VARIATION AMONG WHITE ASH FAMILIES IN FLUSHING

AND SPRING FROST SUSCEPTIBILITY

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Abstract.—Leaf flushing of 52 white ash families was scored in a southern Illinois plantation in 1980 and 1981. Southern trees flushed early, northern trees flushed somewhat later and mid-range trees flushed last. Southern families showed less injury from a light spring frost than northern families. Northern trees were generally shorter than southern trees and, hence, more likely to suffer frost injury. Southern trees with fully expanded leaves appeared less susceptible to frost than northern trees with leaves in the process of unfolding. Thus, both flushing and frost susceptibility in white ash are in part, related to geographic origin.

Additional keywords: *Fraxinus americana*, bud break, clinal variation, geographic origin, tree height, leaf development.

Phenological events such as growth initiation and growth cessation show clinal variation associated with latitude of seed origin in many forest tree species. Other environmental or genetic factors may also have an effect. When 228 families of white ash (*Fraxinus americana* L.) were grown in a southern Illinois nursery, date of leaf fall was closely correlated (r = -0.75) with latitude (Bey *et al*. 1977) but was also strongly affected by ploidy level (Clausen *et al*. 1981). Therefore, it seemed appropriate to study the variation pattern in leaf flushing of some of these families and, when the opportunity arose, to look for family differences in spring frost susceptibility.

METHODS

In March 1976, 1-0 seedlings of 52 white ash families from 15 States and 2 Provinces (table 1) were planted in Union County, Illinois (lat. 37.5° N, long. 89.3° W, elevation 130 m). The seedlings were planted in a randomized block design with 5-tree plots and 5 replications at a spacing of 3.66 m x 3.66 m. The site, a former cornfield on Raymond silt loam, was plowed and disced before planting. After planting, a 1.2 m diameter circle around each plant was treated with Diphenamide herbicide at a rate of 9 kg of active ingredients per ha. Additional weed control consisted of hoeing around the plants and discing between the rows. The area was disced during the first three growing seasons and later mowed.

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Table 1. Spring 1980 flushing and frost injury of 52 white ash families planted in Union County, Illinois.[a]

Family no.	Geographic origin: State or Province	Geographic origin: Lat.	Flushing dates: 4-28	Flushing dates: 5-9	Trees frosted 5-9
		°N	- -Score- -		Percent
676804	TX	30.3	4.6	5.0	10
676805	TX	30.3	4.9	5.0	12
676806	TX	30.3	4.7	5.0	19
673801	LA	30.5	4.7	5.0	10
673804	LA	30.5	4.7	5.0	21
673808	LA	30.5	4.4	5.0	7
673701	MS	30.8	4.9	5.0	9
673702	MS	30.8	4.9	5.0	5
674004	MS	33.4	5.0	5.0	4
674007	MS	33.4	5.0	5.0	0
674008	MS	33.4	4.6	5.0	0
673306	AL	34.5	5.0	5.0	0
673308	AL	34.5	5.0	5.0	0
672804	TN	35.2	4.7	5.0	8
672805	TN	35.2	4.8	5.0	4
672802	TN	35.3	4.9	5.0	0
687106	TN	35.5	4.6	5.0	8
672700	MO	36.7	4.6	5.0	0
673402	KY	36.8	4.1	4.9	0
673403	KY	36.8	3.7	4.9	0
673401	KY	36.9	3.5	4.7	16
679209	KY	37.0	4.0	5.0	4
679203	KY	37.3	3.3	4.8	4
672109	IL	37.7	3.9	5.0	0
672112	IL	37.7	3.1	4.8	0
672113	IL	37.7	4.2	5.0	8
679504	IN	38.3	2.1	4.1	0
679510	IN	38.6	2.3	4.6	0
679506	IN	38.9	3.4	4.8	0
677804	WV	38.9	2.7	4.7	27
677805	WV	38.9	2.6	4.6	55
677104	IL	39.0	2.7	4.7	20
677810	WV	39.1	3.8	5.0	40
672600	IL	39.7	3.5	4.9	47
672900	IN	40.0	2.4	5.0	0
679402	CT	41.3	2.9	4.7	50
679404	CT	41.3	3.6	4.9	67
679405	CT	41.3	3.5	4.0	80
672400	CT	41.4	2.9	4.7	46
676900	MI	42.2	2.4	4.4	12
678201	VT	43.9	3.0	4.9	59
678202	VT	43.9	3.4	4.6	71
678502	ME	44.9	4.3	5.0	32
678507	ME	44.9	4.1	4.9	81
678509	ME	44.9	3.6	5.0	96
677901	MI	45.2	2.3	4.5	55
679600	ONT	45.6	3.6	4.9	52
672303	WI	45.7	4.1	4.9	84
680400	NBR	45.9	3.6	4.8	64
673604	MI	46.6	3.2	4.7	54
673606	MI	46.7	3.4	4.8	42
673607	MI	46.7	3.4	4.8	76

[a]/Families are listed from south to north.

In 1980, leaf flushing of each tree was scored on April 23, May 1, May 9, and May 15. A 6-point scale was used in which 0 indicated no bud activity and 5 meant that the leaves were at least 35 mm long. During the night between May 8 and 9, the leaves on some trees were injured by a light frost. On May 9, the number of trees with injured foliage was recorded.

Because some of the families were already fully flushed at the time of the first observation in 1980, scoring was begun earlier and was done more frequently in 1981. The trees were scored, again on a 6-point scale, at 3-4 day intervals from April 1 to May 1, and then at weekly intervals until May 15.

Differences among families in percentage of trees with frost-injured foliage were tested by analysis of variance based on arcsine transformed plot means. Regression analysis was used to determine relations between frost injury and variables of seed origins, 1980 flushing scores, and tree height. Family differences in flushing on various dates and in number of days after April 1, 1981, to reach flushing score 5 were tested by ANOVA. Due to a lack of normality in the flushing data, Kendall's rank-correlation test was used both to determine associations between the flushing date and seed origin variables and to determine correlation among flushing scores on different dates. Regression analysis was used to determine relations between time to flushing stage 5 and seed origin latitude.

RESULTS

The April 28, 1980, flushing scores of the 52 white ash families differed significantly and showed the expected pattern of southern families flushing earlier than northern families (table 1). According to the Kendall test, the correlation of flushing scores with latitude was not close (tau = -0.47) but was better than that with average length of the growing season. Surprisingly, trees in two families from southern Indiana (679504 and 679510) were among the last to expand their leaves.

Percentage of trees with frost-injured foliage ranged from 0 in 15 families up to 96 in a Maine family (table 1) and varied significantly among families. In general, northern families had more injury than southern families—the reverse of the expected result. Latitude, which accounted for 35 percent of the variation in frost injury, was more closely correlated with percent injured trees than longitude, length of growing season, average date of last spring frost, and elevation of seed origins. Because frost injury did not show a straight line relation to latitude, other regression models were tested. A cubic model (fig. 1) gave the best fit ($R^2 = 0.694$).

Factors other than the origin variables could also have influenced the variation in frost injury. Shorter families had more injured trees than taller families, and tree height accounted for 31 percent of the variation in frost injury. Because frost susceptibility might also be related to stage of leaf development, the correlation between flushing scores on May 9, 1980, and percentage of trees frosted was examined (table 1). The analysis showed, however, that May 9 flushing was not correlated with percent injured trees. Flushing on May 1 was a little more closely related to frost injury but only accounted for 4 percent of the variation. A stepwise multiple regression analysis showed that adding up to 7 other variables (longitude, length of growing season, date of last spring frost, elevation, tree height, May 1 flushing scores, May 9 flushing scores) to the model gave little improvement over using the single variable latitude.

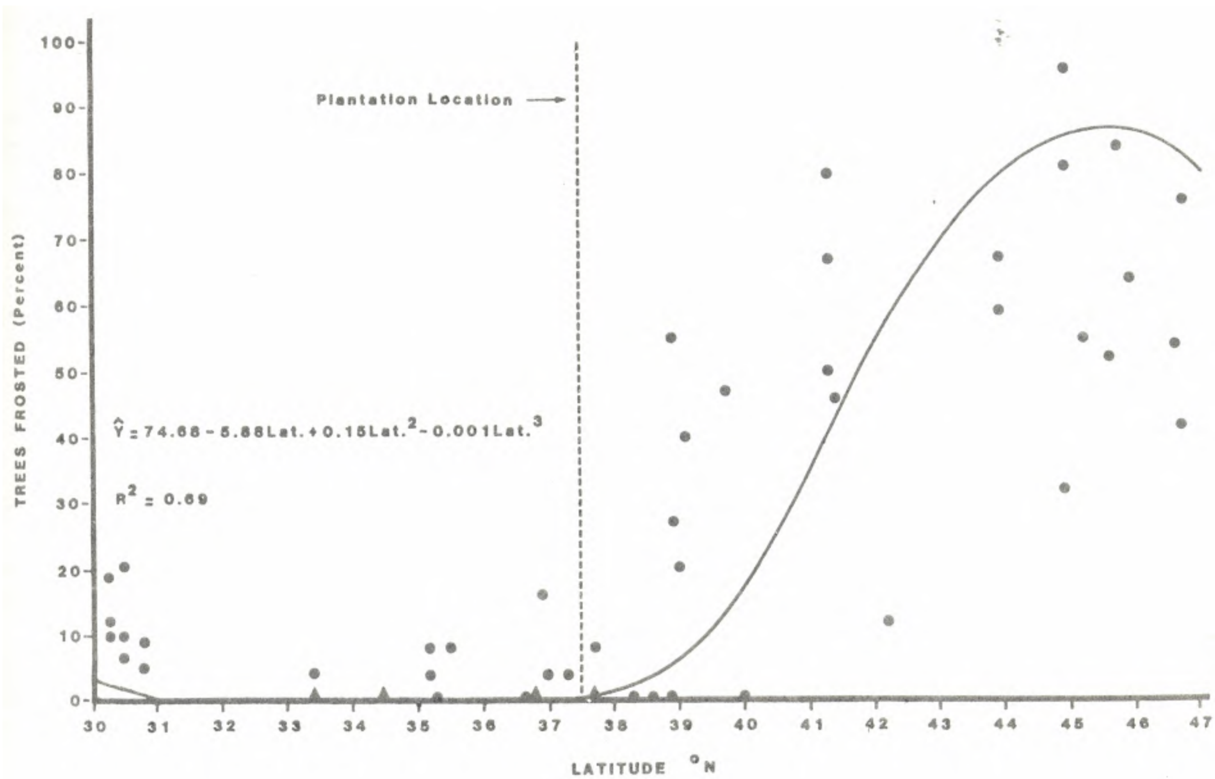

Figure 1. --Injury to 52 white ash families by frost on May 8, 1980, as related to latitude of origin. Triangles indicate places where two observations

In 1981, the earliest date that any family reached an average flushing score of 5 (fully flushed) was April 13 (table 2). The 52 families differed significantly in April 13 flushing scores and, as expected, the earliest families came from Texas, Louisiana, and Mississippi. Again, the latest families were from southern and central Indiana. As was the case with frost injury, a cubic regression model gave the best fit of flushing scores to latitude ($R^2 = 0.771$). The Kendall test showed that flushing was poorly correlated with length of growing season (tau = 0.39).

The progression of flushing can also be measured as the number of days taken by the families to reach a particular stage. In 1981, the number of days after April 1 to reach flushing stage 5 was recorded. This period ranged from 9.6 days for Texas family 676804 to 37.6 days for Indiana family 672900 (table 2) and varied significantly among the families. Again, a cubic regression model (fig. 2) gave the closest relation between days to stage 5 and latitude ($R^2 = 0.747$). According to the Kendall test, length of growing season was not as well correlated with days to stage 5 as latitude was.

Flushing scores on April 20, 1981, (table 2) were very similar to the April 28, 1980 scores (table 1), indicating that flushing began about 1 week earlier in 1981 than in 1980. The rank-correlation test showed a higher correlation between flushing scores on these dates (tau = 0.80) than between the April 28, 1980 scores and the April 13, 1981 scores (tau = 0.78). The April 20, 1981 scores showed family differences and relations to latitude and length of growing season similar to those reported for April 13, 1981.

DISCUSSION

Although flushing of the white ash families in this plantation began about 1 week earlier in 1981 than in 1980, the high rank correlations indicate that the progression of flushing was very similar in the two years. The families differed in flushing scores on several dates but showed the greatest differentiation on April 13, 1981, the earliest date that any family was fully leafed out in that year. Southern families flushed earlier than northern families, but the correlation between flushing and latitude of origin was not as close as expected. In general, families originating south of the plantation location were early, those from mid-range were late, and those from New England, eastern Canada, and northern Wisconsin and Michigan were somewhat earlier than the mid-range group. The similarity in flushing from year to year indicates that this is a general pattern and that other factors besides geographic origin affect leaf flushing in white ash. In contrast to the situation for leaf fall, ploidy level of the families did not affect flushing in this plantation.

There are no obvious reasons why the central and southern Indiana families are slow to leaf out, but the year-to-year consistency suggests that they probably are genetically "programmed" to do so.

Table 2. Spring 1981 flushing of 52 white ash families planted in Union County, Illinois[a]

Family no.	Geographic origin		Flushing dates		Time to reach Stage 5
	State or Province	Lat.	4-13	4-20	
		°N	- -Score- -		Days[b]
676804	TX	30.3	5.0	5.0	9.6
676805	TX	30.3	5.0	5.0	12.8
676806	TX	30.3	4.7	5.0	15.0
673801	LA	30.5	5.0	5.0	11.2
673804	LA	30.5	4.2	4.8	10.6
673808	LA	30.8	4.9	5.0	12.0
673701	MS	30.8	4.9	5.0	15.2
673702	MS	30.8	4.9	5.0	12.8
674004	MS	33.4	4.7	5.0	13.6
674007	MS	33.4	5.0	5.0	11.2
674008	MS	33.4	3.4	4.7	23.0
673306	AL	34.5	4.7	5.0	14.4
673308	AL	34.5	4.8	5.0	14.4
672804	TN	35.2	4.4	5.0	18.0
672805	TN	35.2	4.4	5.0	16.4
672802	TN	35.3	4.1	5.0	16.4
687106	TN	35.5	2.4	4.8	23.0
672700	MO	36.7	3.4	4.9	20.0
673402	KY	36.8	2.6	4.5	23.6
673403	KY	36.8	1.9	4.2	27.6
673401	KY	36.9	1.4	3.7	28.4
679209	KY	37.0	1.9	4.2	25.2
679203	KY	37.3	0.7	3.0	31.8
672109	IL	37.7	2.4	4.5	24.6
672112	IL	37.7	0.7	2.8	31.2
672113	IL	37.7	2.2	4.4	23.6
679504	IN	38.3	0.6	2.2	32.4
679510	IN	38.6	0.5	2.6	30.6
679506	IN	38.9	1.4	3.5	28.8
677804	WV	38.9	0.9	2.8	29.4
677805	WV	38.9	1.2	3.5	30.6
677104	IL	39.0	1.0	3.3	28.6
677810	WV	39.1	2.0	4.2	26.0
672600	IL	39.7	1.8	3.4	26.8
672900	IN	40.0	0.3	1.8	37.6
679402	CT	41.3	1.2	3.3	28.8
679404	CT	41.3	2.0	4.1	25.2
679405	CT	41.3	1.5	3.9	26.8
672400	CT	41.4	0.9	3.0	27.6
676900	MI	42.2	1.0	3.0	30.8
678201	VT	43.9	1.9	4.3	25.4
678202	VT	43.9	1.6	3.9	26.0
678502	ME	44.9	2.1	4.1	24.6
678507	ME	44.9	1.8	4.0	26.8
678509	ME	44.9	1.4	3.8	26.8
677901	MI	45.2	0.8	2.7	30.6
679600	ONT	45.6	1.6	3.7	29.4
672303	WI	45.7	2.7	4.6	23.0
680400	NBR	45.9	1.8	3.8	26.8
673604	MI	46.6	1.5	3.7	28.6
673606	MI	46.7	2.0	4.2	25.4
673607	MI	46.7	1.4	3.7	29.4

[a]/Families are listed from south to north.

[b]/Days after April 1, 1981.

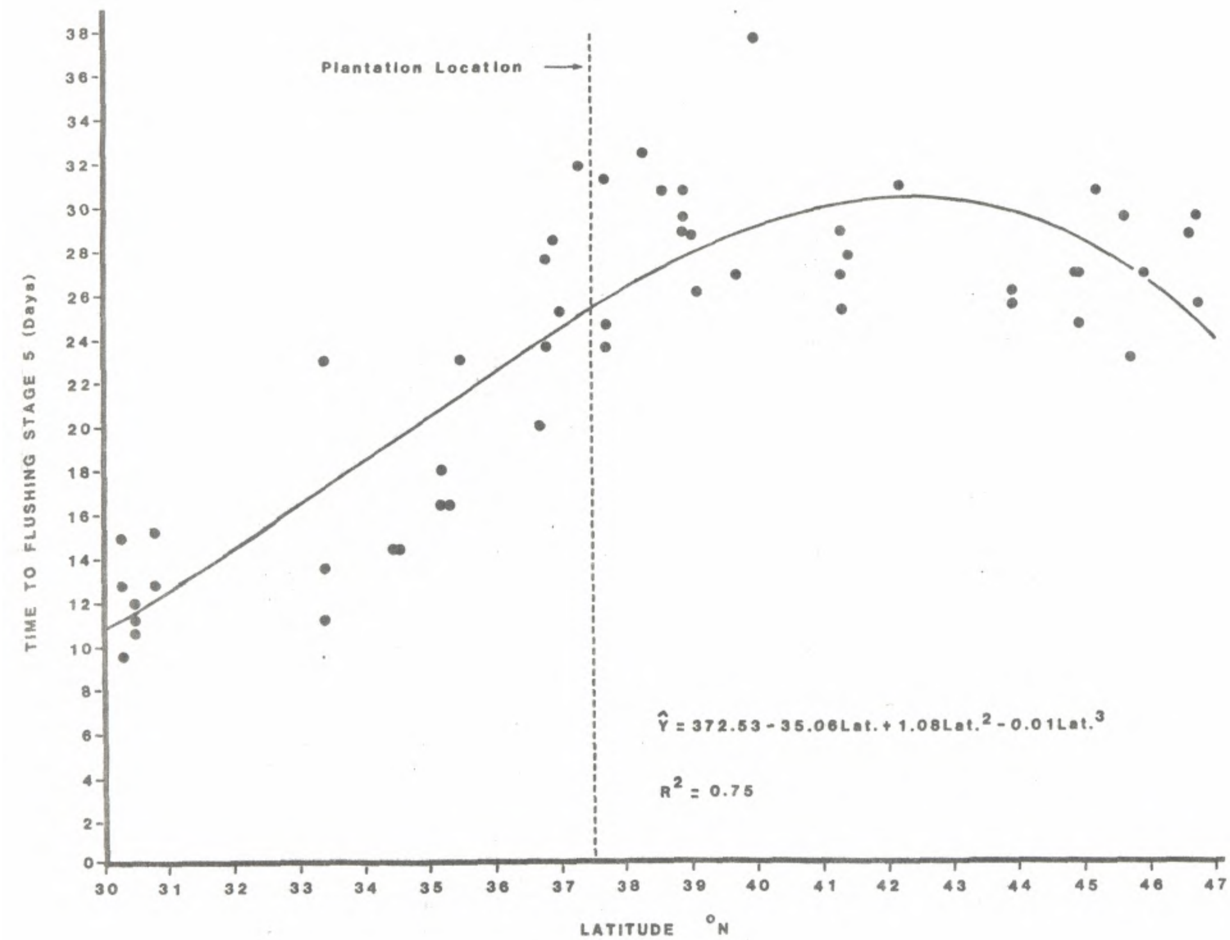

Figure 2.—Number of days after April 1, 1981, taken by 52 white ash families to reach flushing stage 5 (fully flushed) as related to latitude of origin.

Families of similar origin often varied in the number of days they took after April 1, 1981, to reach stage 5. In provenances represented by 2 families each, within-provenance variation ranged from no difference in Alabama provenance 6733 to 6.6 days in Kentucky provenance 6792. In 3-family provenances it ranged from 1.4 days in Louisiana provenance 6738 to 11.8 days in Mississippi provenance 6740. Usually within-plot variation was not large but occasionally one tree in a plot was much earlier or later than the other four trees.

The frost that occurred in this plantation during the night between May 8 and 9, 1980, only caused minor injury to the foliage and did not affect subsequent tree growth. Most of the families with few or no injured trees were of southern origin; those with the most injured trees came from northern Michigan, northern Wisconsin, and New England. Part of the reason for this unusual pattern appears to be that tree height is related to geographic origin. Because northern trees tended to be shorter than southern trees, they were also more likely to suffer frost injury. Although flushing was not directly related to frost injury, southern trees with expanded leaves were apparently less susceptible to frost than northern trees with leaves in the process of unfolding.

CONCLUSION

The pattern of leaf flushing in white ash is consistent from year to year. Flushing is related to latitude of seed origins but other factors apparently also have an effect. Susceptibility to late spring frost appears to depend, in part, on tree height and on the relative stage of leaf development. If the trees in the study had not been monitored for leaf flushing, it would have been easy to conclude falsely that southern white ash trees are more frost hardy than northern trees. These results demonstrate that both timing and kind of observations can significantly affect interpretation of data.

LITERATURE CITED

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