A Graphic Technique for Identifying Superior Seed Sources for Central Hardwoods

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To maximize forest production, foresters need to plant the best genotypes provided by forest geneticists. Where should the forest geneticist search for the best seed sources? How far can one go south, or north to find them? The answer may rely on the species and the location of the test plantation. For example, when black walnut trees were tested in Illinois, Indiana, Missouri, and southern Michigan, trees from southern seed sources grew faster than those of local and northern seed sources. However, in Iowa and Minnesota, trees from northern sources were generally larger than trees from southern sources, and in Kansas and Ohio, tree size was not associated with latitude of seed source (Bey 1973, 1979). As the number of plantation increases, we may find that the most southern plantation will have only northern seed sources and the most northern plantation will have only southern seed sources, we may not be able to make a simple statement as to the best seed zone for each plantation location. Since a picture is better than a thousand words, we suggest a simple graphic solution useful to answer these questions.

METHOD AND PROCEDURE

The procedure can be summarized as follows. Seed sources are first selected according to their standardized performance. Their position is plotted on a diagram using latitude of the plantation as the x-coordinate and the difference between provenance latitude and plantation latitude as the y-coordinate. Employing this graphic technique, probable locations for superior genotypes can be easily defined.

To illustrate the procedure with a practical example, we applied this technique to data from 12- and 13-year-old rangewide provenance/progeny tests of white ash planted at 12 locations throughout the eastern United States (Table 1). The average tree height of each provenance is first standardized according to the plantation mean and standard deviation among provenances in that plantation, so that after standardization the distribution of provenance performances in each plantation will have zero mean and unit variance. The standardization is necessary for valid performance comparisons.

The next step is to define superior seed sources. To make sure that the seed sources we have selected will have at least one standard selection differential above the plantation mean, we intentionally discard those with standardized scores of less than one. This level of selection intensity allows us to retain about 15% of the seed sources. The most probable geographic searching areas then will be delineated by these top 15% seed sources.

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Table 1.—Height of white ash at various provenance and plantation combinations. The original data are sorted from top to bottom by latitude of provenance in descending order, and sorted from left to right by latitude of plantation in ascending order.

Provenance					Plantation												Mean
State	No.	Lat.	Long.	Elev.	LA	AL	AR	IL	IN	KY	WV	KS	OH	NE	MI	WI	
		-.1 Deg-		Ft.						-Height in cm.-							
MI	6736	466	896	1300	125			550	200			241	785	298	546	297	380
NBR	6807	460	673	500											615		615
NBR	6804	459	661	50				540							481		511
WI	6723	457	890	1675	138			590	154	291	295	258	861	313	631	276	381
ONT	6796	456	767	300				584									584
ONT	6731	456	771	590											612		612
QUE	6808	455	742	48										347	591		469
MI	6780	454	849	800									849		632		741
MI	6779	453	836	640	144			567				233	745		567	252	418
ME	6785	449	686	100	233			561	60	250			743	247	565		380
ME	6786	447	687	240							269	243				205	239
MI	6802	445	857	1060								313					313
VT	6782	440	729	1700	109			539						377	631		414
VT	6788	429	729	1400			366										366
NY	6793	428	761	1640					188	354	508	291		319	647	262	367
MI	6769	422	837	850				598				302		338	623		465
CT	6724	414	728	350				551	120				827	331	621		490
CT	6794	413	730	210	160			644		254	313		722	221	542		408
PA	6725	408	780	1175											591		591
OH	6732	407	819	1059							376	244	847	386	559	316	455
NE	6720	406	957	900			275		233	353	280	458		371	581	415	371
IL	6726	397	912	700				656	357		400	372		331	589	242	421
OH	6739	396	847	1000					400			419	907	386			528
WV	6806	392	801	1300							481			372	549		467
OH	6798	392	841	956						393					621		507
IL	6771	391	884	590	275		289	738	368	454	384	292	916	393	503	242	441
WV	6778	391	796	2500	151			580			479	297	820				465
IN	6795	380	862	650	279		149	802	252	330	441	440	1000	342	644	261	449
IL	6721	377	893	477	362			844	376	494	418	383	858	321	512		508
IL	6722	376	883	500		618	282					331				266	374
KY	6792	372	874	500	336	622	245	790				376	906	324	524	261	487
KY	6799	372	830	1250						446							446
KY	6734	369	882	495	348			834	379	451	306		933	382	605		530
MO	6727	367	911	847				845						354	471		557
TN	6865	365	858	980												258	258
TN	6868	365	875	650					376	477						208	354
TN	6864	365	854	1170					344	454	296	358				239	338
TN	6866	365	886	350			245		432								339
AR	6735	364	929	885		635	322		307	381	357	342		321	585	228	386
TN	6870	364	837	1050		688	239										464
NC	6797	358	786	350										367	598		483
TN	6862	357	842	980					298	443	287	345				207	316
NC	6783	357	826	2400											550		550
TN	6871	355	852	1100	368	610		814				335					532
TN	6873	354	867	800		618	287				324			349	534		422
TN	6874	353	850	760		722											722
TN	6728	352	859	1110	312	676	211	729	276	376	319	310		292	553	216	388
TN	6861	351	872	900		650	243			438						233	391
SC	6784	350	830	750								268				232	250
TN	6872	350	847	830		656	234							356	628		469
GA	6781	348	839	3000								310					310
AR	6790	346	936	700		701	299										500
AL	6733	345	865	1000	317	652	266	707	346	394	263		847	354	529		468
MS	6730	339	889	200				787									787
MS	6740	334	888	380	473	692	290	898	356	456	289	267	591			206	452
LA	6738	315	910	30	548	935	476	603	361	362	358	268	417				481
MS	6737	310	888	250	473	843	410	681	330	447		286	435	206	329		444
TX	6768	303	944	100	488	868	448	680		337			392				536
Mean					297	699	293	681	296	393	354	318	770	333	569	253	
Lat.					304	324	346	375	381	382	390	391	400	405	423	430	

Once the superior seed sources are identified, we subtract the plantation latitude from provenance latitude, so that the latitude of the seed source is transformed to a relative scale in reference to the plantation. Positive sign indicates northern seed source and negative sign represents southern seed sources. The difference was used as the y-coordinate and the latitude of the plantation was used as the x-coordinate of the selection. The positions then were plotted (Figure 1a).

In order to generalize the application of the technique to the high-value central hardwood, results from a 22-year-old, 7-plantation black walnut provenance/progeny test are also presented (Figure 1b). Data for black walnut were obtained from Bresnan (personal communication) and were summarized in Table 2.

DISCUSSION OF METHOD

Due to differences in genotype stability, it seems probable that plantation means, and the variance of provenance performances in different plantations, will not be equal. Standardization allows us to compare selections on a common base. However, in the case of equal variances but unequal means, the original data can be transformed to percent of plantation mean to facilitate comparison. To most people, it is easier to visualize percentage gain than gain in standard units. The question "If I want the seed sources that are 20% better than the average, where can I find them?", is more pragmatic than a similar question "If I want the seed sources which have a selectional differential of 1.4 unit, where can I find them?"

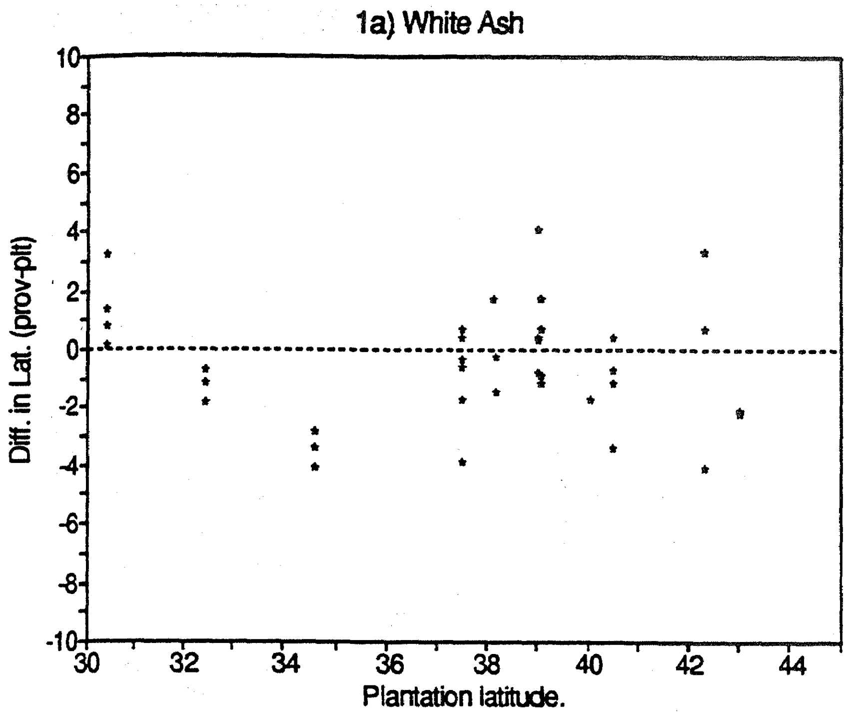
To answer the last question above, we arbitrary set the cut-off point of selection at one standard unit. The reader is free to choose some other selection intensity or selection proportion to meet the need of a particular tree improvement program. Too few or too many selections usually make the seed collection zone less clearly defined.

We used latitude as an independent variable because our data indicates that correlation is strongest between height growth and latitude, but is weak between height and degrees of longitude or elevation. However, readers may find the use of some other variables would be more meaningful for their models, for example, the variable minimum temperature at the source as deviation from that of the planting site may be of interest (Schmidtling, 1992). Minimum temperature is related to many climatic variables such as average temperature, number of frostfree-days, and number of degree-days; and to many geographic variables such as longitude, latitude, and elevation.

DISCUSSION OF RESULTS

The attraction of such a graphical approach results from the ease of making predictions about where to look for the superior seed sources in a given untested location. For example, if you want to find a good white ash seed source for planting at 31 degrees north latitude, Figure 1a shows that you have a better chance by going north. If you want to plant white ash at 38 degrees north, you may find them within 2 degrees latitude of the planting areas.

As seen in Figure 1a, there are 23 asterisks above the zero line, the probability of finding a superior white ash is 23 out of 38, or 61% south of the planting site, and 15 out of 38, or 39% north of the plantation. In other words, it is 1.6 times (61%/39%) more likely to find a good seed source from the south than that from the north. The "odds ratio" of finding a good seed source from the south than that from the north is therefore 1.6. The odds ratio is even higher for black walnut trees (5:3:1). However, one must keep in mind that the experimental design and sampling procedure contribute to the outcome of finding the good seed sources. When a plantation is located at the southern perimeter of the species distribution range, such as the Louisiana plantation for



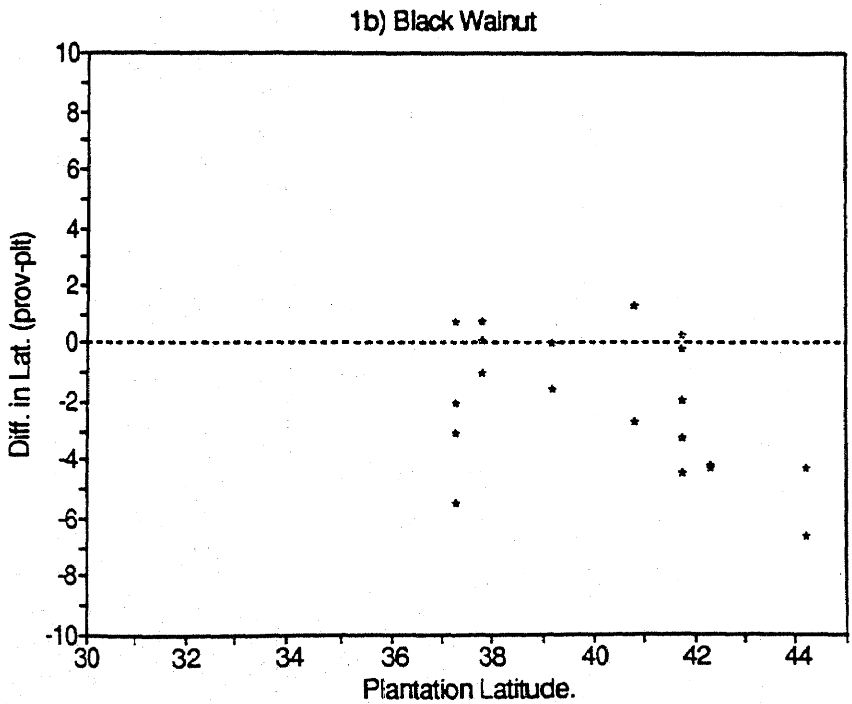


Figure 1.—Location of the top 15% provenances in each plantation.

Table 2.—Height of black walnut at various provenance and plantation combinations, sorted by latitude of provenance and by latitude of plantation

Provenance					Plantation							
State	No.	Lat.	Long.	Elev.	IL	MO	KS	OH	IA	MI	MN	MEAN
MN	2503	44.4	94.5	1000						103		103
MN	2501	43.6	92.3	1300							69	69
HI	2406	43.1	85.7	800							75	75
IA	1807	42.8	92.8	950					75			75
IA	1809	42.5	96.4	1100					72			72
HI	2405	42.5	83.8	850						121		121
IA	1803	42.3	91.2	900	60		143			108		104
IA	1801	42.1	93.6	950							71	71
HI	2403	42.0	85.7	840				120	64	114		99
IL	1607	41.9	89.3	790				135				135
IA	1802	41.8	91.9	700		81			82		74	79
IL	1602	41.5	90.4	600						122		122
IL	1605	41.4	88.1	610	56				81			69
IL	1603	41.2	89.2	700							71	71
PA	3502	41.0	77.1	640				130		123		127
IA	1810	40.7	95.7	1100							48	48
IA	1805	40.7	92.5	950	55							55
IN	1705	40.2	86.9	600					71		70	71
OH	3202	40.1	84.7	1000				132				132
PA	3503	40.0	77.1	640				124	65			95
OH	3201	39.8	84.6	920							71	71
IN	1702	39.8	86.9	730				129		112		121
MO	2705	39.7	91.4	660							86	86
MO	2702	39.6	94.7	878		86			81			84
IN	1707	39.3	85.0	950		79						79
KS	1903	39.1	94.9	900			159	131		115		135
KS	1901	39.1	96.1	1050					78			78
IN	1709	39.1	86.9	490	70	75						73
IN	1704	39.0	86.1	780			161			118		140
IN	1701	38.7	86.5	640				120	63		79	87
OH	3203	38.6	82.6	600					77			77
MO	2708	38.3	94.1	800	71				80			76
KS	1902	38.3	95.2	975		92	159				54	102
IN	1708	38.2	86.5	775	61		148	124	59	112		101
KY	2002	38.0	83.5	1000						121	44	83
MO	2703	37.9	93.9	925				134		119		127
WV	4202	37.9	80.2	1950				135		140	73	116
VA	4101	37.8	79.5	1000	78				65	132		92
KY	2005	37.6	84.3	1100	59			131				95
MO	2704	37.6	91.5	1170		93						93
VA	4102	37.5	80.1	1450				127				127
IL	1601	37.4	89.3	540	71				60		94	75
MO	2706	37.4	91.0	795				124				124
KS	1904	37.3	94.8	875			161					161
VA	4104	37.1	76.9	120				130	82			106
KY	2004	37.0	84.3	1150	67			123		120		103
KY	2001	36.9	86.8	520		76				120		98
VA	4103	36.9	78.7	460			149	122	38	124		108
KY	2003	36.7	84.1	1700			150		59		51	87
MO	2707	36.6	94.4	900		93	158		70			107
TN	3804	36.4	82.0	2040		77	145	125		112		115
TN	3805	36.4	8.4	650				122				122
TN	3803	36.3	83.7	1275	60	71		130	63	125		90
NC	3101	36.0	81.7	1500	76			125	62		74	84
AR	1101	35.8	92.3	1200	64	74	159		73			93
NC	3105	35.5	82.6	2200	72		155		41			89
NC	3102	35.4	83.7	2900	66	68				127		87
NC	3103	35.3	82.8	2500				130	62			96
TN	3802	35.2	85.9	1700				130				130
TN	3806	35.2	88.3	480	78							78
AR	1102	34.9	93.9	1916	60							60
MS	2602	34.0	88.9	400	81	85	147					104
SC	3601	33.9	82.1	510			136	114				125
MS	2601	32.3	89.4	450	68	83		90				80
TX	3901	31.6	96.0	360	90							90
TX	3902	31.5	94.6	308		72						72
TX	3903	31.1	94.9	260			143					143
Mean					68	80	152	125	68	119	69	96
Lat.					37.3	37.8	39.2	40.8	41.8	42.3	44.2	

white ash, only the northern seed sources are available for selection; consequently no southern seed sources can be selected. On the opposite extreme, in Minnesota, only southern black walnut seed sources are available; no northern seed sources can be selected. A valid argument in favor of the southern or northern provenances can be made only when equal numbers and equal ranges of southern and northern provenances are present at the same plantations.

The probability of finding a good seed source from the south is more consistent in black walnut than that in white ash. In all seven black walnut plantations, the southern seed sources outnumber or equal the northern seed sources in selected numbers. But in the white ash study, in three (LA, WV and MI) out of the 12 plantations the northern seed sources provide better results. Therefore it can be said that there are more plantation-by-provenance interactions in white ash than in black walnut. In a previous analysis we found that the variance component for the plantation-by-provenance interaction was 5% for black walnut (Kung and Smith, 1989), and 8% for white ash (Kung and Clausen, 1983).

When the "local seed source" is defined as a provenance within 200 miles of the plantation, most of selections are local. Black walnut and white ash trees seem to be well acclimated or adapted to local environments on the basis of tree height.

CONCLUSIONS

The application of this graphic technique is mainly for provenance tests planted in many locations. The technique enables visualization of the pattern of locations for superior seed sources. Foresters can use it as a guide to find the best seed source for the planting location.

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