PERFORMANCE OF EASTERN COTTONWOOD AND HYBRID POPLARS ON ALLUVIAL AND UPLAND SITES IN THE SOUTH

Randall J. Rousseau, Landis B. Herrin, and Oludare S. Ogunlolu

Abstract—Continued emphasis on woody biomass production under short rotation woody crop strategies has focused on both hybrid poplar and eastern cottonwood. The advantages of hybrid poplars in comparison to eastern cottonwood include superior rooting, better wood properties, and the ability to grow well on upland sites. Unfortunately, one specific disease, *Septoria musiva*, which results in stem canker and mortality, has shown to be the most serious impediment to the use of hybrid poplars in the Southern United States. Although disease still ranks as a significant problem in the Southern United States, a limited number of hybrid poplar clones have shown tolerance and changed the thinking about the use of hybrid poplars. In addition, a small population of eastern cottonwood clones has shown high survival and good growth on upland soils. New selections within parent populations may provide an even greater ability to develop more hybrid populations suited to the environment of the Southern United States.

INTRODUCTION

Woody biomass programs in the Southeastern United States have focused primarily on fast-growth hardwoods, which have included *Populus* species and their various hybrids, American sycamore (*Platanus occidentalis* L.), sweetgum (*Liquidambar styraciflua* L.), and Eucalyptus (*Eucalyptus* spp.) as well as loblolly pine (*Pinus taeda* L.). Eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.) has a long history of research efforts in the Mississippi Alluvial Valley (MAV) beginning with the U.S. Forest Service located in Stoneville, MS where collections and testing resulted in genetically superior clonal selections that were used by numerous pulp and paper companies located along the lower portions of the Mississippi River (Stettler and others 1996). Eastern cottonwood, like most hardwood species, is very site-specific and attains its best growth on newly deposited alluvial soils that possess high fertility, good moisture availability during the growing season, and a lack of restrictive layers. In the past, eastern cottonwood genetic programs have been developed for such sites, with little testing on upland soils. There is no doubt that, when planted on alluvial sites along the Mississippi River, eastern cottonwood demonstrates very rapid growth reaching harvestable pulpwood size of approximately 10 inches at diameter at breast height (DBH) and total height of 80 to 90 feet within 8 to 10 years. Although rapid growth is the most positive aspect of eastern cottonwood, the species does not possess extremely good rooting, which at times has led to overall survival problems since dormant unrooted cuttings are the desired planting stock. These survival problems have shown up when the species has been either moved offsite or deployed under stressful environments.

The Stoneville program took a cursory look at hybrids, but for the area along the MAV, the various hybrid taxa did not fare well, thus eliminating them from further research efforts. In the late 1980s, a limited number of F_1 hybrid poplar clones resulting from the mating of *P. deltoides* and *P. trichocarpa* and these F_1 hybrids backcrossed to eastern cottonwood, developed by the University of Washington and Washington State University, were tested on sites within the MAV. However, all of the clones tested quickly succumbed to *Septoria musiva* stem canker and were eliminated from any further testing in the MAV. It wasn't until the mid-1990s that hybrid poplars were again examined in the South, but in this case the various taxa were being tested on upland sites. The approach at that time was to introduce clones that were performing well in the Pacific Northwest to upland sites in Kentucky, Tennessee, Virginia, and West Virginia. These clones were primarily *P. trichocarpa* x *P. deltoides* taxon (TD), but also included DN34, a *P. deltoides* x *P. nigra* hybrid, and NM6, a *P. nigra* x *P. maximowiczii* hybrid, with the latter two hybrid clones supposedly resistant to Septoria stem canker. Results indicated that certain hybrid clones

Author information: Randall J. Rousseau, Extension/Research Professor, Mississippi State University, Mississippi State, MS 39762; Landis B. Herrin, Research Associate, Mississippi State University, Mississippi State, MS 39762; and Oludare S. Ogunlolu, Graduate Student, Mississippi State University, Mississippi State, MS 39762.

Kirschman, Julia E., comp. 2018. Proceedings of the 19th biennial southern silvicultural research conference. e-Gen. Tech. Rep. SRS-234. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 444 p.

from a variety of taxa showed excellent first-year growth and survival on these sites. However, after 9 years the trees again succumbed to Septoria. Additional testing in western Kentucky of a variety of Populus hybrids in 1999 examined 10 clones from each of five taxa, which included TD taxon (*P. trichocarpa* x *P. deltoides*), TDD taxon (*P. trichocarpa* x *P. deltoides* hybrid backcrossed to *P. deltoides*), TN taxon (*P. trichocarpa* x *P. nigra*), TM taxon (*P. trichocarpa* x *P. maximowiczii*), and TMM taxon (*P. trichocarpa* x *P. maximowiczii* hybrid backcrossed to *P. maximowiczii*). This new material was the first of its kind in the mid-South area. Differing results clouded the issue as Newcombe and Ostry (2001) stated that TD F_1 hybrids were uniformly susceptible to Septoria stem canker, yet Rousseau and others (2008) showed variable Septoria resistance among clones within the TD F_1 hybrids tested in Kentucky. However, Rousseau and others (2008) identified two of the 10 TD F_1 hybrids that exhibited high survival, good growth, and disease resistance.

METHODS

The 2010 Consolidated Populus Feedstock Trial was a joint effort under the Sun Grant Initiative by the University of Minnesota, Mississippi State University, ArborGen, and GreenWood Resources. All three groups have a history in *Populus* development in various geographic areas throughout the United States. The initial test of this program focused on each group contributing 20 selected clones and each group establishing at least one site in 2010 and one site in 2011. Mississippi State University requested enough clonal material from each group to establish two test sites over the 2-year period, with one to be located on a Mississippi River alluvial site and the second on an upland site in northeast Mississippi approximately 90 miles east of the MAV. The alluvial test site was located in New Madrid County, MO while the upland site was located in Pontotoc County, MS. The experimental design employed was a nested design with three blocks, with clones nested within source in each of the three blocks. Clones were arranged in two-tree row plots and planted at a spacing of 9 by 6 feet with dormant unrooted cuttings. Prior to planting, both test sites were disked and then subsoiled to a depth of 14 inches. The alluvial site was planted April 10, 2010, and the upland test site planted on April 8, 2010. Immediately after planting of each respective test site, the test was treated with a broadcast application of Goal® 2XL at a rate of 64 ounces per acre. Additional herbaceous control during the first year was accomplished by a combination of chemical and mechanical means.

The 2010 Consolidated Populus Feedstock Trial consisted of 80 clones, of which 36 were eastern cottonwood clones and 44 were hybrid poplars. The hybrid clones represented a variety of taxa including *P. deltoides* x *P. nigra* (DN), *P. deltoides* x *trichocarpa* (DT), *P. deltoides* x *P. maximowiczii* (DM), *P. trichocarpa* x *P. deltoides (TD)*, *P. nigra* x *P. maximowiczii* (NM), and *P. trichocarpa* x *P. nigra* (TN). Both the NM and TN taxa were eliminated from the analysis because each was represented by only a single clone. Both trials were measured on an annual basis with total height measured at age 1 and total height, diameter, and occurrence of stem disease (i.e., Septoria stem canker) measured at ages 2 through 5. Volume outside bark was computed using equations developed by Mohn and Krinard (1971) for small cottonwood in plantations:

$$\text{Total volume outside bark} = 0.21099 + 0.00221(D^2H) \quad (1)$$

where

D = diameter at breast height

H = total tree height

RESULTS

Survival

Age 1 survival of the alluvial test site (table 1) was 7.5 percent lower than that of the upland site and remained lower through the following 4 years. Age 1 survival of the alluvial site was 76.7 percent but dropped each year. Mortality at ages 2, 3, and 4 was between 2.7 and 4.5 percent, however mortality between ages 4 and 5 increased to 21.2 percent lowering overall test survival to 44.9 percent. In comparison, survival of the upland test site (table 2) was 84.2 percent at age 1 and showed a much slower decline in mortality, with survival dropping to 81.0 percent at age 5. Survival was relatively the same at ages 1, 2, and 3 at 84 percent. At age 4, survival dropped only 1 percent and only 2 percent between the ages of 4 and 5.

Examination of survival by taxon provides a more in-depth look at potential contributing factors. On the alluvial site, survival of eastern cottonwood at 64.4 percent was much lower than the hybrid taxa which ranged in survival between 90.3 and 80.6 percent. However, almost immediately, the hybrid taxa survival dropped at age 2 and continued to drop through age 5. The most significant mortality was in the DM taxon where survival dropped from 80.6 percent at age 1 to 69.5, 58.4, 41.7 and 5.6 percent for ages 2, 3, 4, and 5, respectively. By age 5, survival of the DN, DM, DT, and TD hybrid taxa was 36.1, 5.6, 61.1, and 13.0 percent, respectively. The DN, DT, and TD hybrid taxa showed an age 4 survival that was still in the 70-percent range but dropped dramatically for the DN and the TD taxa. The DT taxon dropped the least between ages 4 and 5 but still fell nearly 17 percent. Survival among the taxa

Table 1—Survival, total height, and volume by taxon at ages 1, 3, and 5 years when planted on the alluvial site in New Madrid County, MO

	Survival *percent*			Total Height *feet*			Volume *cubic feet*	
Taxon[a]	Year 1	Year 3	Year 5	Year 1	Year 3	Year 5	Year 3	Year 5
DD	64c	64d	64a	13.3a	27.1a	42.0a	0.9606a	3.0457a
DM	81b	58e	6d	12.7a	22.6b	28.3b	0.5325b	1.0920b
DN	90a	81a	36b	10.4c	20.8c	30.2b	0.3944c	1.1880b
DT	83b	78b	61a	11.5b	21.1c	30.6b	0.5311b	1.4804b
TD	83b	74bc	13c	10.3c	18.8d	27.8b	0.3053c	0.8157b

[a] DD = eastern cottonwood; DM = *P. deltoides* x *P. maximowiczii*; DN = *P. deltoides* x *P. nigra*; DT = *P. deltoides* x *P. trichocarpa*; TD = *P. trichocarpa* x *P. deltoides.*

Note: survival, total height, and volume means with the same letter are not significantly different at $p < 0.05$.

Table 2—Survival, total height, and volume by taxon at ages 1, 3, and 5 years when planted on the upland site in Pontotoc County, MO

	Survival *percent*			Total Height *feet*			Volume *cubic feet*	
Taxon[a]	Year 1	Year 3	Year 5	Year 1	Year 3	Year 5	Year 3	Year 5
DD	71d	71d	69d	5.0d	17.5b	28.1a	0.2623b	0.8616a
DM	92b	92bc	78c	8.4a	23.2a	28.9a	0.4371a	1.0268a
DN	98a	98a	92b	6.6bc	14.3c	19.8c	0.1561c	0.2329c
DT	94b	94b	94a	6.7b	18.6b	27.1ab	0.2553b	0.8515a
TD	91b	91b	91b	6.0c	16.8b	24.8b	0.2315b	0.6152b

[a] DD = eastern cottonwood; DM = P. deltoides x P. maximowiczii; DN = P. deltoides x P. nigra; DT = P. deltoides x P. trichocarpa; TD = P. trichocarpa x P. deltoides.

Note: survival, total height, and volume means with the same letter are not significantly different at $p < 0.05$.

on the upland site was similar to that observed on the alluvial site, with survival of eastern cottonwood being much lower than all of the taxa included in the group of hybrid poplars. Age 1 survival of eastern cottonwood was 71.3 percent and remained fairly constant through age 5. The hybrid taxa on the upland site did not exhibit a significant change in survival through time as observed on the alluvial site. Survival of the TD and the DT hybrid taxa was 90.7 and 94.4 percent, respectively, at age 1 and remained the same through age 5. Age 1 survival of the DN taxon was 97.9 percent. Survival remained constant at ages 1, 2, and 3 and dropped slightly at age 4 to 96.4 percent and at age 5 to 93.8 percent. Similar to the survival of the DM taxon observed on the alluvial site, this taxon was again the most impacted, as survival dropped from 91.7 percent at age 1 to 77.8 at age 5.

Total tree height was significantly different between the two sites and, as expected, the alluvial site was taller for all 5 years. Differences increased from a low of 5.9 feet at age 1 to a high of 12.3 feet by age 5. Height growth averaged approximately 7 feet per year, with the exception of the third year which was 3.5 feet. This reduced growth was during a severe drought. Height growth of the upland site was the highest at age 1 but continued to drop each year resulting in growth of only 3.8 feet during the fifth growing season. Diameter and volume followed the trend shown by height, where the alluvial test site exhibited much better growth. The diameter and volume of the alluvial site at age 2 were similar to that of age 5 of the upland site.

When examining the difference between eastern cottonwood and hybrid poplars on both sites at ages 1, 3, and 5 years, the results indicate that eastern cottonwood and hybrid poplars are very different when planted on an alluvial site as compared to an upland site. Height differences between eastern cottonwood and hybrid poplars on the alluvial site at ages 1, 3, and 5 are 2.4, 4.7, and 12.7 feet, respectively. By age 5, eastern cottonwood volumes were nearly three times that of the hybrid poplars on the alluvial site. On the upland site, the eastern cottonwood group of clones was 1.9 feet shorter than the hybrid poplar group. By age 2, this was reversed with the eastern cottonwood group being a foot taller than the hybrid poplar group, and this difference was enlarged by age 5 to 5.3 feet. Volume differences followed the same trend as seen in height with the largest differences observed at age 5, where the eastern cottonwood group (0.8314 cubic feet) was larger than the hybrid poplar group (0.5244 cubic feet).

Breaking this down to the taxon level provides a clearer picture of performance. Rather than looking at each year, the results are shown at ages 1, 3, and 5. The results from the alluvial site show that eastern cottonwood was significantly better than the hybrid taxa for all traits exhibited for early age (i.e., ages 1 and 3) except for survival (table 1). The results from the upland site showed that survival of the hybrid taxa was significantly better than eastern cottonwood (71 percent), with DN being the highest at 98 percent, followed by DT, DM, and TD taxa (table 2). The DM taxon was significantly taller than the other taxa at ages 1 and 2, but by age 5 both eastern cottonwood and the DT hybrid taxon were very similar. The DN hybrid taxon was significantly shorter with lesser volume than the other taxa. The DM taxon exhibited higher volume at age 3 than eastern cottonwood and all of the other hybrid taxa. By age 5, the DM taxon ranked number one for volume but was not significantly different than the DT hybrid taxon and eastern cottonwood.

The top 10 percent of the test population is represented by eight clones regardless of taxa. The age 5 alluvial test means for DBH, height, and volume were 4.8 inches, 37.0 feet, and 2.352 cubic feet, respectively. The top 10 percent of the alluvial test population exhibited DBH, height, and volume of 5.7 inches, 44.0 feet, and 3.534 cubic feet, respectively. Examination of clones within taxa at age 5 showed that, for the alluvial site, the top eight volume-producing clones were all eastern cottonwood clones (table 3). Clone 414 displayed exceptional growth performance through age 5, with a mean diameter, height, and volume of 7.1 inches, 45.8 feet, and 5.403 cubic feet, respectively. Comparing clone 414 to the next highest ranking clone (i.e., 412), the differences were that 414 was an inch larger in diameter, almost 3 feet taller, and 1.627 cubic feet larger. The age 5 test means for the upland site were considerably lower than the alluvial site for diameter, height, and volume at 2.7 inches, 24.7 feet, and 0.668 cubic feet, respectively. In comparison, the top 10 percent of the test population showed mean diameter, height, and volume of 4.4 inches, 33.9 feet, and 1.496 cubic feet, respectively. Further evaluation of the top eight clones showed that only two clones were hybrids, with the remaining six being eastern cottonwood. The best clone on the upland

Table 3—Survival (SUR), DBH, total height (THT), and volume (VOL) of the top 10 percent of the test population for the alluvial site located in New Madrid County, MO and the upland site located in Pontotoc County, MS

	Alluvial					Upland			
	---------- Age 5 ----------					---------- Age 5 ----------			
	SUR	DBH	THT	VOL		SUR	DBH	THT	VOL
Taxon - Clone	%	*in.*	*ft.*	*ft.*^{3}	Taxon - Clone	%	*in.*	*ft.*	*ft.*^{3}
DD - 414	83	7.1	45.8	5.403	DM - 8019	100	4.5	37.5	1.926
DD - 412	83	6.1	43.0	3.776	DD - 443	83	4.4	35.1	1.800
DD - 66	83	6.0	45.1	3.714	DD - 171	100	4.1	34.4	1.482
DD - 71	100	5.4	45.0	3.334	DD - 142	100	4.2	33.8	1.437
DD - 142	100	5.5	45.4	3.180	DD - 412	83	4.1	33.6	1.376
DD - 31	100	5.5	43.4	3.033	TD - 2128	100	4.0	31.4	1.360
DD - 151	83	5.2	41.0	2.919	DD - 151	100	3.7	31.1	1.336
DD - 184	83	5.3	43.0	2.912	DD - 31	83	3.7	34.2	1.324
Test Mean	**45**	**4.8**	**37.0**	**2.352**	**Test Mean**	**81**	**2.7**	**24.7**	**0.668**

[a] DD = eastern cottonwood; DM = *P. deltoides* x *P. maximowiczii*; TD = *P. trichocarpa* x *P. deltoides.*

site was a hybrid poplar 8019, which is a DM hybrid that exhibited means for diameter, height, and volume of 4.5 inches, 37.5 feet, and 1,926 cubic feet, respectively.

DISCUSSION

The fact that the eastern cottonwood outperformed the hybrid poplars on the alluvial test site was expected as previous testing indicated, however it was hopeful that a few of the newly developed hybrids would be able to withstand the formation of Septoria stem cankers (Coyle and others 2006, Kaczmarek and others 2013, Rousseau 2014). Based on age 1 survival of both sites, it was also very apparent that the rooting characteristics of the various hybrid poplars are superior to that of eastern cottonwood (May 2012). But, because of hybrid poplars' disease susceptibility, especially to Septoria, survival at the alluvial site was severely impacted through age 5. The survival of the hybrid poplars at the upland site was not impacted by Septoria until after the third growing season, and even at that time the clones included in the DM taxon were the most affected dropping from 92 percent survival to 78 percent by age 5. Even then, the DM clone 8019 remained at 100 percent survival at age 5, providing hope that within the most affected taxon there is some resistance level to Septoria. The level of Septoria present on upland sites is probably not to the level found in the MAV where it occurs naturally and where eastern cottonwood is found in large stands. During the 5-year time frame of the upland site, Septoria seems to be building, and susceptibility of clones has become more apparent, but the question remains if there are races within the disease and, if so, how much variability in virulence exists among the various races.

Examining the top 10 percent of the 80 clones tested at each site showed that neither the eastern cottonwood clone (414) nor the DM hybrid clone (8019) was among the top 10 percent of the both tests. However, eastern cottonwood clones 142 and 412 were among the top five highest ranking clones for both test sites. Additionally, eastern cottonwood clones 31 and 151 also ranked in the top 10 percent of the population for both test sites. Growth of the taxa and clones can be explained in a couple of ways. A number of clones in the DN taxon were bred and selected for the cooler climate found in Minnesota. Thus, the northern DN hybrid clones are adapted to a much milder environment than either Mississippi or Missouri. It was apparent that these northern hybrid clones were poorly adapted to the longer, warmer growing seasons, especially on the upland site in Mississippi. The clones with the TD, DT, and DM taxa were bred and selected for growth in the Pacific Northwest, where Septoria is not indigenous. Thus, clones within these taxa showed variability in tolerance to the disease. The performance of the eastern cottonwood clones on the upland site was unexpected; generally, eastern cottonwood has not performed well on sites outside of the alluvial area of the Mississippi River. Although growth was suitable on the alluvial site, this area cannot be classified as a marginal site; however, because of historic flooding followed the next year by a severe drought, all of the clones were greatly impacted. The upland site certainly fits the characteristics of a marginal site as it was originally in cotton production but was deemed too poor for that purpose and has been, for a considerable period, in pasture. The growth of the best clones on the upland site was less than half of the volume produced on the alluvial site. This production needs to be higher. The key to better growth on upland sites appears to be a combination of clones of specific taxa that exhibited hybrid vigor, excellent rooting, and increased Septoria resistance. Based on this trial, the hybrid poplars belonging to the DT and DM taxa seem to hold the most promise for use in the Southern United States. However, there is a critical need for continued examination of hybrid poplars of both taxa based on growth and disease resistance prior to planting recommendations being finalized. As seen in most *Populus* tree improvement programs around the world, the use of eastern cottonwood as a mainstay in breeding efforts is critical and thus the need for moving forward with a recurrent selection program should be a priority.

SUMMARY

The 2010 Consolidated Populus Feedstock Trial provided a view into some of the newest eastern cottonwood and hybrid poplar clones to determine possible use as biomass clones in the Pacific Northwest, Midwest, and Southeastern United States. The two test sites chosen by Mississippi State University represented a site where eastern cottonwood should perform well but is known to have diseases that will be challenging for hybrid poplars and a site where nutrient and moisture levels will be challenging for eastern cottonwood. The results of the study again indicate that hybrid poplars are a very poor choice for any site where the Septoria level is high such as in the MAV area. In addition, there is no doubt that upland sites will be challenging in nutrients and moisture. On the positive side, this test indicated that even the most susceptible and quite possibly the fastest-growing taxa showed disease resistance variability among clones.

REFERENCES

Coyle, D.R.; Coleman, M.D.; Durant, J.A.; Newman, L.A. 2006. Multiple factors affect pest and pathogen damage on 31 *Populus* clones in South Carolina. Biomass and Bioenergy. 30(8–9): 759–768.

Kaczmarek, D.J.; Coyle, D.R.; Coleman, M.D. 2013. Survival and growth of a range of *Populus* clones in central South Carolina USA through age ten: Do early assessments reflect longer-term survival and growth trends? Biomass and Bioenergy. 49: 260–271.

May, B.D. 2012. *Populus* species and hybrids for use on bottomland and upland sites in the southern United States. Mississippi State, MS: Mississippi State University. 103 p. Master's thesis.

Mohn, C.A.; Krinard, R.M. 1971. Volume tables for small cottonwoods in plantations. Research Note SO-113. New Orleans, LA: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 4p.

Newcombe, G.; Ostry, M. 2001. Recessive resistance to Septoria stem canker of hybrid poplar. Phytopathology. 91: 1081–1084.

Rousseau, R.J. 2014. Hybrid poplars: Can they survive in the Mississippi Alluvial Valley and surrounding uplands? In: Woody crops: production alternatives for multiple uses. 10th biennial Short Rotation Woody Crop Operations Working Group meeting. July 17–19, 2014. Seattle, WA. Presentation available on: http://www.woodycrops.org/.

Rousseau, R.J.; Adams, J.P.; Wilkerson, D.W. 2008. Nine-year performance of a variety of Populus taxa on an upland site in western Kentucky. In: Guldin, J.M., ed. Proceedings of the 15th biennial southern silvicultural research conference. e-Gen. Tech. Rep. SRS-175. U.S. Department of Agriculture Forest Service, Southern Research Station: 299–306. https://www.srs.fs.fed.us/pub/gtr/gtr_srs175.pdf.

Stettler, R.F.; Bradshaw, H.D., Jr.; Heilman, P.E.; Hinckley, T.M. 1996. Biology of *Populus* and its implications for management and conservation. Ottawa, Ontario, Canada: NRC Research Press. 539p.