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# THE SEARCH FOR EASILY PROPAGATED GREY POPLAR CLONES

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## ABSTRACT

Hybrids of various species from sections *Tacamahaca* and *Aigeiros* of the genus *Populus* are commonly used around the world to produce a range of products and ecosystem services. In addition to their other favorable characteristics, clones of these commercial hybrids are easily and economically propagated from dormant hardwood cuttings. Unfortunately, many of these commercial hybrid poplar varieties are susceptible to diseases that can render them unusable in some regions of North America. However, there are other poplar hybrids from section *Populus* (the white poplars and aspens) that grow well and resist many of these disabling diseases, but which are less easily propagated, owing to their inability to develop roots from dormant hardwood cuttings. This paper summarizes thirteen years of field investigations at Michigan State University that have identified a promising hybrid from section *Populus* that 1) grows well, 2) is resist disease, and especially 3) reproduces reliably from dormant hardwood cuttings.

## INTRODUCTION

The genus *Populus* (poplar) encompasses about 30 species that are subdivided into six taxonomically distinct sections[1]. Intra- and inter-species poplar hybrids have been tested around the world and have shown great potential for use in short rotation (less than 15 years) plantations systems. Successful taxa exhibit superior vigor, broad adaptability, and are easily and inexpensively propagated as genetically identical individuals, or clones. Clonal propagation of poplars can occur in several ways including; (1) "sprouts" that arise from cut stumps, (2) "suckers" that arise from parental root systems, and (3) whole plants that arise from stem segments of the parent plant. The first two mechanisms are often relied upon for post-harvest regeneration of established stands, while the latter mechanism is most often used to establish new plantations. Establishing plantations from unrooted dormant (or "hardwood") cuttings is by far the most economical method. In the Lake States region of the United States, individual hardwood cuttings cost 20¢ US[2], rooted cuttings cost 30¢ US[2], and containerized poplar "stecklings[3]" cost 95¢ US[4]. So, if each type of stock costs 5¢ US to plant (a typical contract planting rate for Michigan), then plantations established with rooted cuttings are 1.4 times as expensive and with stecklings are 4 times as expensive as those established with hardwood cuttings.

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[1] The six sections in the genus *Populus* are: *Abaso, Turanga, Leucoides, Aigeiros, Tacamahaca,* and *Populus.*

[2] Hramor Nursery, Manistique, MI.

[3] A "steckling" is a fully functioning young tree (with roots and a shoot); equivalent to a "seedling" but of asexual rather than sexual origin – a clone.

[4] Itasca Nursery, Cohasset, MN.

Numerous factors influence the degree to which a hardwood cutting will successfully survive and grow when planted in the field. These include:

1. The time of year the cutting is collected – environmental preconditioning.
2. Position along the parent shoot from which the cutting was taken.
3. Diameter and length of the cutting.
4. Conditions and diseases present at the nursery production facility.
5. Conditions under which the cutting was stored prior to planting.
6. Pretreatment of the cutting (*e.g.* soaking or treating with rooting hormones).
7. Date of field planting and method of planting.
8. Soil conditions (*e.g.* moisture and temperature) following planting.
9. Clonal variation and genetic interaction with any or all of the above factors.

The genetic predisposition of various taxa for efficient propagation using hardwood cuttings has been a major factor in their selection for use in commercial short rotation plantations.

Most poplar taxa used in commercial plantations around the world are clones of inter-species poplar hybrids from the sections *Tacamahaca* (the balsam poplars) and *Aigeiros* (the cottonwoods and black poplars). These propagate reliably and inexpensively from hardwood cuttings and selected lines show very vigorous early growth. In addition to clonal plantations, natural poplar forests containing members of section *Populus* (the aspens in North America and white poplars in Europe) are also of great economic importance. These section *Populus* poplars resist certain diseases and insects that plague *Tacamahaca* and *Aigeiros* poplars in the Lake States and Northeastern regions of the United States[5]. Accordingly breeders have repeatedly sought to create promising hybrids of section *Populus* parents that have elite performance and are easily cloned. These hybrids are collectively known as the "grey" poplars. Grey poplars reproduce easily from stump sprouts and root suckers but rarely from hardwood cuttings. This makes it difficult to produce large numbers of specific genotypes and renders them expensive to plant. Consequently, in spite of their superior disease and insect resistance, the grey poplars have been largely passed over for use in short rotation plantations.

Hardwood cuttings of most grey poplar hybrids develop roots less than 50% of the time when planted directly in the field even with special pretreatment and conditioning. Similar cuttings of other poplar hybrids from other sections routinely root at rates in excess of 90% in field plantings. One strategy to obtain full stocking of stands of poor-rooting varieties would be to compensate by simply planting extra cuttings. For example, if cuttings of a particular variety were only expected to root half of the time, then one might double the number of cuttings initially planted in order to obtain full stocking of the final stand.

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[5] Pests that eventually cripple the "cottonwood" poplars in the Lake States include diseases like; *Melampsora* spp., *Septoria musiva*, and *Marssonina brunnea* and insects like *Chrysomela scripta*.

The down-side of this strategy is that establishment costs for poor-rooting varieties will necessarily be higher than for good-rooting varieties. In the preceding example, establishment cost of the poor rooting variety would be double because twice as many cuttings would be planted. An alternative strategy would be to only plant varieties with better rooting success. A calculation of the value of a variety with improved rooting can easily be made using the 25¢ per planted cutting figure cited above. Figure 1 shows what happens to establishment costs when extra cuttings are planted to compensate for expected mortality in a final stand of 680 trees per acre. If a variety with 80% rooting potential (and hence survival) is used in place of a variety with 50% rooting potential, a grower could save 37% of their establishment costs - or $127 per acre. Using a variety with 90% rooting potential could save a grower almost half of their establishment costs – or $151 per acre. So, developing varieties of grey poplars that root and survive at these higher rates would significantly improve their cost effectiveness for use in short rotation plantations.

Just such a grey poplar clone was developed in 2004 by the McGovern breeding program in Grand Rapids, Michigan, USA[6] and has been tested at Michigan State University's Tree Research Center (TRC) in East Lansing, MI and at the Forest Biomass Innovation Center (FBIC) in Escanaba, Michigan, USA since 2005. Figure 2 depicts an outline of the lineage of this grey poplar family and includes brief descriptions of the four FBIC field trials in which it was included.

McGovern crossed *P. ×villafranca* with *P. ×bolleana* in 1992 and noticed that even though the resulting family had poor form, cuttings of one of the offspring (ortet AA2101 in Figure 2) rooted with 100% success in greenhouse trials. This was unexpected since both parents' rooting success was below 50% and was the first indication that other offspring of these parents might root similarly well.

An earlier cross made in 1991 between a *P. alba* variety known as "A10" and *P. ×bolleana* had resulted in a vigorous ortet with good form known as "AA4102." McGovern crossed this ortet with *P. ×villafranca* in 2004 to produce the full-sib family known as "83XAA04" (Figure 2).

Seedlings of family 83XAA04 were included in a full-sib progeny test at the FBIC planted in 2005. After promising rooting results in a TRC greenhouse trial in 2008, hardwood cuttings (ramets of members of this family) were subsequently included in a field rooting trial planted in 2009, a clonal trial planted in 2010, and a yield trial planted in 2010 at the FBIC. What follows, is a description of these four field trials and a discussion of what they have shown to date.

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[6] Much of McGovern's original breeding stock was obtained from Canadian breeding programs *via* Dr. Harvey Anderson and Mr. John Winters.

## 2005 PROGENY TEST

A full-sib progeny test of ten grey poplar families and one commercial check clone of *P. nigra* × *P. maximowiczii* (commonly identified as "NM6") was established at FBIC in the spring of 2005. 1-year-old, dormant, bare-root grey poplar seedlings and 10 inch-long hardwood cuttings of NM6 were planted on 9' square spacing (538 trees/acre) in a randomized block arrangement composed of six blocks and 4-tree row plots. The test site was a retired hay field that had been treated with glyphosate and mechanical tilling to kill existing vegetation prior to planting and then was kept relatively weed-free for three years after plantation establishment using a combination of chemical and mechanical treatments. The site preparation method, and plantation maintenance program were the same for each of the four field trials reported in this document and so the description is not subsequently repeated.

Six of the full-sib families were pure *P. alba* from a common male parent (AA4102). The remaining families contained at least one native poplar parent[7]: two families were *P. tremuloides* × *P. tremula*[8], one family was *P. alba* × *P. grandidentata* [9], and one family was *P. grandidentata* ×*P. alba* (Table 1).

Measurements of stem diameter at breast height[10], and stool survival were made at the end of each growing season. Stool basal area[11] was computed in the 13th year by summing the individual stem basal areas for each stool. Stool basal area is a preferred way to compare trees because it integrates the impact of multiple stems emanating from a single stool.

An analysis of variance of stool basal area at age thirteen revealed significant differences among the families. 83XAA04 survived and grew best of the six families in the better performing group (Table 1). There was no consistency in the way families with the common father performed (one family was the best and another was the worst performer). Five of the *P. alba* families performed equally as well as or perhaps better than the NM6 commercial check clone. This suggests that hybrids of this taxa have potential to substitute for NM6, which displays high susceptibility to cankering diseases in the Lake States region.

The four families containing native poplar genes (*tremuloides* and *grandidentata*) grew notably less well than the NM6 check clone (Table 1). This suggests that more work is needed to find useful native poplar hybrids from the section *Populus* for use in short rotation plantations in the

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[7] The North American native poplars referred to here are aspens; *P. tremuloides* and *P. grandidentata*.

[8] One *P. tremuloides* × *P. tremula* family was diploid (containing two sets of chromosomes) and the other was triploid (containing three sets of chromosomes).

[9] This particular cross is collectively known as *P.* ×*rouleauiana.*

[10] Breast height is 1.4m above the ground.

[11] Basal area is the cross-sectional area of a stem as measured at breast height (1.4m above the ground). Basal area is commonly used as a surrogate parameter to represent tree volume or biomass.

Lake States region of the United States. Meanwhile, subsequent testing was conducted to quantify the field rooting characteristics of the best performing family in this progeny test.

## 2009 FIELD ROOTING TRIAL

Two tenth-acre blocks of trees were planted on a 10’ x 7’ spacing (622 trees/acre) in the spring of 2009 at FBIC. One block was composed of 10”-long hardwood cuttings (ramets) from numerous individuals (ortets) of *P. alba* family 83XAA04. The second block was composed of rooted stecklings (3’-tall potted plants), which had been produced in the TRC greenhouses in East Lansing, MI. The stecklings began as 15cm hardwood cuttings of 22 robust ortets from family 83XAA04. These were divided into two equal-size lots. One was treated with rooting hormone[12] while the other was not. Both lots were placed in 15cm pots in a greenhouse. The treated lot experienced 87% rooting success and the untreated lot experienced 83% rooting success; essentially the same. All surviving stecklings were transported to FBIC and planted while actively growing in the spring of 2009.

Initial stool survival after one year in the field was 94% for the stecklings and 79% for the hardwood cuttings. Hardwood cuttings rooted nearly as well in the field (79%) as they had in the greenhouse (83%). Survival dipped slightly in the third year and remained constant after that. Steckling survival after nine years had dropped to 90% while cutting survival had dropped to 77% (Table 2). Field survival of hardwood cuttings approached 80% for members of the 83XAA04 family which suggests that members of this family are strong contenders for use in short rotation plantations.

Individual cutting-origin trees were 9% larger than steckling-origin trees (as measured by basal area). There were 560 steckling-origin trees per acre and only 479 cutting-origin trees per acre left after nine years. Cutting-origin trees probably took advantage of the extra growing space provided by the trees around them that had died. Both test plots followed similar growth trajectories (Figure 3). Steckling-origin trees produced 32.4 dry tons/acre while cutting-origin trees produced 30.2 dry tons/acre after nine years (Table 2). This 7% increase in biomass production hardly compensates for the fact that stecklings cost 400% as much as cuttings to establish.

Members of the 83XAA04 poplar family were demonstrating comparable establishment and growth characteristics to other poplars used in short rotation plantations. Additional testing was done to explore variability within the family.

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[12] RootoneF™ (a commercial rooting hormone combined with thiram fungicide).

## 2010 CLONAL TRIAL

Ramets of fifteen 83XAA04 family members (ortets) were established in the spring of 2010 at the FBIC. Ortets were selected from among the most vigorous individuals in the TRC nursery beds on MSU's main campus. Eight 10" hardwood cuttings were harvested from each ortet and held in cold storage prior to plantation establishment. These ramets were planted on an 8' x 7' spacing (778 trees/acre) in a randomized block arrangement with 4 blocks of 2-tree plots. The commercial check clone "NM6" was also included. Measurements of diameter, and survival were made after eight growing seasons, in the fall of 2017. Individual stem diameters were converted to basal area and summed for each stool (when there were more than one stem per stool) to yield a measure of basal area per stool. This measure of basal area served as a surrogate for biomass production potential.

An analysis of variance in basal area production among clones revealed significant differences among clones but no discernable block effects (Table 3). However, there is so much variation within clones (Figure 4) that it is difficult to reliably differentiate among them. This pattern of variation has been seen in other poplar trials. Analysis of variation in a five-site trial of numerous poplar clones in Michigan revealed that 52% of total variation was due to environmental factors, 23% was due to genetic differences among varieties, and 25% was due to within variety differences (Miller and Bender, 2016).

Despite the wide variation among and within varieties seen here, certain ortets appear to be capable of growing at least as well and possibly better than the commercial check variety (NM6) included here. To test this, a large-plot yield trial was conducted with 83XAA04 and a variety of other poplars that had shown promise for inclusion in future commercial short rotation plantations.

## 2010 YIELD TRIAL

A yield trial of 10 poplar varieties (including ramets of members of the *P. alba* family "83XAA04") was established in the spring of 2010 at FBIC. The commercial clone "NM6" was included again for comparison. Three legacy clones of *P. deltoides* × *P. nigra* (known as DN164, DN170, and DN177) were included based on previously published outstanding performance in the region (Netzer, et. al.). All of these varieties were planted as 10"-long hardwood cuttings. Five newly developed *P. deltoides* × *P. nigra* varieties from the University of Minnesota's Natural Resources Research Institute (labeled NRRI-1 through NRRI-5) were included because they had performed well in recent clonal trials in the region. These NRRI varieties were planted as actively growing 30cm to 40cm-tall containerized stecklings.

All of the taxa included in this trial were genetically identical clones with the exception of family 83XAA04. No single ortet could provide enough cuttings to supply all that were required for this test so ramets of numerous ortets were used. This "multi-clonal" group, or taxa, was therefore more genetically diverse than the other “mono-clonal” taxa in the test and was expected to be more variable.

The cuttings and stecklings were planted on an 8’ x 7’ spacing (778 trees/acre) in a randomized block arrangement with 3 blocks of 64-tree rectangular plots (8 rows wide with 8 trees in each row). Measurements of diameter and survival were made after eight growing seasons, in the fall of 2017. Individual stem diameters were converted to basal area and summed for each stool (when there were more than one stem per stool) to yield a measure of basal area per stool. The basal area of the inner 16 trees in each plot were summed and converted to basal area per unit area. Using a similar procedure, the stool basal areas were used to predict dry biomass using a local poplar allometric equation[13] (Table 4).

The group of ramets from 83XAA04 performed exceptionally well after eight years in this test. It was the leader in the top yielding group, along with two of the new NRRI varieties and the NM6 standard variety. 83XAA04 produced an average of 24 dry tons per acre after eight years, or a mean annual biomass increment of 3.0 dry tons per acre-year. Yields here are within the range observed elsewhere in Michigan for better performing poplar varieties, which are routinely expected to be between 3 to 4 dry tons per acre-year at age eight (Miller, et. al. 2016[14]).

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[13] Poplar biomass estimates were computed using an equation developed specifically for hybrid poplar in Michigan by Miller in 2016. Forest Biomass Innovation Center Research Report 2016(a).
Stool dry biomass (in pounds) = 562.089 X Stool Basal Area (in square feet).

[14] Miller, et. al., 2016. Common short rotation poplar growth patterns observed in ten trials over 18 years in Michigan, USA. Forest Biomass Innovation Center Research Report 2016(e).

## CONCLUSIONS

1. **Many 83XAA04 ortets are excellent biomass producers.** 83XAA04 family members survived and grew as well as or better than NM6 in both the 2005 progeny test and the 2010 clonal trial (Tables 2 and 4).
2. **Ramets of 83XAA04 will cost no more than commercial poplar to establish.** 83XAA04 hardwood cuttings root and survive at rates in excess of 80%[1] when planted directly in the field. This is comparable to many current commercial taxa that arise from *P. deltoides*, *P. nigra*, and *P. maximowiczii* parents. This suggests that there can be parity in establishment costs between the older "cottonwood" and newer *P. alba* clones.
3. **Ramet groups from ortets of 83XAA04 are variable.** Variation within certain 83XAA04 clonal lines is considerable (Figure 4) but this is not particularly unusual for poplar clones used elsewhere in short rotation plantings.
4. **More work is needed to find native poplars for short rotation plantations.** Hybrids containing native "aspens" grew poorly compared to the pure *P. alba* hybrids in our 2005 progeny trial (Table 2). Those containing *P. tremuloides* "Clone 5" survived and grew especially poorly. Since it is desirable to include some of the favorable characteristics of the native poplars (*e.g.* range of site adaptability and resistance to pests) in future short rotation plantation taxa, continued interbreeding with superior *P. alba* family members identified here and subsequent field testing is recommended. It may be possible to combine some of the native poplar traits with the growth and rooting ability of these new hybrids to yield truly elite taxa for future short rotation plantations.

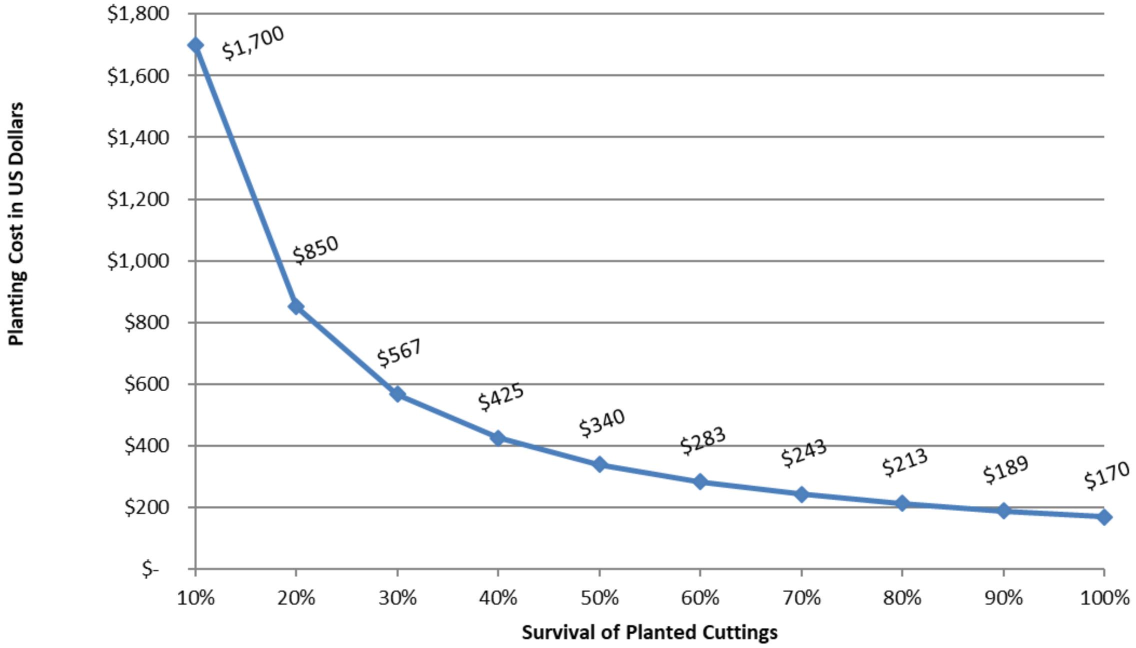
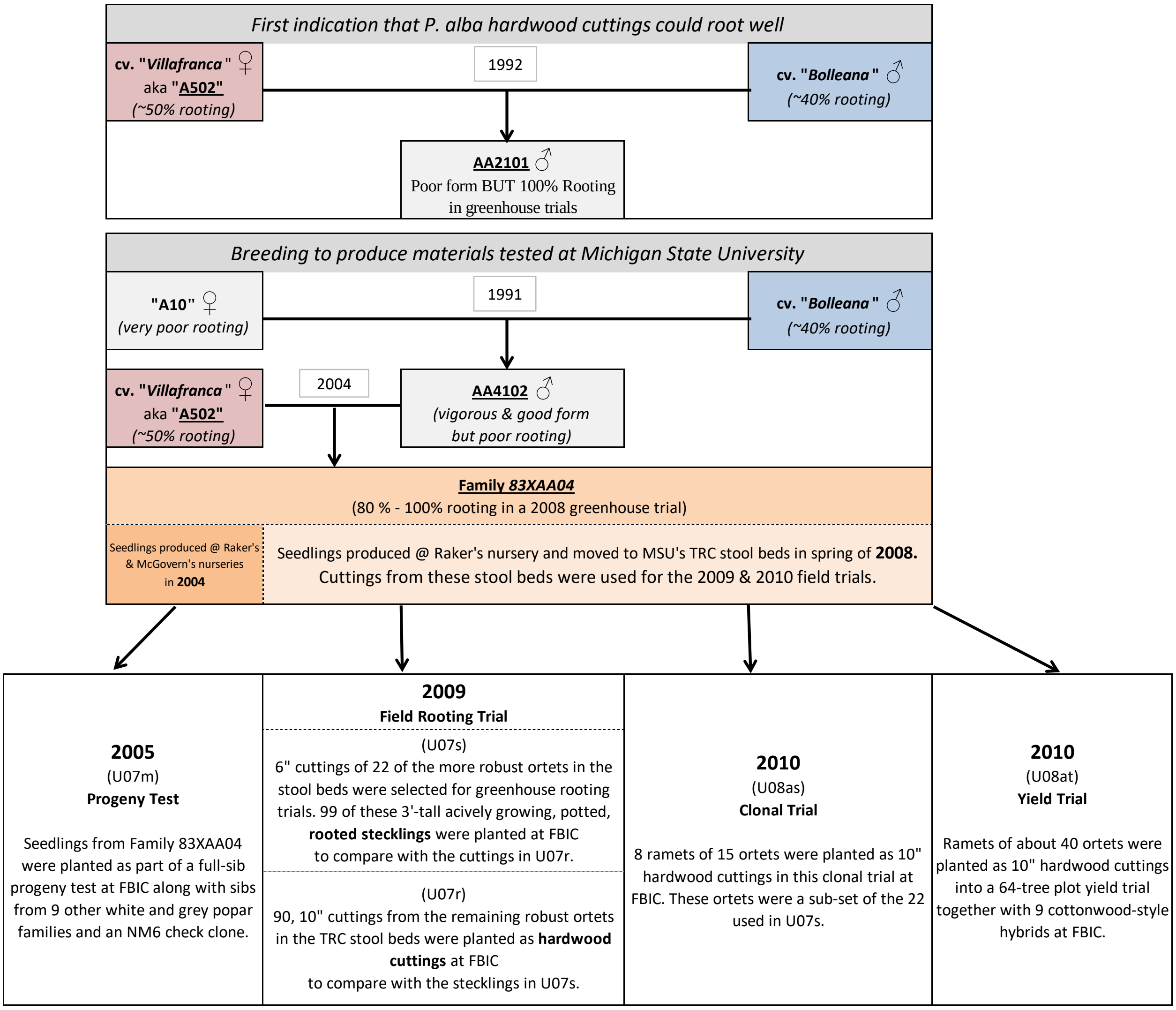


**Figure 1. Cost per acre to achieve 680 live plants per hectare (roughly 8' X 8' spacing) at varying survival rates.**

**Figure 2. The development and testing of a hybrid of *Populus alba* whose hardwood cuttings exhibit the ability to reliably root and grow well under field conditions.**



Poor form BUT 100% Rooting in greenhouse trials

(80 % - 100% rooting in a 2008 greenhouse trial)

Seedlings produced @ Raker's & McGovern's nurseries in **2004**

Seedlings produced @ Raker's nursery and moved to MSU's TRC stool beds in spring of **2008.** Cuttings from these stool beds were used for the 2009 & 2010 field trials.

Seedlings from Family 83XAA04 were planted as part of a full-sib progeny test at FBIC along with sibs from 9 other white and grey popar families and an NM6 check clone.

6" cuttings of 22 of the more robust ortets in the stool beds were selected for greenhouse rooting trials. 99 of these 3'-tall acively growing, potted, **rooted stecklings** were planted at FBIC to compare with the cuttings in U07r.

90, 10" cuttings from the remaining robust ortets in the TRC stool beds were planted as **hardwood cuttings** at FBIC to compare with the stecklings in U07s.

8 ramets of 15 ortets were planted as 10" hardwood cuttings in this clonal trial at FBIC. These ortets were a sub-set of the 22 used in U07s.

Ramets of about 40 ortets were planted as 10" hardwood cuttings into a 64-tree plot yield trial together with 9 cottonwood-style hybrids at FBIC.

Table 1. Lineage, survival, and basal area growth after 13 years of full-sib *Populus* families included in a 2005 progeny trial in Escanaba, MI. .

| McGovern Family ID | Female Parent (McGovern ID) | Male Parent (McGovern ID) | 13th Year Growth | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Survival | Stool Basal Area ($ft^2$) | | | | |
| 83XAA04 | P. alba (a502) | P. alba (aa4102) | 96% | 0.606 | a | | | |
| 80XAA04 | P. alba (aa2301) | P. alba (aa4102) | 88% | 0.508 | a | b | | |
| 81XAA04 | P. alba (aa3201) | P. alba (aa4102) | 71% | 0.432 | a | b | | |
| 82XAA04 | P. alba (aa901) | P. alba (aa4102) | 83% | 0.425 | a | b | c | |
| NM6 | P. nigra | P. maximowiczii | 90% | 0.406 | a | b | c | d |
| 84XAA04 | P.alba (aa3001) | P. alba (aa4102) | 88% | 0.386 | a | b | c | d |
| 18XAG04 | P. alba (aa4101) | P. grandidentata (gg101) | 88% | 0.264 | | b | c | d |
| 17XGA04 | P. grandidentata (gg102) | P. alba (aa4102) | 94% | 0.236 | | b | c | d |
| 1XTE04 | P. tremuloides (clone 5) | P. tremula (ta-4-83) | 42% | 0.194 | | b | c | d |
| 2XT4E04 | P. tremuloides (clone 5) | P. tremula (ta10) | 13% | 0.142 | | | c | d |
| 85XAA04 | P. alba (aa4101) | P. alba (aa4102) | 17% | 0.086 | | | | d |

Growth of families marked with the same letter are not significantly different ($\alpha = 0.05$).

Table 2. Comparison of two 0.04 hectare plantings of a *Populus alba* variety (83XAA04), established with either containerized stecklings or dormant hardwood cuttings, after nine growing seasons in Escanaba, MI.

| ***Attribute*** | ***Stecklings*** | ***Cuttings*** |
|---|---|---|
| Type of Planting Stock | 1m-tall Potted Stecklings | 25cm Dormant Hardwood Cuttings |
| Field Planting Date | 6/19/2009 | 5/15/2009 |
| ***Survival*** | | |
| Age 2 | 94% | 79% |
| Age 3 | 91% | 77% |
| Age 9 | 90% | 77% |
| Stand Density @ Age 9 | 560 trees/acre | 479 trees/acre |
| ***Average Tree (Stool) Size After 9 Years*** | | |
| Average Stool Basal Area @ Age 9 (ft²) | 0.2061 | 0.2254 |
| | | **9% larger than Stecklings** |
| ***Biomass Production After 9 Years*** | | |
| Total Computed Biomass (dry tons/acre) | 32.43 | 30.22 |
| | **7% more than Cuttings** | |

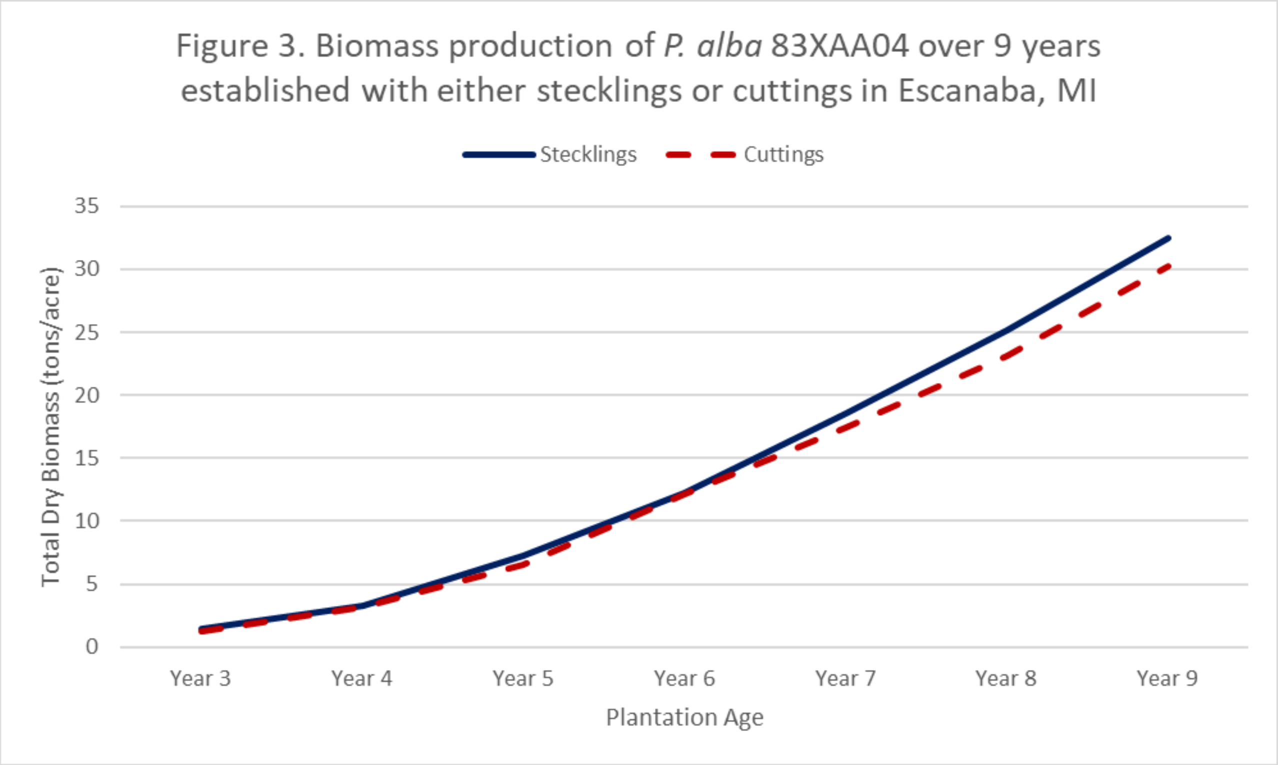


Figure 3. Biomass production of *P. alba* 83XAA04 over 9 years established with either stecklings or cuttings in Escanaba, MI

Table 3. Growth of ramets of 15 ortets of *Populus alba* family 83XAA04 and one P. nigra X maximowiczii "NM6" ortet after 8 growing seasons in a clonal trial in Escanaba, MI. Planting density was 778 trees/acre in 2-tree plots were arranged in four incomplete blocks.

| ***Ortet ID*** | ***Survival*** | ***Basal Area (ft²)*** | | | ***# of live ramets*** |
|---|---|---|---|---|---|
| 66 | 67% | 0.384 | a | | 6 |
| 67 | 71% | 0.271 | a | b | 5 |
| 74 | 100% | 0.240 | a | b | 8 |
| 64 | 63% | 0.237 | a | b | 5 |
| 70 | 100% | 0.229 | a | b | 8 |
| 73 | 89% | 0.216 | | b | 7 |
| 68 | 57% | 0.200 | | b | 4 |
| 69 | 86% | 0.197 | | b | 6 |
| 75 | 90% | 0.191 | | b | 8 |
| 71 | 75% | 0.168 | | b | 6 |
| 65 | 100% | 0.164 | | b | 8 |
| NM6 | 88% | 0.152 | | b | 7 |
| 76 | 77% | 0.139 | | b | 6 |
| 72 | 100% | 0.133 | | b | 7 |
| 62 | 63% | 0.127 | | b | 5 |
| 63 | 100% | 0.123 | | b | 8 |

Ortets marked with the same letter are not significantly different (α = 0.05).

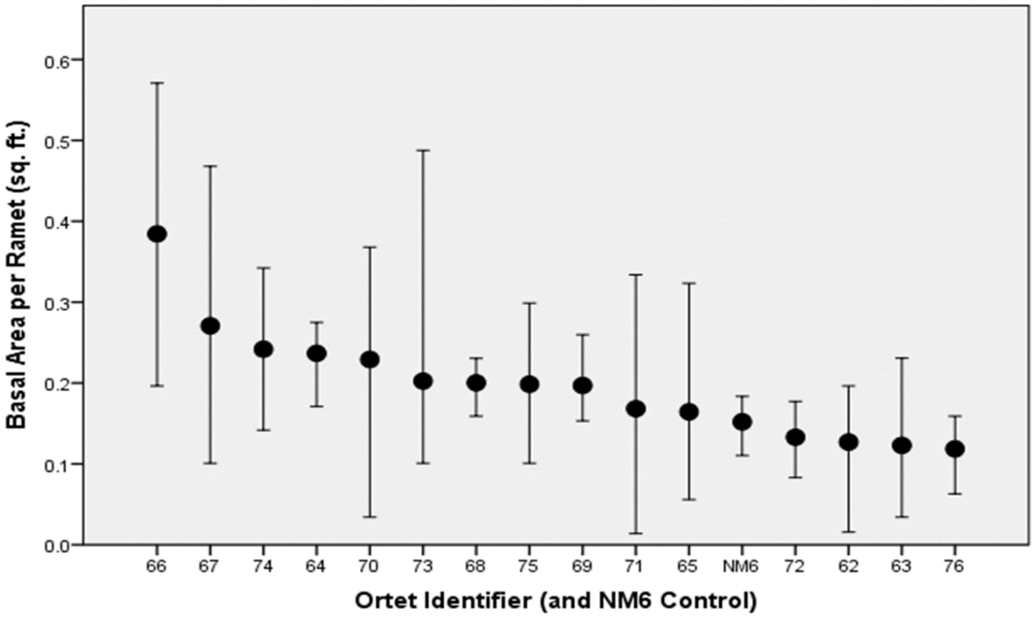


**Figure 4. Basal area of ramets of 15 full-siblings of Populus alba family 83XAA04 and an NM6 control variety (the ortets) after eight years in a replicated clonal trial in Escanaba, MI. The dark circles depict the average ortet preformance and the bars show the range of observed basal areas of ramets within each ortet. Data from 4 to 8 ramets per ortet, depending on survival.**

Table 4. Poplar hybrid growth after 8 years in Escanaba, MI. Four plots of each variety were arranged in a randomized block design. The inner 16 trees of each 64-tree plot were measured.

| Variety | Survival | Plot Basal Area (ft$^2$/acre) | Average Tree Basal Area (ft$^2$) | Predicted Biomass (dry tons/acre) | *Varieties marked with the same letter are not significantly different* | | | |
|---|---|---|---|---|---|---|---|---|
| 83XAA04 | 81% | 85 | 0.135 | 24.0 | a | | | |
| NRRI-1 | 98% | 74 | 0.098 | 20.9 | a | b | | |
| NM6 | 98% | 73 | 0.096 | 20.6 | a | b | c | |
| DN164 | 95% | 72 | 0.097 | 20.2 | a | b | c | |
| NRRI-2 | 96% | 69 | 0.093 | 19.4 | a | b | c | |
| NRRI-4 | 98% | 56 | 0.073 | 15.7 | | b | c | d |
| NRRI-3 | 85% | 56 | 0.084 | 15.6 | | b | c | d |
| DN170 | 50% | 51 | 0.131 | 14.3 | | | c | d |
| DN177 | 56% | 45 | 0.103 | 12.7 | | | c | d |
| NRRI-5 | 85% | 29 | 0.043 | 8.1 | | | | d |

Varieties marked with the same letter are not significantly different ($\alpha = 0.05$).