TVA'S HARDWOOD TREE IMPROVEMENT PROGRAM

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In the last two decades, tree planting has resulted in thousands of acres of thrifty pine plantations. These plantings have and will contribute to forest industry growth in the Tennessee Valley. However, the greatest potential for the long haul is restoration of quality hardwood forests on sites that will support them. To this end TVA has been concentrating its tree improvement efforts since 1963.

There are approximately sixty-odd commercial hardwood species in the Tennessee Valley, and we have selected **six** to include in our tree improvement program: black cherry and black walnut because of their high value and present scarcity, yellow-poplar because of its rapid growth on good sites, northern red oak and white oak because of their commercial importance and ability to grow well on a variety of sites, and chestnut oak because of its adaptability to poorer sites. Our efforts include the selection of superior trees and seed orchard establishment.

So far we have the necessary 20 to 30 walnut, yellow-poplar, and cherry selections but lack a few in each of the oaks. Grafting of all six species has been successful and the establishment of grafted seed orchards should be completed by 1968-69 (Hatmaker and Taft, 1966). Current plans call for an orchard of each species in east, west, and southern Tennessee to insure a seed crop from each species every year.

Other approaches are also being investigated. One is the selection of seedlings that exhibit outstanding height and diameter growth at the end of 1 year in the nursery. Selecting these "super seedlings". at such an early age has its theoretical drawbacks, to be sure, but it does provide a simple, easy way of comparing many individuals, and early vigor is certainly a vital factor in hardwood plantation survival (Funk, 1964; Williams, 1966).

Hybridization, a third approach, is possible when seed orchards begin flowering. This method attempts to combine outstanding characteristics of two trees by artificial crossing. If a certain cross consistently produces exceptional seedlings, then a seed orchard of these two parents would result in natural crossing and thus superior seed.

A serious limiting factor in tree improvement is the 10 to 30 years required for a seedling to flower and bear seed. This time must be shortened if progress is to come in our lifetime. The use of an early flowering rootstock may be the answer. Sawtooth oak (Quercus acutissima) is such an understock and seedling scions of northern red oak have been successfully grafted to it, while some difficulty has been encountered with white and chestnut oak. A large flower induction

experiment with all six species is being conducted and involves the use of growth regulator sprays. This was initiated this year and results are not yet available.

All our efforts are being channeled toward one end, genetically superior planting stock. Selection, seed orchard establishment, hybridization, and early flowering are only a few such efforts. Others include seed collection and storage, production of the best possible nursery stock, hardwood plantation establishment methods, pollen handling techniques including pollination techniques, phenology of flowering, and progeny testing.

PAST TO PRESENT--A FEW QUESTIONS ALREADY ANSWERED

Black walnut (Juglans nigra)

Proper spacing and expected yields can be accurately estimated for fruit orchards because data from past orchards are available. This is not the case with tree seed orchards except in a few cases where yields have been recorded. Such is the case in a 32-year-old black walnut orchard located near Norris, Tennessee. In 1934, black walnut grafts of the Thomas variety were purchased from a Pennsylvania nursery and planted with several other varieties at 50 x 50 spacing on a 5-acre site. These grafts began bearing nuts in 1940 but significant crops were not available until 1943. Yield records were kept by individual ramets from 1943-54. In addition, the DBH, total height, and crown radius were measured in 1946, 1956, and 1966.

It should be emphasized that table 1 only describes ramets of the Thomas walnut clone. Experience with pine has shown that when a clone begins to flower usually all ramets of the same age flower and continue to do so in following years. However, this table indicates that all ramets do not yield nuts in a given year. Only 16 produced a significant crop in 1948, whereas 46 produced some nuts in 1944. The important point is that variation in yield does exist between ramets of the same clone in a single year. The average yield of these 40 Thomas walnut grafts over the 12-year period from 1943 through 1954 was 18,560 nuts per year or 380 nuts per ramet per year. Therefore, when viewed from the clone standpoint, it would be safe to state that if 40-50 ramets of a clone are planted in an orchard some seed from this clone will be produced every year.

In addition to yield variation between ramets of a clone, yearly variations in yield of each ramet are apparent. Table 2 emphasizes this point. Consecutively numbered ramets are 50 feet apart so that the site conditions, including weather, should be the same for each of the three pairs of ramets (number 17 is included for another purpose to be explained later). Ramet 48 produces a good crop of nuts in the odd years while 49 produced a crop in the even years. In 1945, ramet 43

Table 1.--Average yearly yield of hulled, dry, nuts from 49 grafted black walnuts of the Thomas variety

	Year											
	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Number of bearing ramets	44	46	44	31	36	16	44	22	30	26	30	35
Total number nuts produced* (thousands)	2.0	11.9	18.6	19.7	27.7	8.3	39.4	16.9	17.8	14.3	12.9	33.5
Average number nuts produced/bearing ramet	45	259	423	635	769	519	895	768	593	550	430	957
Range of nuts produced by individual trees**	350	800	1450	2050	1600	1200	3250	1800	1450	1100	1450	2250

* Yields were originally recorded in pounds. The average cleaned Thomas walnut weighs 20 grams and there are about 22 nuts per pound. The yield in pounds was multiplied by 22 to get total number of nuts.

** Only the upper range is presented, the lower limit is always zero.

Table 2.--Yield in pounds of selected Thomas black walnut ramets

Ramet number	Year 1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
48	15.8	0.0	51.8	0.0	56.0	0.0	95.0	0.0	21.0	29.0	65.0	26.2
49	0.0	36.0	6.5	93.2	0.0	52.0	6.0	66.0	0.0	28.0	5.5	77.6
43	0.2	7.8	36.5	0.0	60.0	0.0	20.0	6.0	32.0	0.0	9.5	3.1
44	0.0	19.8	8.0	53.3	0.8	22.0	27.0	5.2	22.0	0.0	33.0	0.0
6	3.5	0.0	35.0	0.0	50.0	0.0	6.0	48.0	0.0	48.0	4.5	70.8
7	2.5	11.0	9.2	34.3	0.4	21.5	0.0	61.0	2.0	25.0	21.5	27.8
17	5.0	21.0	1.2	43.8	0.0	0.0	37.0	0.5	62.0	0.0	0.0	68.7

began producing good nut crops in odd years but ramet 44 was producing crops in even years until 1949. Apparently a bumper crop was produced that year by ramet 44 which changed an even year cycle to an odd year cycle, as one can see by observing the nut crop through 1954. Ramet 6 looks like an odd year producer but in 1949 it fails to produce a large crop and it becomes an even year producer. Ramet 7 remains an even year producer. Two cycle changes are observed in ramets 44 and 6, but in the first the change results from a bumper crop while the second results in a crop failure with both occurring the same year, 1949. The last, ramet 17, is included to show what appears to be a 2-3-2-3 year cycle. To supplement this data, we have 6-year-yield data on open grown black walnuts in the Tennessee Valley (Zarger, 1946). These data point out that yield cycles are also present between genetically different trees. Zero, 1, 2, and 3 year cycles with variations were observed in these 132 trees. Recognition of these cycles both within and between clones will necessitate records for each ramet in an orchard but should also provide a basis for predicting future walnut seed orchard yields.

Average size measurements of grafted black walnut of three clones are presented in table 3. When trying to determine orchard spacing, one of the most important characteristics to consider is expected future crown size, particularly crown radius. This table indicates that 20 x 20 spacing to age 12 is adequate, probably 30 x 30 to age 22, and somewhere between 35 and 40-foot spacing at age 32. This orchard had no fertilization schedule but did get some unscheduled fertilizer until 1946, either from interplanted soybean crops during the war or direct application. After 1946, only mowing was done in the orchard. From this data TVA has decided to plant its walnut seed orchards in blocks containing two ramets of each clone. One sub-block will contain a ramet of each clone spaced 40 x 40. The second sub-block will be planted between the first so that final spacing between grafts will be 20 x 20. Thinning, if needed, can be accomplished by completely removing a sub-block. This would still leave one ramet of each clone at a 40 x 40 spacing.

Fertilization and cultivation, recommended seed orchard procedures, should result in increased nut yields. One difficulty encountered in the above orchard, even though these procedures were not closely followed, was some extreme yields. Such yields resulted in breakage in the crown of individual trees which unless properly cared for will result in greatly weakening the tree and exposing it to fungi. If the aim is maximum production per ramet, one should be prepared to support heavily laden branches. Whereas, if the goal is maximum production per acre, this should be obtainable by planting more grafts per acre at closer spacing. This will probably reduce yields per graft but not necessarily per acre.

Table 3.--Average diameter, height, and crown radius of a black walnut seed orchard established in 1934

Variety or clone	Year	Number of ramets measured	Average DBH	Average total height	Average crown radius
			Inch	- - Feet - -	
Thomas	1946	49	6.6	26.5	8.4
	1956	49	10.3	33.6	15.0
	1966	47	12.9	35.0	17.3
Stabler	1946	9	7.8	23.2	9.4
	1956	7	12.0	36.4	17.0
	1966	5	16.0	40.0	22.0
Sparrow	1956	4	8.4	29.3	13.3
	1966	4	11.6	37.0	18.7

Black cherry (Prunus serotina)

Our experience with this species is very limited. In 1938, three black cherry grafts were planted 20 feet apart in a straight line. The trees received no special treatment except mowing throughout each growing season. In 1963, at least 6 pounds of clean, dry seed were collected from each graft. Today the trees average 17.0 inches in diameter at 1 foot, 54 feet total height, and the crowns have a radius of 13, 16, and 19 feet.

With this meager data we can suggest that seed orchard spacing be similar to that planned for walnut. Certainly more intensive management should result in good early seed yields and the ability to store the seed should provide an adequate supply each year.

General

Similar information for the oaks and yellow-poplar is not available, but estimates have been made and are included in table 4. After an estimate of the future demand for seedlings of each species has been made, this table can be used to determine the required seed orchard acreage to meet this demand.

Table 4.--Estimated seed production per acre in hardwood seed orchards

Species	Expected production per ramet (in 20 yrs.)	Expected production per ramet (in 10 yrs.) 1/	Seed per bushel 2/	Seed per pound 2/	Germination 2/	Expected nursery seedlings per ramet 3/	Expected seedlings produced per acre of seed orchard at age 20 (in thousands) 4/		
							30'x30'	20'x20'	15'x15'
			Pound	Number	Percent	Number	----	Number	----
Yellow-poplar	1/2 bu.	1/8 bu.	10	14,000	10	5,250	250	570	1,800
Black walnut	360 nuts	90 nuts	-	-	60	162	8	17.5	31.5
Black cherry	2 lb.	1/2 lb.	-	4,800	70	5,000	240	545	965
White oak	1/2 bu.	1/8 bu.	67	150	77	2,900	139	316	559
Northern red oak and Cherrybark oak	1/2 bu.	1/8 bu.	49	140	61	1,570	75	170	300

1/ 25 percent of 20 year production.

2/ Taken from Woody Plant Seed Manual.

3/ Reduced 25 percent for nursery loss.

4/ 30' x 30' spacing = 48 grafts/acre; 20' x 20' spacing = 109 grafts/acre; 15' x 15' spacing = 193 grafts/acre. Probably less fruit produced than indicated at 20' x 20' and 15' x 15' than at 30' x 30' spacing due to competitional effects.

Hardwood tree improvement is today where pine improvement was 10 years ago. More and more research groups are directing their emphasis toward hardwoods. Crash programs, such as the one on black walnut in the Central States and the one on black cherry in the Northeast, are being initiated. There are many more commercial hardwood species than pines and these tend to grow in predominantly mixed stands on relatively good sites. Each must be dealt with individually. TVA has taken a giant step by selecting six species but we hope that others can be added to our program in the future. We look for the day when tall, straight, high-quality hardwoods will be found on all suitable sites throughout the hardwood region, when it will be just as common to plant hardwoods as it is to plant pines, and when all forest planting stock will be superior.

LITERATURE CITED

Funk, D. T.
1964. Premium yellow-poplar seedlings--8 years after planting. U. S. Forest Serv., Central States Forest Expt. Sta. Res. Note CS-20.

Hatmaker, J. F. and K. A. Taft, *Jr.*
1966. Hardwood grafting techniques. Tree Planters' Notes. (In press).

Williams, R. D.
1966. Planting stock grades. Black walnut culture: Papers presented at the Walnut Workshop, Carbondale, Illinois, August 2-3, 1966, pp. 16-17.

Larger, T. F.
1946. Yield and nut quality of the common black walnut in the Tennessee Valley. Northern Nut Growers Assoc. 37th Ann. Report, pp. 118-124.