	DTAC2	NM6
<u>August:</u>			
Height(m)	1.9 c (0.05)	3.1 b (0.07)	4.4 a (0.10)
Basal diameter(mm)	19.1 b (0.54)	24.4 b (0.77)	32.6 a (0.97)
Biomass(kg ha ⁻¹)			
Foliage	1251 c	2534 b	4338 a
Branch	1168 b	1984 b	4298 a
Stem	2312 c	8631 b	16372 a
Total	4731 c	13149 b	25008 a
Biomass distribution(%)			
Foliage	26	19	17
Branch	25	15	17
Stem	49	66	66
<u>November:</u>			
Height(m)	1.8 c (0.04)	3.1 b (0.08)	4.3 a (0.76)
Basal diameter(mm)	17.6 b (0.42)	23.9 b (0.12)	30.1 a (0.96)
Biomass(kg ha ⁻¹)			
Branch	799 b	1677 b	3897 a
Stem	2187 c	8545 b	15618 a
Total	2988 c	10222 b	19515 a
Biomass Distribution(%)			
Branch	27	16	20
Stem	73	84	80

^{1/} Mean values within a row, within a variable, followed by the same letter are not significantly different (P<0.05; Scheffe's). Numbers in parentheses are standard errors.

greater proportion of total biomass in stems than clone DN70 in August.

The November harvest yielded total aboveground biomass of 3, 10, and 20 od MT ha⁻¹ for clones DN70, DTAC2, and NM6, respectively (Table 5-3). Mean annual biomass production of the best performing clone, NM6, at age three years, was only 50% of the projected maximum mean annual biomass production of 16.0 MT ha⁻¹ yr⁻¹ from mini-rotation production systems (Raitanen 1980). The lowest biomass-producing clone, DN70, produced only 10% of the projected mean annual biomass production from mini-rotation production systems.

Biomass production in mini-rotation production systems is primarily related to genetic material, site quality, and intensity of management. Evers et al. (1983) attributed wide variations in yields from mini-rotation production trials in eastern Ontario to variations in intensity of management applied, limited knowledge of genetic material best suited for high density plantations, and specific site conditions. Hybrid poplar clones involved in this study were located on similar sites and received the same management practices. Hence, clonal differences in tree height and basal diameter, and aboveground biomass accumulation and distribution, can be directly related to clonal differences in suitability (as expressed by growth) to a specific site and plantation density.

Nutrient Concentration Changes

There was evidence that transfer and recycling of macronutrients within trees took place during the sampling period (August-November). Results of the comparison of component nutrient concentrations between August and November samples are provided in Table 5-3. Increased concentration of nutrients in November branch and stem samples most likely was the result of nutrient translocations from senescing leaves. Similarly, reduced concentrations of nutrients in November branch and stem samples may be the result of nutrient translocation from branches and stems to roots.

Nutrient concentration changes in component tissues over time can occur as a result of numerous factors, including: 1.) translocation into or out of tissues; 2.) leaching losses; and/or 3.) dilution due to growth. Dilution effects were minimal between sample periods because component and total dry weights did not significantly differ between August and September sampling periods. Therefore, nutrient concentration changes in branch and stems were most likely due to internal cycling-transfer and/or leaching losses.

Nutrient Content Accumulation and Distribution

Nutrient content accumulation followed trends similar to biomass accumulation and allocation to tree components. Total and component nutrient content accumulations in August and November were significantly greater for clone NM6 than for clone DTAC2, which were significantly greater than for clone DN70 (Table 5-4). More nutrients accumulated in foliage than in stems

Table 5-3. Hybrid poplar clone nutrient concentrations in August and November branch and stem samples.

Component	Weighted Concentration			
	August (a)	November (b)	Change (c=b-a)	% Change (c/a x 100)
<u>Clone DN70:</u>				
	-----% N-----			
Branches	0.46	0.75	0.29*	63
Stems	0.31	0.56	0.26*	81
	-----% P-----			
Branches	0.045	0.074	0.029	64
Stems	0.035	0.043	0.008	23
	-----% K-----			
Branches	0.52	0.48	-0.04	-8
Stems	0.33	0.28	-0.05	-15
	-----% Ca-----			
Branches	0.98	1.21	0.23*	23
Stems	0.65	0.74	0.09	14
	-----% Mg-----			
Branches	0.24	0.27	0.03	13
Stems	0.15	0.18	0.03	20
<u>Clone DTAC2:</u>				
	-----% N-----			
Branches	0.41	0.64	0.23*	56
Stems	0.22	0.48	0.26*	118
	-----% P-----			
Branches	0.050	0.074	0.024*	48
Stems	0.037	0.050	0.013	35
	-----% K-----			
Branches	0.45	0.52	0.07	16
Stems	0.26	0.32	0.06	23
	-----% Ca-----			
Branches	0.98	0.90	-0.08	-8
Stems	0.45	0.53	0.08	17

Table 5-3. continued.

Component	Weighted Concentration			
	August (a)	November (b)	Change* (c=b-a)	% Change (c/a x 100)
<u>Clone DTAC2:</u>				
	-----% Mg-----			
Branches	0.26	0.24	-0.02	-8
Stems	0.09	0.11	0.02*	22
<u>Clone NM6:</u>				
	-----% N-----			
Branches	0.42	0.54	0.12*	29
Stems	0.26	0.38	0.12*	46
	-----% P-----			
Branches	0.040	0.055	0.015*	38
Stems	0.024	0.039	0.015*	63
	-----% K-----			
Branches	0.37	0.36	-0.01	-3
Stems	0.25	0.26	0.01	4
	-----% Ca-----			
Branches	1.30	1.32	0.02	2
Stems	0.54	0.83	0.29	54
	-----% Mg-----			
Branches	0.18	0.16	-0.02	-11
Stems	0.06	0.08	0.02*	33

* Denotes significant change ($P \leq 0.05$; Scheffe's).

Table 5-4. Component part nutrient contents of
3-year-old hybrid poplar clones.

	Nutrient ^{1/}				
Clone	N	P	K	Ca	Mg
	kg ha ⁻¹				
<u>August:</u>					
	-----Foliage-----				
DN 70	27.3 b	2.1 b	21.8 c	26.7 b	7.2 b
DTAC 2	43.8 b	4.3 ab	37.6 b	71.1 b	19.7 a
NM 6	75.5 a	6.4 a	61.3 a	138.0 a	23.9 a
	-----Branches-----				
DN 70	5.4 b	0.5 b	6.4 b	11.2 b	2.6 b
DTAC 2	8.2 b	1.0 ab	8.9 ab	19.2 b	5.1 ab
NM 6	18.5 a	1.8 a	15.9 a	55.5 a	7.6 a
	-----Stems-----				
DN 70	6.9 b	0.7 b	7.4 c	15.1 c	3.3 b
DTAC 2	19.1 b	3.2 a	22.4 b	39.0 b	8.1 a
NM 6	42.8 a	4.0 a	40.7 a	87.4 a	9.6 a
	-----Total-----				
DN 70	39.6 b	3.3 b	35.6 c	53.0 b	13.1 b
DTAC 2	71.1 b	8.5 a	68.9 b	129.3 b	32.9 a
NM 6	136.8 a	12.2 a	117.9 a	280.9 a	41.1 a
<u>November:</u>					
	-----Branches-----				
DN 70	6.0 a	0.6 b	3.8 c	9.8 b	2.2 b
DTAC 2	10.4 b	1.2 b	8.3 b	15.7 b	4.3 ab
NM 6	21.0 a	2.1 a	13.8 a	49.8 a	6.2 a
	-----Stems-----				
DN 70	12.3 c	1.0 b	6.1 c	16.5 b	3.8 b
DTAC 2	40.2 b	4.3 a	26.7 b	45.1 b	9.5 a
NM 6	59.0 a	6.1 a	40.7 a	134.0 a	12.1 a
	-----Total-----				
DN 70	18.3 c	1.6 b	9.9 c	26.3 b	6.0 b
DTAC 2	50.6 b	5.5 a	35.0 b	60.8 b	13.8 a
NM 6	80.0 a	8.2 a	54.3 a	183.8 a	18.3 a

^{1/} Component and total nutrient content of clones within a column, within a component part, followed by the same letter are not significantly different ($P \leq 0.05$; Scheffe's).

or branches in the "foliage on" harvest. For "foliage off" harvest, stems accumulated more nutrients than branches. Higher accumulations in foliage were due to higher nutrient concentrations. Stem nutrient accumulations were higher than branch because of the higher proportion of biomass in stems.

Nutrient Utilization Efficiency

Comparison of nutrient utilization efficiency (kg dry matter/kg of nutrient) for the three clones is shown in Table 5-5. Utilization efficiency of P and Ca during August did not significantly differ among the clones, but N, K and Mg did. Nutrient utilization efficiency was greater in November as compared to August. November utilization efficiency of P did not significantly differ among clones, but N, K, Ca and Mg did.

Nutrient utilization efficiency followed trends similar to growth and yield performances. Clone NM6 had the highest biomass accumulation and was the most nutrient efficient, followed by DTAC2 and DN70.

Compared to utilization efficiencies in older intensive culture plantations (Blackmon et al. 1979; Hansen and Baker 1979), utilization efficiency in these relatively young plantations was much lower. This may be due to the fact that young trees have higher nutrient concentrations in tree components than older trees, and that a relatively large proportion of young tree biomass is in higher concentration component parts; e.g. branches and foliage.

Nutrient efficiency has important implications in short-rotation plantations. Nutrient-efficient clones would produce as

Table 5-5. Nutrient utilization efficiency of 3-year-old hybrid poplar clones sampled during August and November.^{1/}

Clone	Utilization Efficiency (kg kg ⁻¹)				
	N	P	K	Ca	Mg
<u>August:</u>					
DN70	120 b	1670 a	142 b	88 a	361 b
DTAC2	186 a	1604 a	191 a	102 a	400 b
NM6	186 a	2072 a	211 a	90 a	608 a
<u>November:</u>					
DN70	163 c	1981 a	289 b	116 b	497 c
DTAC2	200 b	1870 a	299 ab	169 a	769 b
NM6	245 a	2434 a	360 a	114 b	1069 a

^{1/} Utilization efficiency is kg of dry matter/kg of nutrient. Utilization efficiency of a clone within a sample period followed by the same letter are not significantly different ($P \leq 0.05$; Scheffe's).

much biomass as other clones but accumulate less nutrients. As such, nutrient depletion and need for fertilization would be a more critical problem with less efficient clones. Conversely, with the potential for increased application of municipal and industrial sludge in forests, nutrient inefficient clones may be more desirable because they would utilize more heavy metals, etc., than non-efficient clones, removing potentially toxic substances from the soil.

Section 6

WOOD QUALITY ANALYSES OF HYBRID POPLAR CLONES GROWN IN CENTRAL AND SOUTHERN NEW YORK

INTRODUCTION

Utilization of hybrid poplar is dependent on chemical composition of the wood, which is directly a function of both genetic structure and environmental conditions. Evaluation of the suitability of various hybrid poplar clones, grown under specific site conditions, as feedstock substrate for a variety of end products is necessary if intensive plantation systems are to be optimally efficient and effective.

Wood quality analyses were conducted on hybrid poplar clones grown in clone-site trials in central (Heiberg Memorial Forest, Tully) and southern (Big Flats Plant Material Center, Corning) New York. Study sites and planting material were previously described in Section 3. Sample materials were 1- and 2-year-old fresh bolewood harvested during the dormant season from the Heiberg and Big Flats clone-site trials, respectively. The analyses performed included: moisture, ash, extractives, lignin, and alpha-cellulose. These analyses were done to evaluate the effect of clone and site condition on the chemical composition of wood.

MATERIALS AND METHODS

Laboratory Procedures

Moisture content was determined for the wood samples using TAPPI method T264 om-82 (TAPPI 1982). The wood stems were cut into disks using a band saw, dried for 12 hr at 105° C and weighed.

Ash content was determined following the TAPPI method T211 om-80 (TAPPI 1980). Samples were dry-ashed at 580° C for 4 hr and weighed. Ash was determined for various portions of the stems including: bark alone, wood alone and bark and wood together.

Analysis of percent extractives was done using ASTM method D1107-56 (American Society for Testing and Materials 1979). Both the wood samples and extraction thimbles were air-dried and weighed prior to extraction. A 2:1 benzene:ethanol mixture was used in an Soxhlet extraction apparatus. Extractions were carried out for 6 hr. The samples were weighed subsequent to solvent venting to determine loss due to extractives.

Lignin was determined by a variation of the acid digestion method commonly used for softwoods. Due to the partial solubility of hardwood lignin in acid, use of acid digestion tends to cause an underestimate of lignin content (Johnson et al. 1961). For each sample, approximately 20 mg of air-dried wood was placed in a test tube and 10 ml of 25% acetyl bromide was added. After incubating in a 70° C water bath for 30 min, the wood residue/acetyl bromide mixture was quantitatively transferred to flasks containing NaOH and glacial acetic acid. Additionally, 1.0 ml of 7.5 M hydroxylamine hydrochloride was

added to destroy excess acetyl bromide reagent. The absorbance of partially solubilized lignin was read at 280 nm and total lignin content estimated using known extinction coefficients for poplar lignin.

Alpha-cellulose in the samples was determined using ASTM method D1103-60 (American Society for Testing and Materials 1977). The procedure involved addition of air-dried hollock cellulose to flasks held at 20° C. Additions of 17.5 % NaOH were made at 5, 10 and 15 min from the first addition. Between additions, the wood material was stirred and separated using a glass rod. After a total treatment time of 45 min, distilled water was added to the flasks in order to bring the NaOH concentration to 8.3% and allowed to sit for 1 hr. Alpha-cellulose was quantitatively transferred to fritted glass crucibles and washed with liquids in the following order: 8.3% NaOH, distilled deionized water (DDW), 10% acetic acid and DDW.

RESULTS AND DISCUSSION

Wood quality values for the hybrid poplars are presented in Table 6-1. While sample size limitations precluded statistical analysis of these wood quality values, it is apparent that there is both within site and between clone variation in wood quality. Percent moisture for Heiberg and Big Flats poplar ranged from 97.0 to 127.0, and 36.9 to 182.8%, respectively. The variability between and within sites may be due to sample material age (Heiberg's and Big Flat's material was 1 and 2 years old, respectively), growth rate (material at Big Flats grew at a

Table 6-1. Wood quality values for hybrid poplar clones grown in two clone-site trials.

Clone	Moisture	Ash			Extractives	Lignin	Alpha-cellulose
		Wood	Bark	Wood plus bark			
----- % -----							
<u>Heiberg clone-site trial:</u>							
DN33	127.0	0.50	4.87	1.68	8.70	25.55	36.69
DN30	102.9	1.19	4.88	2.28	10.73	24.68	36.39
NM5	119.0	0.41	1.47	3.37	13.86	23.77	38.50
DN173	97.0	0.82	3.04	1.54	10.61	24.04	36.08
JAC4	113.1	0.38	4.51	3.66	10.58	23.81	38.11
DTAC7	117.2	0.81	4.14	1.74	12.60	25.03	38.14
DN149	116.3	0.57	3.37	1.92	13.04	25.24	38.32
DN128	110.1	0.75	3.77	3.09	13.01	26.31	37.90
DN106	107.8	0.51	4.96	1.69	12.28	23.93	37.74
DN2	119.7	0.79	2.65	3.16	10.93	25.49	37.50
<u>Big Flats clone-site trial:</u>							
DN1	36.9	0.79	5.83	2.02	4.30	23.33	38.57
NM1	72.7	0.75	3.89	0.89	6.06	25.48	39.27
DN70	78.9	0.79	5.54	0.69	8.83	24.27	41.60
JACN5	45.8	0.78	4.21	2.38	-	25.74	41.14
NM5	96.5	0.85	3.85	0.66	10.17	24.49	39.33
DTAC8	88.0	0.72	6.11	1.92	-	25.20	41.46
DN55	85.7	0.72	5.18	0.54	7.18	25.70	42.50
DN19	182.8	0.76	5.59	1.67	-	25.41	40.05

much faster rate; see Section 3) and inherent clonal differences. Ash, lignin and alpha-cellulose percent were more consistent within a specific component (wood, bark, wood plus bark), both between and within sites, but still exhibited a level of variability to indicate that among-clone differences did exist. Extractives appear to be relatively higher for the Heiberg clones compared to Big Flats.

The effect of site condition and material age may be seen by comparing clone NM5, which was grown in both the Heiberg and Big Flats trials. Heiberg NM5 had higher percent moisture, lower ash, higher extractives and generally equal lignin and alpha-cellulose as compared to Big Flats' NM5.

Section 7

MONITORING SOIL SOLUTION CHEMISTRY AFTER INTENSIVE SITE PREPARATION AND TENDING OPERATIONS IN HYBRID POPLAR PLANTATIONS

INTRODUCTION

Intensive cultural systems for fast-growing hardwoods includes clean cultivation and herbicide application during site preparation and tending operations. These techniques, used to provide a competition-free environment (above- and belowground) for hardwood cutting growth, are necessary for the successful establishment and growth of hybrid poplar. Because of the intensive nature of these techniques and the high level of site alteration, soil solution chemistry was sampled for two years after planting in two clone site trials (Big Flats and Heiberg Forest; Section 3) in order to monitor potential movement of selected ions (NO_3 , NH_4 , PO_4) and herbicides after intensive site preparation and tending.

MATERIALS AND METHODS

Lysimeter Installation and Laboratory Analyses

Study areas were previously described in Section 3.

Ceramic cup vacuum lysimeters were installed to allow collection of soil water samples at 60 cm depth; 18 at Big Flats and 9 at Heiberg Forest.

Big Flats soil solution samples were analyzed for NO_3 (Cd reduction method), NH_4 (specific ion electrode), PO_4 (stannous chloride for orthophosphate), Ca, Mg and K (atomic absorption spectrophotometry), and pH (glass electrode), within 48 hr after sampling (American Public Health Association 1965, 1980;

Bickelhaupt and White 1982).

In addition to ion analysis, soil solution samples collected during 1984 and 1985 were analyzed for concentrations of the herbicides terbacil and simazine at Big Flats, and simazine at Heiberg Forest, at the Analytical Laboratories, New York State Agricultural Experiment Station, Cornell University, Geneva, New York. Measured volumes of water were passed through a Waters C-18 Sepak which had been activated with methanol followed by a water rinse. Samples were eluted from the solid phase adsorbant with 2.0 ml of methanol, and the volume reduced to 1.0 ml with N₂. Samples were then analyzed on a Hewlett-Packard Model 5880 capillary gas chromatograph using N-P thermionic detector run in the N mode. Percent recovery for terbacil (94.3 %) and simazine (82.3 %) was considered adequate.

RESULTS AND DISCUSSION

Soil Solution pH and Ion and Herbicide Concentration

Mean ion concentration for each sample collection period at Big Flats are reported in Table 7-1. Calcium, Mg and NO₃ showed a trend of increasing concentration over the sample period. Potassium, P and pH were relatively constant over time. Ammonium nitrate (not reported in Table 7-1) was measured at less than 0.1 ppm for all samples.

Nitrate levels can be attributed to past land use practices, specifically growth of nitrogen fixing crops and breakdown of organic matter turned over during site preparation. Additionally, maintaining a bare soil surface may have resulted

Table 7-1. Soil solution pH and ion concentrations in a 2-year-old clone-site trial of intensively cultured hybrid poplar plantations grown in southern (Big Flats) New York.

Date	pH	Ca	Mg	K	P	NO ₃
- - - - - ppm - - - - -						
<u>North block</u>						
6/21/85	6.9	28.4	5.7	0.77	0.017	4.1
7/10/85	6.9	23.8	6.6	0.82	0.014	8.2
8/7/85	7.0	31.9	5.5	0.97	0.008	17.8
8/24/85	6.8	35.9	4.5	0.72	0.011	16.3
9/19/85	6.3	54.1	7.7	0.54	0.003	24.5
10/11/85	6.8	35.8	6.4	0.70	0.012	27.2
11/29/85	6.3	42.4	7.5	0.53	0.006	31.6
<u>South block</u>						
6/21/85	7.1	43.9	5.6	1.03	0.025	19.5
7/10/85	6.7	52.6	6.4	0.88	0.023	30.1
8/7/85	6.2	64.4	8.0	0.76	0.016	37.4
8/24/85	6.7	49.8	6.8	0.99	0.021	42.0
9/19/85	6.8	36.4	6.3	0.77	0.014	35.9
10/11/85	6.3	53.4	7.0	0.56	0.018	35.9
11/29/85	6.5	56.0	10.6	0.77	0.014	50.1

in higher temperatures and more rapid leaching than on vegetated sites. These conditions, ideal for the mineralization and conversion of organic matter N into NO₃ were determined to be localized. Therefore, groundwater will not be adversely affected. As the breakdown of organic material is completed, NO₃ levels should decrease.

Measurement of herbicide residues indicated that levels were extremely low for both simazine and terbacil, and declined over time (Tables 7-2 and 7-3). The low levels were expected since these herbicides react in the soil by adhering tightly to soil colloids. Biological breakdown certainly accounted for the decline in concentration over time.

Table 7-2. Soil solution herbicide concentrations after intensive site preparation and tending operations in an 1- and 2-year-old hybrid poplar clone-site trial grown in southern (Big Flats) New York.

Date	Terbacil	Simazine
- - - - - ppb - - - - -		
<u>North block:</u> ¹		
July 10, 1984 (n=6)	trace	5.9
August 24, 1984 (n=6)	2.1	2.0
October 11, 1984 (n=2)	<2	0.6
June 25, 1985 (n=3)	<2	0.3
<u>South block:</u> ²		
July 10, 1984 (n=9)	<2	3.6
August 24, 1984 (n=10)	<2	2.0
October 11, 1984 (n=5)	<2	0.2
June 25, 1985 (n=2)	<2	0.2

^{1/} Simazine applied during October 1983, and August and September 1985 at 4.5 and 3.4 kg a.i. ha⁻¹. Terbacil applied during September 1984 at 1.1 kg a.i. ha⁻¹.

^{2/} Simazine applied during October 1983 at 4.5 kg a.i. ha⁻¹. Terbacil applied during June 1985 at 1.1 kg a.i. ha⁻¹.

Table 7-3. Soil solution simazine concentrations after intensive site preparation and tending operations in an 1-year-old hybrid poplar clone-site trial grown in central (Heiberg Forest) New York.

Date (n=8)	Simazine
	- - - ppb - - -
July 19, 1985	8.3
October 22, 1985	1.9

1/ Simazine was applied at 4.5 and 2.2 kg ha⁻¹ during October, 1984, and August, 1985, respectively.

Section 8

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APPENDICES

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