PERFORMANCE OF BLACK WALNUT IN THE YELLOW RIVER WATERSHED OF THE PEOPLE'S REPUBLIC OF CHINA

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The introduction and evaluation of black walnut (*Juglans nigra* L.) into the People's Republic of China is a relatively recent development (Xi and others 1999). Small isolated black walnut plantings established by missionaries from the United States can be found throughout much of China; however, few written records document the growth of the surviving black walnut trees. In the early 1980s, the Chinese Academy of Forestry in Beijing and the University of Nebraska initiated a cooperative venture with the Friendship Nursery in Henan Province to exchange walnut and pecan germplasm. Wang (1996) estimates this venture resulted in more than 40 acres of black walnut plantings as nine demonstration plantings, nut cultivar trials, or scionbank orchards.

In March 1995, the Forestry Research Institute of China, the University of Nebraska, the Northern Nut Growers Association, and the Forestry Bureau of Luoning County called together nursery specialists and research horticulturists from China and the United States to evaluate the suitability of introducing black walnut and its economic potential for plantation culture in the semi-arid regions of China. Evaluation of existing plantings indicated black walnut is well adapted to the lower and middle regions of the Yellow River watershed.

Wang (1996) report expected annual growth of 4 to 6 feet for height and 0.6 to 1.0 inches in trunk diameter. He also reported walnut to be tolerant of droughts and deeply rooted with taproot length exceeding height. Because of the rapid growth and high value for the wood, the economic value of black walnut was estimated at 10-fold that for Chinese poplar (*Populus* spp.) and paulownia (*Paulownia tomentosa* (Thunb.) Sieb. & Zucc.). One conference recommendation suggested that black walnut should gradually replace both poplar and paulownia when reforesting farming areas in the Yellow River watershed. Under the Natural Forest Conservation Program initiated in 1998, China plans to convert 15 million acres of farmland to plantation forests within 10 years for soil erosion control in the Yangtze and Yellow River watersheds (Zhang and others 2000). Recently, Xi (1999) published guidelines in Chinese for the introduction, establishment and management of black walnut.

In the fall of 1996, a 10-person delegation from the Chinese Academy of Forestry and the Henan Bureau of Forestry journeyed to Nebraska, Kansas, Missouri, and Illinois to collect nuts from timber-type black walnut trees. Their objective was to establish multiple progeny tests and possibly identify the most appropriate areas in the United States for future seed purchases. Nuts were collected from plus-trees growing at the following five locations: the Pleasant Valley seed orchard (PVSO) located in Alexander County, IL and maintained by the Shawnee National Forest; the Tree Improvement Center arboretum (TICA) located in Jackson County, IL and maintained by Southern Illinois University; a grafted orchard (HGO) maintained by Leander Hay and located in Saline County, MO; Tuttle Creek Experimental Area provenance test (KPT) located in Riley County, KS and maintained by the Kansas State University; and several natural stands located near the Blue Bird Nursery (BBN) in Colfax County, NE. When possible, the source of the maternal germplasm was determined from plantation records or cultivar histories to identify county and state of origin, plant hardiness zone (Cathey 1990), and normal annual total precipitation and mean length of frost-free period (Hicks 1998). Plant hardiness zones are 4a for BBN, 5b for KPT and HGO, 6a for TICA, and 6b for PVSO.

Nuts from 37 individual trees (half-sib families) were cleaned and floated at the University of Nebraska. Sound seed was flown to Beijing, stratified for 3 months, pre-germinated, and planted into containers in a greenhouse. In-leaf seedlings of

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most families were transported and planted at sites in plant hardiness zones 6 (Beijing provenance), 7 (Shanxi provenance), and 8 (Henan provenance) (Widrlechner 1997).

The Beijing progeny test (40.5 N, 116.5 E) is located on a first terrace site near the Badaling station of the Great Wall (Fig. 1). This planting site has loam soils and subject to periodic flooding. The Shanxi progeny test is part of the XiaoYi Nursery in the TaiYuan Basin (Fig. 1). This site has deep, slightly alkaline, dark brown soils and a mean annual precipitation of 18 to 20 inches with a 160- to 180-day growing season. The Henan progeny test (34.8 N, 113.5 E) is part of the Friendship Nursery near Zhengzhou (Fig. 1). This planting site has a deep sandy loam with a 60-foot deep water table, mean annual precipitation of 23 to 24 inches falling primarily in the fall, and a 220-day growing season.

In-leaf seedlings of 30 or more families were planted in June 1997 in each progeny test using a randomized block design with row plots within each of four blocks. Planting design used four-tree plots at Henan and Shanxi tests and five-tree plots at Beijing test. Tree spacing is nominally 10 feet apart within row and 12 to 15 feet between rows. Within row vegetation was controlled for 4 years by hand cultivation. Survival, stem height (H) and trunk diameter (D) have been determined annually. Stem volume was estimated as D^2H. For each planting site, the performance index of each family was calculated as the average of the individual family percentile rank for stem height, diameter, and volume. Percentile rank within plantings was calculated as ((family mean—mean of poorest family)/(mean of best family—mean of poorest family) for each variable.

Figure 1.—Black walnut progeny tests were established within the Yellow River watershed near Beijing, in Shanxi provenance near Taiyuan, and in Henan Provenance near Zhengzhou. For comparison, maps of China and North America are aligned along 18 and 54 degrees north latitude.

After four growing seasons, survival of the walnut seedlings has exceeded 95% at both the Henan and Shanxi plantings. Survival among families at the Beijing progeny test range from 20% to 95%. Mortality is the result of a summer flood in 1997 when 26% of the seedlings died and then failure to overwinter when an additional 17% of the seedlings died. In the spring of 1999, the ambrosia beetle (*Xylosandrus germanus*) attacked many of the surviving saplings causing extensive stem dieback and resprouting but little additional mortality.

The Henan progeny test has had the most rapid tree growth with average tree heights ranging from 16 to 23 feet among families after four growing seasons (Table 1). Because of the rapid height growth, the trees are exceedingly thin with average trunk diameters of only 1.1 to 1.5 inches. In the fall 2000, many of the trees showed premature defoliation in response to walnut anthracnose (*Gnomonia leptostyla*). Although anthracnose has relatively little impact on growth of walnut in the Central Hardwood region (Van Sambeek 2002), the longer growing season in China will likely result in a higher incidence of premature defoliation and a greater impact on tree growth. In addition, future growth in the Henan progeny test is likely to be slowed following the removal of all lateral branches during August 2000 and used as scionwood in the nursery.

The Beijing progeny test had the most variable height growth ranged from 14 to 24 feet among families (Table 1). Part of the variation is in response to the ambrosia beetle that caused extensive stem dieback and subsequent basal sprouting in the spring 1999. Weber and McPherson (1984) indicate this insect was introduced from eastern Asia into the United States. One growing season after being attacked, most trees had produced basal sprouts that were nearly as tall as the pre-attack tree heights. Weber (1981) reported similar basal sprouting and height growth on walnut saplings attacked by the ambrosia beetle in the Central Hardwood region. The walnut saplings in the Beijing progeny test are also exceedingly thin with average trunk diameters of only 0.7 to 1.3 inches.

Table 1.—Black walnut progeny collection number and name; site of nut collection; origin of maternal germplasm by state, plant hardiness zone, annual rainfall, and frost-free days; performance index (mean of the percentile rankings[1]); and mean height of 4-year-old saplings at three locations in Yellow River watershed of central China.

Progeny		Harvest	Maternal Germplasm Variables				Perf.	Walnut Age 4 Height		
No.	Name[2]	Site	Origin	P.H. Zone	Rain-Fall	Frost-Free	Index	Henan	Shanxi	Beijing
					-in-	-days-	-%-	-ft-	-ft-	-ft-
16	NC-5869 AA-34	TICA	IL	6a	41	200	0.90	22.2	14.4	-----
27	NC-6134 IB-07	TICA	TN	7a	52	180	0.80	20.4	16.6	-----
20	NC-6616 B#1	PVSO	IL	6b	45	210	0.73	23.2	14.4	-----
23	Native Hay	HGO	MO	5b	40	180	0.72	20.9	13.5	23.0
4	NC-6600 B#4	PVSO	TN	7a	50	200	0.71	21.7	-----	23.3
29	NC-6603 B#3	PVSO	TN	7a	50	210	0.68	20.4	13.3	-----
8	NC-6138 PB-09	TICA	IA	5a	32	170	0.67	22.1	16.3	17.4
13	Carb #1	BBN	NE	4b	30	160	0.65	19.2	16.2	21.0
15	Cheeks #2 B#3	HGO	unk	unk	unk	unk	0.61	19.5	13.3	24.3
21	NC-5872 CC-20	TICA	MO	6a	45	190	0.59	21.8	13.3	-----
24	Big Tree Clark	BBN	NE	4b	30	160	0.56	21.9	12.9	17.7
9	Kwik Krop	HGO	KS	6a	40	200	0.54	19.9	13.0	18.4
33	NC-6609 B#1	PVSO	KY	6b	48	200	0.54	-----	14.4	18.4
22	NC-6622 B#2	PVSO	TN	6b	50	190	0.52	19.4	14.0	-----
3	NC-5869 AA-30	TICA	IL	6a	41	200	0.52	-----	12.3	21.3
6	KS-2707 #1	KPT	MO	6a	44	200	0.51	21.2	13.4	20.3
12	NC-5875 EE-20	TICA	MI	5b	34	150	0.49	20.7	14.0	19.7
28	Walter Jackson	HGO	KS	5b	37	190	0.47	17.7	15.2	-----
1	KS-2707 #3	KPT	MO	6a	44	200	0.46	17.4	14.2	20.3
36	Clarkson #3-2	BBN	NE	4b	30	160	0.45	22.7	-----	19.0
11	Mixed seedlot	HGO	MO	5b	40	180	0.36	19.3	14.0	18.0
7	NC-6160 KK-13	TICA	IN	5a	38	170	0.36	20.5	13.3	14.4
18	NC-6164 FA-07	TICA	IN	5a	38	170	0.34	16.9	14.3	-----
2	NC-6176 MB-09	TICA	VA	7a	40	180	0.33	20.6	11.2	17.2
10	NC-6163 OA-09	TICA	IN	5a	38	170	0.31	16.0	13.1	20.0
26	NC-6134 IB-05	TICA	TN	7a	52	180	0.25	17.7	14.0	-----
25	Carb #2	BBN	NE	4b	30	160	0.24	-----	12.7	15.4
17	NC-5875 EE-20	TICA	MI	5b	34	150	0.24	18.0	12.9	-----
37	Clarkson #2	BBN	NE	4b	30	160	0.23	17.6	12.5	16.4
5	Clarkson #3-1	BBN	NE	4b	30	160	0.11	16.3	11.7	17.0

The Shanxi progeny test had the slowest height growth and tree height among families averaged between 11 and 17 feet (Table 1). As found in the other two progeny test, the trees in the Shanxi progeny test were also exceeding thin for their height with average trunk diameters of 0.7 to 1.5 inches.

No families were consistently the best or poorest performers across all three plantings (Table 1); however, computing a performance index from percentile ranks did allow us to rank the families across the three plantings. The performance index of 0.90 for progeny #16 indicates it was not always the top performer for height, diameter, and volume; however, it does suggest it was one of the best performers in the progeny tests that it was included in. Likewise, the performance index of 0.11 for progeny #5 indicates it performed poorly but was not consistently the poorest performer.

All five locations (PVSO, TICA, HGO, KPT, and BBN) from which nuts were collected produced families with performance indices above and below the mean. All locations, except for the BBN, were established with seed or scionwood from the walnut range, thus, the source of the paternal genes (pollen parent) is largely unknown. We determined the original source of the maternal genes for most of the open-pollinated families. Presumably by analyzing climatic variables from which maternal genes originated and the family performance index, we could identify the most appropriate provenances within the Central Hardwood region for future seed collections.

Maternal genes originated from 10 states and four plant hardiness zones (Table 1). Families originating from Tennessee (plant hardiness zones 6b and 7a) frequently have higher performance indices than families from Nebraska (plant hardiness zone 4b). Statistically, there is a significant linear relationship between the plant hardiness zone from which the maternal genes originated and the mean performance index of the half-sib progeny (R^2 = 0.161, p = 0.031, 27 df). This relationship may be curvilinear because the performance index for families originating from plant hardiness zones 6a and 6b have the greatest percentage of families with above average performance (Fig. 2).

There is a highly significant linear relationship between mean annual rainfall from the region where the maternal genes originated and the mean performance index of the half-sib progeny (R^2 = 0.3011, p = 0.002, 27 df). Seven of the eight families originating from areas in the United States with greater than 40 inches of annual rainfall had above average performance indices (Fig. 3). This was unexpected considering precipitation averages less than 25 inches annually at all three sites in China.

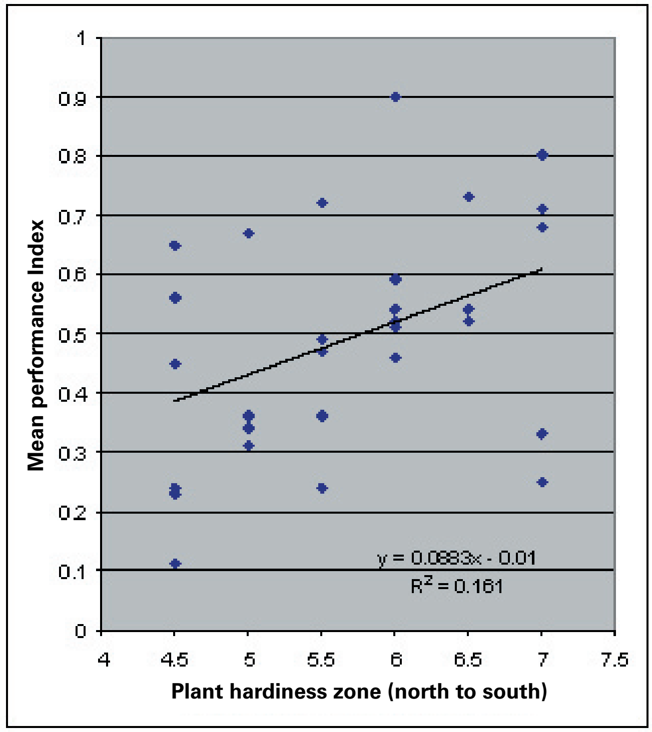

Figure 2.—Performance index for open-pollinated families in Yellow River watershed and plant hardiness zone origin of maternal genes.

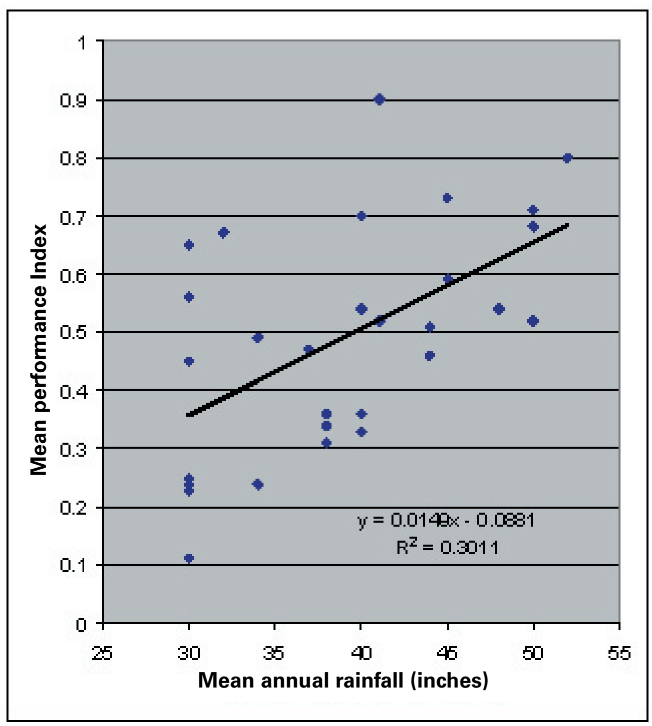

Figure 3.—Performance index for open-pollinated families in Yellow River watershed and mean annual rainfall for region from which maternal genes originated.

There is also a highly significant linear relationship between mean number of frost-free days in region from which maternal genes originated and the mean performance index of the half-sib progeny (R^2 = 0.2868, p = 0.003, 27 df). Nearly all families where maternal genes originated from regions with 190 or more frost-free days during the growing season had above average performance indices (Fig. 4).

In conclusion, we found families throughout the Central Hardwood region that performed well in the Yellow River watershed of China. We also found that seed collections from certain geographic regions were more likely to yield highly successful families. Preliminary guidelines suggest seed should originate from areas within plant hardiness zones 6a and 6b that have a mean annual rainfall in excess of 40 inches with a growing season of 190 or more frost-free days.

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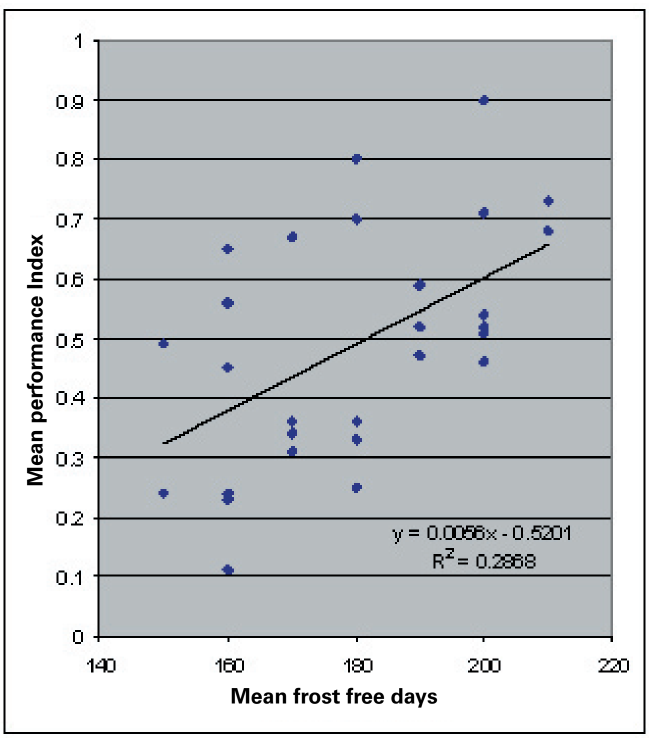

Figure 4.—Performance index of open-pollinated families in Yellow River watershed and length of growing season where maternal genes originated.

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