United States
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Research Paper
NC-319

A Guide for Determining When to Fertilize Hybrid Poplar Plantations

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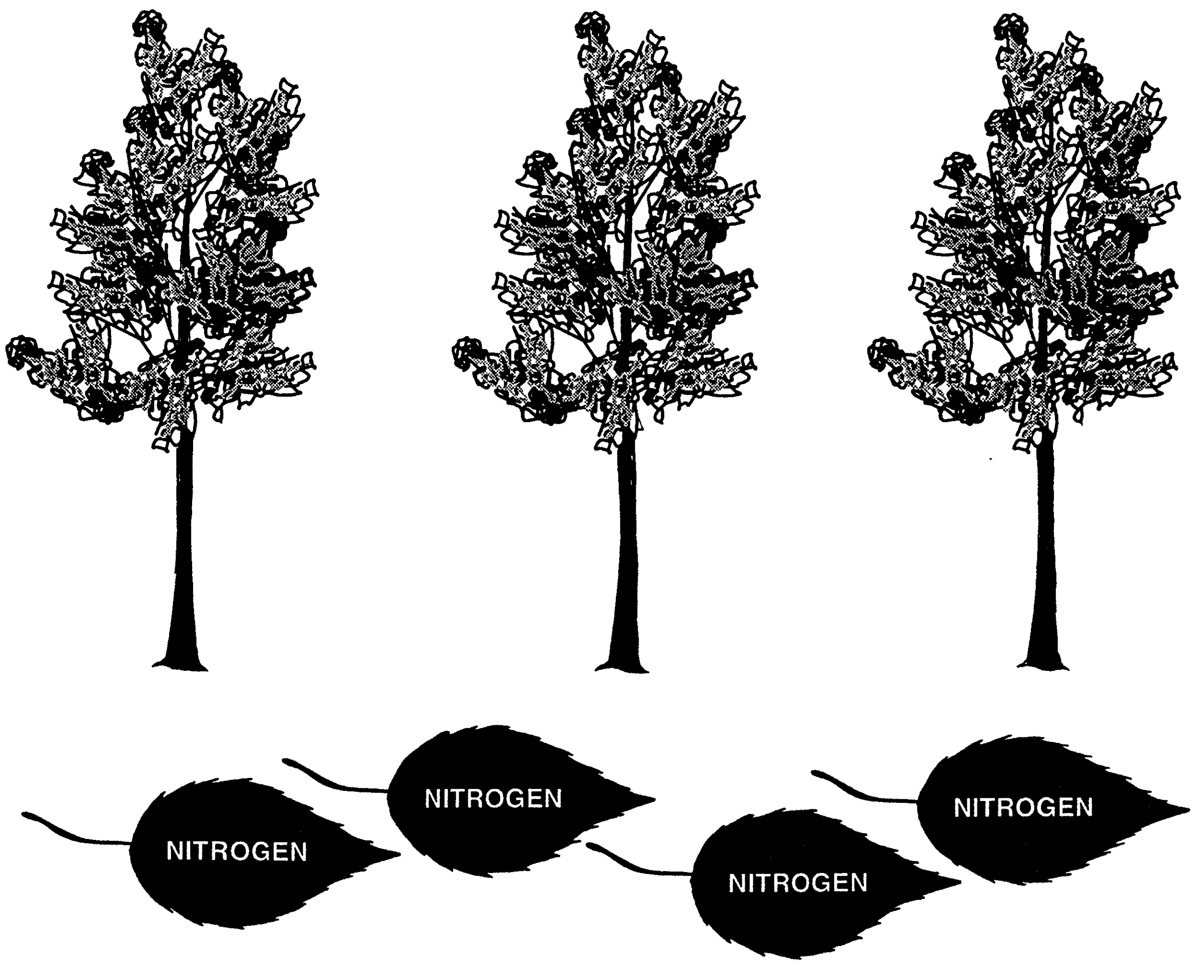

Research partially funded by the Department of Energy under Interagency Agreement #DE-AI05-89OR21871.

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1992 Folwell Avenue
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Manuscript approved for publication July 15, 1994
1994

A Guide for Determining When to Fertilize Hybrid Poplar Plantations

Edward A. Hansen

Hybrid poplar (*Populus* spp.) plantations are of increasing interest as a source of fiber and fuel in the north central U.S. (Brower *et al.* 1993, WesMin RC&D 1993). One area of concern about these plantations is fertilization—how much is needed and how often. But first comes the task of determining **IF** the plantation needs to be fertilized.

Nitrogen (N) has been the nutrient most often deficient in plantation culture of poplars (Blackmon 1976). Consequently, most research on plantation nutrition has emphasized N. The few published fertilizer recommendations suggest that poplar foliar N concentrations in recently matured, mid-season, upper canopy leaves of 2.0 to 2.7 percent indicate N deficiency (Heilman 1993), and that 3.0 percent is the minimum that should be maintained (Hansen *et al.* 1988). Field experience and small-plot fertilizer trials on agricultural sites across the north central region showed that plantations usually had foliar tissue N levels above 3 percent, indicating that fertilization was not necessary (Hansen 1992). Foliage samples taken over a 7-year period at nine widely dispersed sites indicated only one site with low N that warranted fertilization.

Fertilizer guidelines can be based on either soil- or plant-tissue nutrient content (Heilman 1993). However, foliar analysis is often preferred for woody plants (Lavender 1970) and has a long history of use on *Populus* (White and Carter 1970, Blackmon and White 1972, Heilman 1985). Early research results at Rhinelander, WI suggested that foliar tissue was at least as good as soil for determining plantation nutrient status (Hansen *et al.* 1988). The current extent of hybrid poplar plantations in this region can be characterized as a limited number of small plantations located on a wide range of highly variable soils both over a wide area and often within a single field. Consequently, I decided to use foliar tissue analysis as the basis for determining plantation nutrient status because it might provide a more stable assay for determining N needs (Hansen *et al.* 1993).

It is generally known that small pale-yellow leaves indicate possible N deficiency, and large dark-green leaves indicate adequate N (Hacskaylo and Vimmerstedt 1967). But in between these two extremes lies a large area where N concentrations may limit growth, but leaf color does not exhibit obvious visual symptoms. This paper reports foliar nutrient concentrations that can be used in identifying plantations that may benefit from fertilization. Recommendations based on these data will help in maintaining nutritionally well-balanced plantations. However, do not assume that these data identify nutrient levels required for maximum growth rates. That goal will require more detailed fertilizer trials on a number of clones and soils.

METHODS

These data originate from 435 foliar samples collected over the past 10 years from a number of studies involving tree nutrition. In the aggregate, the studies encompass 24 clones and 9 sites located across a four-State area in the north-central U.S. (fig. 1). Tree age ranges from 1 to 7 years. Although not all clones were present at all sites, these data are the best available on plant nutrient levels under a variety of inherently fertile, or fertilized conditions in the region. Data from Rhinelander were from fertilized plots where high rates of nitrogen were added. Data from the other field sites represented unfertilized (but

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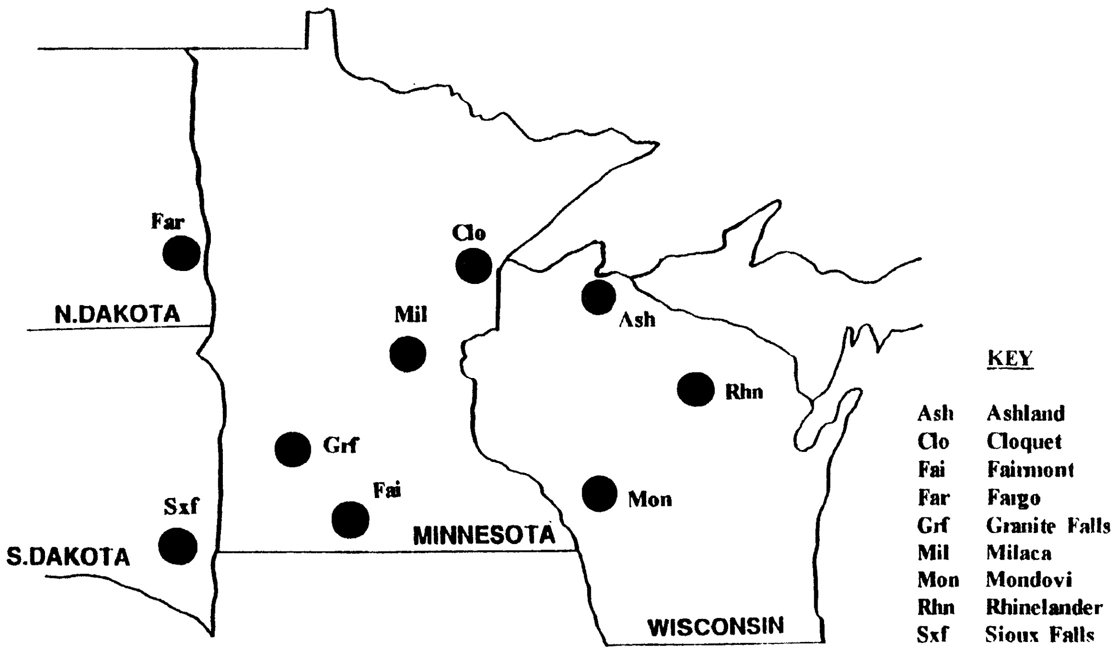


Figure 1.—*Foliar sampling sites.*

apparently fertile) conditions during the early years, and then fertilized conditions during years 4 to 7. Fertilization of test plots in the latter field plantations resulted in significant increases in foliar tissue N, but no significant increases in tree growth, suggesting that original fertility levels were adequate for good tree growth. Hence, the data are believed to reflect good nutritional levels. Limited data on foliar levels of phosphorous (P), potassium (K), and calcium (Ca) are also presented. No fertilization was done with these elements.

Foliar samples consisted of the uppermost two to three fully expanded leaves on the terminal shoot collected between July 1 and August 15. These leaves were selected because they had developed rapidly within the 10 days before the sampling date and therefore represented current nutritional status, and because they provided an identifiable standard physiological sampling point. Initially, the leaves were picked from the terminal shoot, placed in plastic bags and sealed, and kept on ice until oven dried at 70° C (158° F). More recently, the technique involved putting the leaves in paper bags, keeping them cool until drying (bag and leaves) in a microwave oven shortly after removal from the tree. The dried leaf with petiole was ground to 40 mesh and analyzed for total Kjeldahl N (Nelson and Sommers 1973), and for P, K, and Ca by ICP emission spectroscopy at the University of Minnesota Research Analytical Laboratory.

RESULTS

Nutrient Concentration

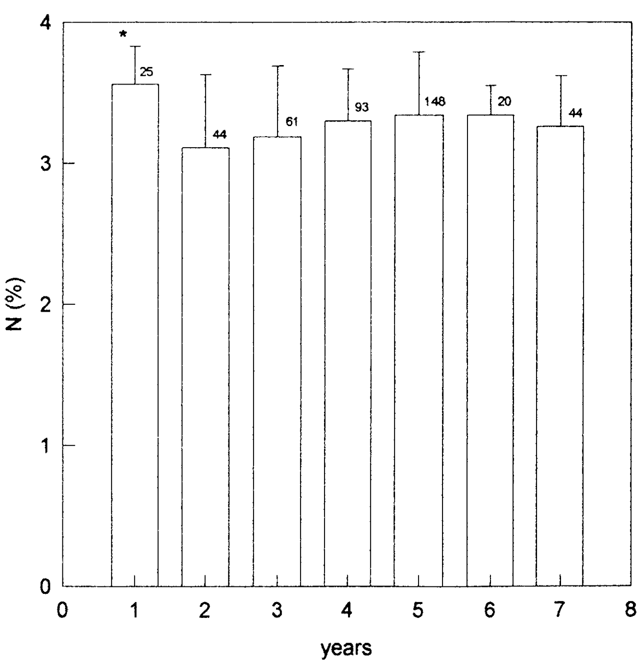
The mean concentration of macronutrients N, P, K, and Ca in foliage from nutritionally adequate hybrid poplar plantations in the north-central U.S. is:

	Percent	S.D.
N	3.29	±.43
P	.33	±.08
K	1.51	±.27
Ca	.63	±.27

These levels are believed adequate for fast growth. Given the lack of evidence for response of trees to P, K, and Ca, I suggest not fertilizing with these nutrients unless foliar samples show levels that are less than one standard deviation below the means in the tabulation above. At one standard deviation below the mean, the proportion of P, K, and Ca to the mean N is still close to that considered to be optimum for maximum growth (Ericsson *et al.* 1992). We recommend that foliar N generally be maintained above 3 percent (Hansen *et al.* 1988). Trials have shown that foliar tissue N below 3 percent will increase measurably when fertilized. However, a caution: it has not been demonstrated that fertilization at N levels below 3 percent will consistently result in growth increases.

Tree Age Effects

Foliar N was not influenced by tree age, except in 1-year-old trees, which had consistently higher N levels (fig. 2). A study of poplars in the Pacific Northwest likewise found the highest levels of foliar N during the first growing season, but also reported a significant decline with age over the first 6 years (Heilman 1985). In this study, tree age was confounded with clone and site. Also, the sampling period encompassed record drought and record floods that may have masked any tree age - foliar N relation. Miller (1983) notes that there can be significant year to year variation in



Standard deviation shown as a bar (I). Numbers represent number of observations. Only 1-year-old trees differed significantly (p>.05) from others.

Figure 2.—*Influence of tree age on leaf N concentration.*

foliar nutrient levels. Higher first-year foliar N may be a physiological age-related phenomenon, or it could be a microenvironmental effect of warmer/moister soil with associated higher soil-N mineralization and consequent greater soil-N availability (McLaughlin *et al.* 1985). In any event, fertilization is not recommended during the first, and often the second, growing season on sites with at least moderate fertility (Dickmann and Stuart 1983, Hansen *et al.* 1988). Not enough foliar samples of P, K, or Ca were obtained from 1-year-old trees to determine if they differed significantly from older trees.

Clonal Parentage Effects

Foliar N and Ca differ significantly by clonal parentage. Clones with *P. nigra* parentage had the highest concentrations with N consistently above 3 percent, while clones with *P. trichocarpa* or *P. maximowiczii* ranged from 2.6 to 3.2 percent (table 1). This corroborates results of Heilman (1985) where a hybrid clone of *P. deltoides* x *P. nigra* had significantly more foliar N than clones of *P. trichocarpa.* In that study the *P. deltoides* x *P. nigra* clone had a mean foliar N of 3.25 percent as compared to 3.37 percent in this test. Likewise, reported mean concentration for *P. trichocarpa* clones was 2.70 percent, which compares closely with the 2.62 to 2.67 percent range for hybrids in this test that had *P. trichocarpa,* but no *P. nigra* in the parentage. Clones with *P. nigra* x *P. trichocarpa* parentage were intermediate in foliar N. Published data for *P. deltoides* show foliar N levels around 2.0 percent (Blackmon and White 1972, Carter and White 1971). Results of this study suggest that when *P. deltoides* is hybridized, it reflects the N levels of the clonal parentage it is paired with: high with nigra, and low with trichocarpa (table 1). Because the effect of clone on the range in foliar nutrients in this study is substantial (about 0.7 percent for N, and about 0.5 percent for Ca), clonal parentage needs to be considered when assessing field fertility levels. Foliar P was only weakly related to parentage, although once again nigra parentage tended to have high concentrations and *P. trichocarpa* parentage low concentrations. Foliar K showed no significant relation to parentage.

Table 1.—*Influence of parentage on leaf nutrient concentration*

Parentage[1]	n	Age	Trials or sites	N	P	K	Ca
		Years		*Percent*			
DN	251	1-7	10	3.37 a[2]	0.37 a	1.57 a	1.06 a
N	36	1-5	9	3.36 a	.33 ab	1.40 a	.67 b
NT	10	2-7	1	3.22 ab	.31 ab	1.44 a	.54 b
NM	13	1-5	1	3.11 bc	--	--	--
DT	8	2-5	1	2.67 bc	.35 ab	1.63 a	.41 b
MT	5	2-5	1	2.62 c	.27 b	1.62 a	.52 b

[1] DN *P. deltoides* x *P. nigra*
N *P. nigra*
NT *P. nigra* x *P. trichocarpa*
NM *P. nigra* x *P. maximowiczii*
DT *P. deltoides* x *P. trichocarpa*
MT *P. maximowiczii* x *P. trichocarpa.*

[2]Concentrations within each nutrient not followed by the same letter are significantly different at $p \geq 0.05$.

Site Effects

All sites had foliar N levels near or above 3 percent, demonstrating that inherent fertility was good (table 2). However, the sites still had a range in N of nearly 0.5 percent. It is possible that N fertilization could decrease this site variation somewhat, but the Rhinelander site that was heavily fertilized still ranks near the bottom of all sites in foliar N. This suggests that differences should be expected in foliar N among sites and that N fertilization will not completely eliminate those differences. Other nutrients, soil structure, and moisture availability may be of major importance in causing site differences.

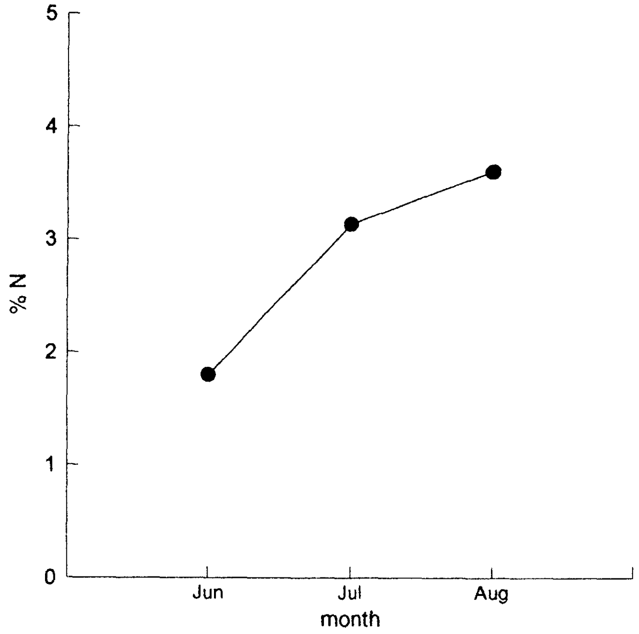
Table 2.—*Influence of site on leaf N concentration. Tree age ranges from 1 to 7 years at a site with a minimum of three age classes sampled per site.*

Site	N[1]
	Percent
Milaca-1	3.46 a
Cloquet	3.45 a
Sioux Falls	3.40 a
Milaca-2	3.38 ab
Ashland	3.28 ab
Rhinelander-1	3.20 ab
Fairmont	3.18 ab
Fargo	3.17 ab
Rhinelander-2	3.14 ab
Granite Falls	3.00 b
Mondovi	2.99 b

[1]Sites not followed by the same letter are significantly different.

Seasonal Effects

Foliar tissue N (in the uppermost fully expanded leaves) generally increases during the summer (fig. 3). June foliar samples often have low N contents, sometimes below 2 percent regardless of prior fertilization (Hansen *et al.* 1988). Therefore, a low N value in June may indicate only that the plantation should be resampled in July to check whether it is just seasonal influence. A subsequent July sample may indicate adequate N levels. Other factors such as an unusually cool summer or flooding have also been observed to markedly depress foliar N levels for that period of time. In such cases, any fertilization should be done on a trial basis with associated careful monitoring to determine effectiveness. I caution that sampling after about mid-August may encounter declining N, a pattern reported by others (Leaf 1973, Heilman 1985). Samples we collected after mid-August also showed declines in N. Baker and Blackmon (1977) report a decline in foliar N concentration as early as July. However, they were sampling total foliage of trees during the first growing season. Lower leaves contain less N and would tend to decrease the overall mean N content of the total foliage sample. In our study (as in Heilman's), foliar samples were collected only from the upper canopy.



Data replotted from figure 2b in Hansen et al. 1988; 150 lbs/acre/year fertilization rate on silt loam site.

Figure 3.—*Leaf N trends during the growing season.*

Plantation Development Effects

Nutrient uptake rate changes rapidly in a developing hybrid poplar plantation. Trees are most likely to be nutrient deficient during the years just before canopy closure (Miller 1983). The rapid change in nutrient demand is illustrated with data that show the amount of fertilizer required annually to maintain foliar N greater than 3 percent (fig. 4). The data are from a plantation at Rhinelander with trees spaced at 3.3 x 3.3 feet so the canopy closed early. The fertilization rate required to maintain foliar tissue N at greater than 3 percent peaked the second year, the same year the canopy closed. Fertilization rates required before or after the second year were substantially less. Peak increase in the uptake rate for P and K probably also occurs during the transition from open-growing trees to a completely closed canopy. Foliar biomass (the major "sink" for these elements) is expanding most rapidly at this time, and therefore the demand for additional nutrient input is greatest.

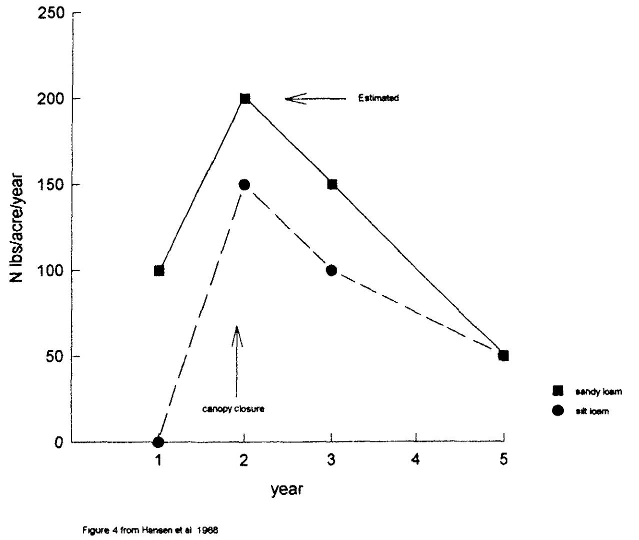


Figure 4.—*Annual fertilization rate necessary to maintain July and August foliar N at greater than 3 percent during the first 5 years on a silt-loam site and a sandy-loam site.*

Once the canopy closes, foliar biomass remains fairly constant from year to year with as much as 50 percent of the required N translocated into woody tissue followed by retranslocation the next season to the new expanding leaves (Bernier 1984). Additional nutrients are recycled through leaf fall, decomposition, and uptake (McLaughlin *et al.* 1987). The result is that if fertilization is required at all, it is most likely needed near the time of canopy closure when the rate of increase in N demand is at its peak. However, fertilization may also be needed at other times during the rotation.

As a guideline for monitoring fertility status of hybrid poplar plantations, use the foliar nutrient data on page 2 together with the following recommendations:

RECOMMENDATIONS

1. Look for visual symptoms; if leaves are pale yellow and small, sample to confirm N deficiency. If leaves are dark green and large, don't fertilize.

2. Control weeds first. Then fertilize, if needed.

3. Don't fertilize the first year (or two) on sites with at least moderate fertility.

4. Establish base fertility levels and trends by sampling the same clones and at the same time each year.

5. Maintain N levels in July to mid-August foliar samples at greater than 3 percent for all clones with nigra in the parentage.

6. Be aware that June and late August foliar samples, and clones with *P. trichocarpa* or *P. maximowiczii* parentage, may have as low as 2.5 percent N and still have adequate nutrition. Unusual weather events may also result in low N.

7. Maintain other foliar macronutrients above the minimum values defined by the lower range of the standard deviations on page 2.

8. Fertilize with 100 to 150 lbs/acre N as a first approximation until experience is gained.

9. Keep a record of nutrient status by clone and site. This will help you fine-tune fertilization in future years.

10. Until more experience is gained, sample foliar N and measure tree diameters before and after fertilization in small fertilized and unfertilized (control) plots. This will provide valuable information for other fields, or for future years on the same field.

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Poplar leaf nitrogen should generally be maintained at more than 3 percent, but concentration varies with clonal parentage, tree age, year, and site. Recommendations are given for establishing a fertility monitoring program.

KEY WORDS: Nitrogen fertilization, tree nutrition, SRIC, biomass plantations, leaf bioassay.