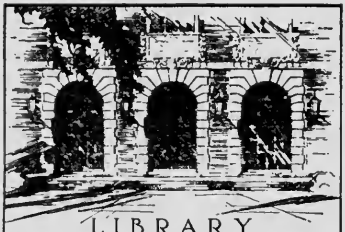

Cold Weather and Glaze Damage to Forest Plantations in Southern Illinois

By
W. R. BOGGESS
and
F. W. MC MILLAN

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Cold Weather and Glaze Damage to Forest Plantations in Southern Illinois[1]

By W. R. Boggess and F. W. McMillan[2]

REFORESTATION IS AN IMPORTANT PHASE of forestry in southern Illinois.[3] There are now about 75,000 acres of forest plantations in the state. Spaeth (7)* estimates that at least 750,000 more acres should be planted to trees. These would include land in the lowest soil fertility classes, excessive slopes, and untilled bottoms.

Southern Illinois was originally covered by excellent stands of hardwood. After the land was cleared for agriculture, it was often badly farmed and then abandoned. The top soil washed away, gullies formed, and the soil lost much of its capacity to hold water. Such land will rarely support hardwoods of commercial value. Consequently it has been necessary to go down the ecological scale to find coniferous species that can be grown successfully on these degraded sites.

Both shortleaf (*Pinus echinata* Mill.) and loblolly pine (*P. taeda* L.) appear to be adapted to southern Illinois conditions. They have been used extensively in reforestation programs in this area as well as in neighboring states, and they are now growing at the limit or north of their present natural range. The northern limit of shortleaf pine in the Central States area, is along the bluffs of the Mississippi river in southern Illinois. Loblolly pine extends northward to the southwestern part of Tennessee. Both species, however, reach latitudes north of this area along the eastern seaboard.

When species are planted north of their natural range, there is always the danger that they will be unable to survive in the more rigorous climate. This study represents observations made on damage to forest plantations, particularly shortleaf pine and loblolly pine, by the extreme cold weather of 1950-51 and two glaze storms in 1950 and 1952. The location of plantations observed is shown in Fig. 1.

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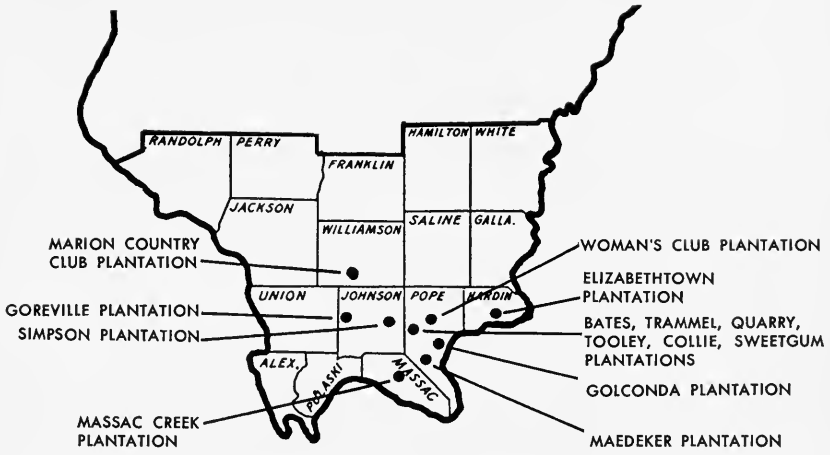
[1] A contribution from Research and Marketing Forestry Project 402.

[2] W. R. Boggess, Professor of Forest Research, and F. W. McMillan, Assistant in Forestry, both of Dixon Springs Experiment Station.

[3] Southern Illinois includes the 16 southernmost counties.

* See "Literature Cited," page 23 for this and similar references.



Location of southern Illinois forest plantations studied in an appraisal of damage from low temperatures and the glaze storms of 1950 and 1952. (Fig. 1)

COLD WEATHER DAMAGE

Weather Data

Two periods of extreme cold occurred during the winter of 1950-51. The first came in late November. On November 23, a maximum temperature of 51° was recorded during the forenoon at the Dixon Springs Experiment Station in Pope county, Illinois. During the early afternoon a cold air front moved in rapidly with strong northwesterly winds accompanied by snow. A minimum of −4° occurred prior to 7 a.m. on the 24th. During the next 24-hour period a maximum of 16° and a minimum of −11° was recorded. Killing frosts occurred early in the month, and below-freezing temperatures had been recorded 12 times prior to November 23.

The coldest weather of the winter was from January 28 to February 3, 1951, when the daily maxima were below freezing. Minima reached −19° and −18° on February 1 and 2. Four other nights had near-zero temperatures. Weather bureau stations in this area recorded lows as follows: Anna, −11°; Carbondale, −22°; Elizabethtown, −14°; Golconda, −10°; Harrisburg, −23°; and New Burnside, −15°.

Observations and Results

The first visible damage was noted on loblolly pine at the Dixon Springs Station about 10 days following the November freeze when

the foliage of terminal shoots began to brown. Within a month, about half of the trees in this plantation appeared to have been burned. Some browning was noted on shortleaf pine.

During the late spring and summer of 1951 more than 30 plantations were examined for evidence of low-temperature damage. Those observed ranged as far north as West Frankfort in Franklin county and were from 3 to 19 years old. When appreciable damage was found, detailed appraisals were made.

Damage to shortleaf pine was slight. In most cases no permanent damage was evident. In one plantation at the Dixon Springs Station, about 3 percent of the trees browned, but all recovered.

Eight loblolly pine plantations from 3 to 22 years in age were examined. Only three were severely damaged. Two of these were in Pope county, at the Dixon Springs Station and at Eddyville, and one was in Massac county. The extent of injury to these three plantations is shown in Table 1.

The plantation at the Dixon Springs Station was the most severely damaged of all those examined. In another loblolly pine plantation,

Table 1. — Extent of Cold Weather Injury to Three Loblolly Pine Plantations in Southern Illinois

	Age in years	Extent of injury (percent)			
		Complete killing	Partial killing	Defoliated and recovered	No damage
Dixon Springs Station	13	32	32	8	28
Massac county	10	37	5	9	49
Eddyville, Pope county	16	12	39	..	49

approximately one mile away, only 3 percent of the trees were damaged. Both plantations are growing on a south slope, although the badly damaged one is on the better site.

Nineteen-year-old loblolly pine plantations near Goreville, Johnson county, and Elizabethtown, Hardin county, were also damaged. Growth records have been maintained on these plantations for a number of years by the University of Illinois Department of Forestry (2,3). In the Goreville plantation 3 percent of the trees showed cold weather damage. At Elizabethtown, 30 out of 482 (or 6 percent) measured trees were killed, many of which had been damaged by the ice storm in February, 1950. Killing was largely confined to trees near the edge of the plantation or in a low area at the foot of a slope.

Because of the number of trees killed, there was no net growth in the plantation during the 1951 growing season.

A 5-year-old sweetgum (*Liquidambar styraciflua* L.) plantation[1] at Dixon Springs was badly damaged. It had been established in the spring of 1946 on bottomland planted to soybeans the previous year. Survival was excellent. During the second and third years a dense stand of alder (*Alnus rugosa* (DuRoi) Spreng.) seeded in and was soon seriously competing with the sweetgum. At the end of the 1950 growing season the sweetgum was from 1 to 2 feet taller than the alder. However, the low temperatures damaged 98 percent of the sweetgum, killing trees back from 1 to 10 feet, or an average of 4 feet. As a result, at the end of the 1951 growing season, practically all of the sweetgum was overtopped by the alder.

Cold-weather damage was not confined to forest plantations. Such native species as sassafras and persimmon were frequently killed back to the ground. Peach orchards were badly damaged, many trees being completely killed, and commercial nurseries had heavy losses in both evergreen and deciduous stock.

Discussion

Although loblolly pine is more susceptible to cold injury than shortleaf pine, it should not be discounted as an important species for planting in southern Illinois strictly on the basis of lack of resistance to low temperatures. The fact that several plantations were relatively undamaged indicates that the species can be successfully grown in this area.

Seed source, unknown for these plantations, has undoubtedly influenced the behavior of the trees. Experience at the Union County State Tree Nursery has shown less browning and other winter injury when loblolly pine seedlings are grown from seed collected at the northern limits rather than from the middle or southern part of the natural range of the species.[2] Both Wakeley (8) and Minckler (6) have emphasized the importance of securing seed from a suitable geographic source for use in any particular locality.

It is difficult to say what proportion of the damage was done by the extreme cold weather in November and in February. From ob-

[1] The sweetgum was grown at the Union County State Tree Nursery, Jonesboro, Illinois, from locally collected seed.

[2] The writers are indebted to L. H. Kahler, superintendent, Union County State Tree Nursery, Jonesboro, Illinois, for these observations.

servations made throughout the winter on the Dixon Springs loblolly pine plantation it appeared that only foliage and some terminal shoots were killed by the November freeze. Damage to stem tissue was not noted until after the February freeze.

Some trees on which all the foliage had been killed started shoot growth in a normal manner, but after the terminal growth reached 2 or 3 inches, the trees died. Apparently the cambium and part of the living sapwood had been killed. The uninjured part was sufficient to start, but not to maintain growth in the absence of cambial activity. This situation, however, was not common as most of the killing was complete.

GLAZE DAMAGE

The glaze storms of 1950 and 1952 were among the most severe in the recollections of persons living in southern Illinois. Both storms caused considerable damage to timber and public utilities. Ice formation was concentrated in the area south of Illinois Highway 13, which crosses the state in an east-west direction between Shawneetown and Murphysboro. The 1952 storm was the more severe of the two and was especially destructive in territory near the Ohio river.

Description of Storms

The 1950 storm began about 1:30 p.m. on January 30. Freezing rain fell in heavy showers until dark, followed by a freezing drizzle which ended temporarily on the morning of February 1. The drizzle began again during the afternoon of the 1st and lasted until early morning of the 2d. This was followed by a heavy fog that did not dissipate until the afternoon of the 3d. February 4 was clear and thawing started about 9:30 a.m. *There was no wind accompanying the thaw.* Temperatures were constant at 30° to 32° from January 31 through February 3. Rainfall amounted to about one inch during the same period. There was no fog drip since it accumulated on the trees as glaze.

The 1952 storm started at 2 p.m. on January 1 with a freezing rain which continued throughout the 2d and until early morning on January 3. There was some thawing between 10 a.m. and 2 p.m. on the 3d, with the freezing rain starting again about 4 p.m. and lasting until the morning of February 4. Again there was some thawing accompanied by moderate winds. The wind caused considerable damage to timber that was already heavily loaded with ice. There was no thawing on

the 5th and 6th, and the ice did not all melt until January 8. Air temperature varied from 29° to 32° throughout the storm. Total rainfall during the storm amounted to 2.78 to 3 inches at several locations on the Dixon Springs Experiment Station. At one location, where rainfall was measured under the canopy of a 15-year-old shortleaf pine plantation and in the open, an estimated 2 inches of rainfall was intercepted by the trees in the form of glaze.

Because of the heavy ice load and the winds accompanying the thaw, the ice storm of 1952 did more damage than that of 1950.

Appraisal of Damage

From February to July, 1952, forest plantations were examined to determine how greatly they were damaged by the storm. Detailed information was taken in plantations that were a part of studies already under way at the Dixon Springs Experiment Station and in places where the damage was typical of that occurring over a wider area. In some instances damage was so severe that it was evident without close study that the plantation was practically destroyed.

In many cases the damage to shortleaf and loblolly pine was directly compared to learn which species was more resistant to ice damage.

Not all the data collected are presented here. Instead a number of specific cases have been chosen that are typical of damage conditions observed over the entire area affected by the storm.

When the damage appraisal was started about a month after the storm, the rather rapid initial recovery from bending, especially in shortleaf pine, had taken place. In a number of plantations which appeared hopelessly lost during the height of the storm, the trees came back rapidly whenever the bending was not too severe. A typical view of a shortleaf pine plantation during the 1950 storm is shown in Fig. 2. The same area, in July 1952, appears in Fig. 3. This plantation was even more flattened by storm in 1952 than in 1950.

In the first plantations examined, bending was classified in three categories:

B-1. Trees bent no more than 20 degrees from the vertical. Recovery is fairly certain.

B-2. Trees bent more than 20 degrees but less than 45 degrees. Recovery is doubtful.

B-3. Trees bent more than 45 degrees. A part of the stem is frequently parallel to the ground. Complete recovery is rare.

An 8-year-old shortleaf pine plantation at the Dixon Springs Experiment Station during the 1950 storm. Compare with Fig. 3. (Fig. 2)

The same plantation shown in Fig. 2 in July, 1952. The plantation was more severely flattened by the glaze storm of 1952 than by that of 1950. Note how the trees have recovered. (Fig. 3)

This system was given up after the first 2 to 3 months, as most of the B-1 trees had recovered. Where trees are merely classified as "bent," they correspond to B-2 and B-3 trees.

Stem or top breakage was classified on the basis of the length of the broken section. The following classes were used: 1-5 feet, 6-10 feet, 11-15 feet, 16-21 feet, and 21 feet and over.

A type of damage observed only in loblolly pine was a stripping of the side branches by the weight of the ice. Trees were observed with their tops still intact but with all of the side branches torn away.

Shortleaf pine (Bates). This plantation was established in 1937 by the Civilian Conservation Corps. The site is level to gently sloping and on top of a bluff about 3 miles north of the Dixon Springs Experiment Station. The trees were planted in furrows at a spacing of approximately 4 by 6 feet. Survival was good.

This plantation was selected for a thinning study[1] to determine the optimum residual basal area for thinning pine plantations in southern Illinois.

Table 2. — Number and Percent of Trees Broken per Acre in a 15-Year-Old Shortleaf Pine Plantation at Dixon Springs Experiment Station (Bates Plantation)

Diameter class (inches)	Total trees per acre	Trees broken, top-length indicated			Total broken
		1-5 ft.	6-10 ft.	11-15 ft.	
4	340	29 (8.5%)	31 (9.1%)	7 (2.1%)	67 (19.7%)
5	479	33 (6.9%)	38 (7.9%)	2 (0.4%)	73 (15.2%)
6	207	10 (4.8%)	15 (7.2%)	1 (0.5%)	26 (12.6%)
7	22	1 (4.5%)	3 (13.6%)	.....	4 (18.2%)
All classes	1,048	73 (7.0%)	87 (8.3%)	10 (0.9%)	170 (16.2%)

Before the glaze storm of 1952, two blocks consisting of four $\frac{1}{5}$-acre plots, separated by $\frac{1}{2}$ chain isolation strips were established. The d.b.h.[2] of all trees was tallied to the nearest $\frac{1}{10}$ inch.

A preliminary damage appraisal made immediately after the 1952 glaze storm showed that the plots could still be used for the thinning study. When the trees were marked for cutting, priority was given to those damaged by the storm. After the trees were felled, measurements were made of the height where breakage occurred and the diameter of the stem at the point of breakage. The amount of breakage for the plantation as a whole is shown in Table 2.

[1] Conducted jointly by the University of Illinois and the Carbondale Branch, Central States Forest Experiment Station.

[2] Diameter at breast height. Tree diameter, outside of bark, measured at 4½ feet above average ground level.

There were very few bent trees in the entire plantation (Fig. 4), although during the storm it appeared there would be a great many. The "mutual support" given by one tree to another in this well-stocked stand apparently prevented severe bending.

Sixteen percent of the trees had broken tops. In the light thinning treatment, where basal area was reduced to 100 square feet per acre,

A 15-year-old shortleaf pine plantation at the Dixon Springs Experiment Station (Bates plantation) four months after the 1952 glaze storm. Note the absence of bent trees. (Fig. 4)

approximately half of the trees that were cut had been damaged in the glaze storm (Fig. 5).

The amount of breakage ranged from 12.6 percent of the trees in the 6-inch diameter class to 19.7 percent of the 4-inch trees. In many cases the point of damage could be traced back to weak places in the stems resulting from the severe tip-moth infestation in 1948 when the leading shoots were continually killed back from early June through October.

Thinning plot in a 15-year-old shortleaf pine plantation at the Dixon Springs Experiment Station (Bates plantation). This plot was cut to 100 square feet basal area per acre; approximately half of the trees removed had been damaged by the 1952 glaze storm. (Fig. 5)

Shortleaf pine in thinning experiment (Dixon Springs). The Trammel plantation, 13 years old at the time, was thinned in January and February, 1950; about half of the plots had been thinned at the time of the 1950 glaze storm. The experiment consisted of two replications

Table 3. — Stand Data for a 13-Year-Old Shortleaf Pine Plantation, Before and After Thinning, and Two Years After Thinning (Trammel Plantation)

Thinning treatment	Before thinning			After thinning			After two years	
	Number of trees per acre	Basal area	Volume	Number of trees per acre	Basal area	Volume	Basal area growth	Basal area Dec. 51
		sq. ft.	*cu. ft.*		*sq. ft.*	*cu. ft.*	*sq. ft.*	*sq. ft.*
Check	860	96	1,060	860	96	1,060	22	118
Light	900	105	1,185	770	91	1,000	20	111
Medium	845	94	1,050	700	80	885	23	103
Heavy	870	95	1,040	660	70	765	23	93

Table 4. — Glaze Damage in a Thinning Experiment in a 15-Year-Old Shortleaf Pine Plantation, 1952 (Trammel Plantation)

(Trees per acre)

Thinning treatment	Bent—degree[a]				Broken tops—length (feet)					Total damaged trees
	B-1	B-2	B-3	Total	1-5	6-10	11-15	16-20	Total	
Unthinned.....	50	60	17	127	85	88	11	2	186	313
Light.....	20	25	10	55	90	67	7	..	164	219
Medium.....	22	55	5	82	65	62	22	..	149	231
Heavy.....	7	42	25	74	62	35	15	5	117	191

[a] Determination of degree of bending explained on page 8.

of four treatments in a randomized block design. Plots were $\frac{1}{5}$ acre in size and were separated by $\frac{1}{4}$ chain isolation strips. The treatments were:

1. No thinning, check.
2. Light thinning, cut to 90 square feet basal area per acre.
3. Medium thinning, cut to 80 square feet basal area per acre.
4. Heavy thinning, cut to 70 square feet basal area per acre.

The crown thinning method was used. Only those trees that would make a 7-foot fence post were cut. Stand data are shown in Table 3.

There was little damage to the plantation by the 1950 storm. A summary of the damage by the 1952 storm is shown in Tables 4 and 5.

Shortleaf pine (Golconda). This Pope county plantation, established in 1938 on a bluff above the town of Golconda, overlooks the Ohio river. The site is rolling and there had been considerable erosion on parts of the area before planting. The plantation was not damaged by the 1950 storm; the ice load was not so heavy in this area as in 1952. The amount and classification of damage from the 1952 storm are shown in Table 6.

Table 5. — Glaze Damage in a Thinning Experiment in a 15-Year-Old Shortleaf Pine Plantation (Trammel Plantation)

(Percent per acre)

Thinning treatment	Total number trees 1/1/52	Bending—degree[a]				Broken tops—length (feet)					Total damaged trees
		B-1	B-2	B-3	Total	1-5	6-10	11-15	16-20	Total	
Unthinned.....	887	5.6	6.8	1.9	14.3	9.6	9.9	1.2	0.2	20.9	35.3
Light.....	772	2.6	3.2	1.3	7.1	11.7	8.7	0.9	...	21.2	28.4
Medium.....	725	3.0	7.6	0.7	11.3	9.0	8.5	3.0	...	20.5	31.9
Heavy.....	665	1.0	6.3	3.8	11.1	9.3	5.3	2.2	0.7	17.6	28.7

[a] Determination of degree of bending explained on page 8.

Table 6. — Number and Percent of Trees Bent and With Broken Tops in a 14-Year-Old Shortleaf Pine Plantation Near Golconda, Pope County

Diameter class (inches)	Total trees per acre	Trees bent	Trees broken, top-length indicated					Total bent or broken
			1-5 ft.	6-10 ft.	11-15 ft.	16-20 ft.	21 ft. and over	
1	25	10 (40.0%)	.....	.....	.....	.....	.....	10 (40.0%)
2	60	10 (16.7%)	5 (8.3%)	.....	.....	.....	.....	15 (25.0%)
3	325	55 (16.9%)	15 (4.6%)	25 (7.7%)	.....	.....	.....	95 (29.2%)
4	510	110 (21.6%)	5 (1.0%)	40 (7.8%)	5 (1.0%)	5 (1.0%)	.....	165 (32.2%)
5	290	25 (8.6%)	5 (1.7%)	40 (13.8%)	15 (5.2%)	.....	5 (1.7%)	90 (31.0%)
6	60	5 (8.3%)	5 (8.3%)	15 (25.0%)	5 (8.3%)	.....	.....	30 (50.0%)
Total all trees	1,270	215 (16.9%)	35 (2.7%)	120 (9.4%)	25 (1.9%)	5 (0.4%)	5 (0.4%)	405 (31.9%)
Total trees over 4-inch diameter	860	140 (16.2%)	15 (1.7%)	95 (11.0%)	25 (0.6%)	5 (0.6%)	5 (0.6%)	275 (31.9%)

Table 7. — Number and Percent Trees Bent and With Broken Tops in a 14-Year-Old Shortleaf Pine Plantation in Pope County (Maedeker Plantation)

Diameter class (inches)	Total trees per acre	Trees bent	Trees broken, top-length indicated				Total bent or broken
			1-5 ft.	6-10 ft.	11-15 ft.	16-20 ft.	
1	7	.....	.....	.....	.....	.....	.....
2	41	20 (48.8%)	5 (12.2%)	.....	.....	.....	25 (60.9%)
3	115	44 (38.2%)	4 (3.5%)	6 (5.2%)	.....	.....	54 (46.9%)
4	265	76 (28.6%)	24 (9.0%)	26 (9.8%)	10 (3.8%)	2 (0.7%)	138 (52.0%)
5	342	86 (35.5%)	42 (12.2%)	62 (18.1%)	34 (9.9%)	6 (1.7%)	230 (67.2%)
6	76	16 (21.0%)	8 (10.5%)	26 (34.2%)	4 (5.2%)	.....	54 (71.0%)
7	9	2 (22.2%)	3 (33.3%)	4 (44.4%)	.....	.....	9 (100.0%)
Total all trees	855	244 (28.5%)	86 (10.0%)	124 (14.5%)	48 (5.1%)	8 (9.4%)	506 (59.1%)
Total trees over 4-inch diameter	692	180 (26.0%)	77 (11.1%)	118 (17.1%)	48 (6.9%)	8 (1.2%)	431 (62.2%)

This plantation compares favorably with the Bates planting in the total number of trees per acre, although the latter has almost 200 more trees 4 inches d.b.h. and above. The type of damage to the two plantations is radically different. Bending accounted for half of the damage to the Golconda plantation, but for less than 3 percent of the total damaged trees in the Bates planting.

The greater damage done by bending at Golconda may be partially explained by the fact that ice formation there was greater than at Dixon Springs; the total rainfall for the storm period was ¾ inch heavier. The Golconda site is poorer than that of the Bates plantation and with 1,270 trees per acre, the plantation is overstocked. Growth therefore has been slow. Shortleaf pine which has grown slowly tends to bend rather than to break.

If the more seriously injured trees in the 4-, 5-, and 6-inch diameter classes were salvaged, the plantation would be left in an excellent growing condition. Such an operation would remove about a fourth of the basal area in trees 4 inches and over.

Shortleaf pine (Maedeker). This plantation is located in the southwestern part of Pope county, about 4 miles northeast of the loblolly pine planting on Massac creek. The site is gently sloping and in some parts there has been erosion. In general tree growth has been very good.

The plantation was little damaged by the 1950 storm, but in 1952 it suffered serious injury. In fact, of all the shortleaf plantations observed, this was the most heavily damaged. About 60 percent of the trees were bent or had broken tops. More than 40 percent of the damage was from bending. The bent trees would probably have been placed in the B-3 classification since they did not straighten and probably will not. (See Table 7.)

In stocking, this plantation compares favorably with the unthinned plots in the Trammel planting; the Trammel planting, however, was not so heavily damaged.

It was estimated that about one-third of the trees 4 inches and over d.b.h. should be removed because of damage. This would include those trees with more than 6 feet of the top broken and about half of the bent trees.

In comparing damage to this plantation with that to others, it should be stressed that the Maedeker plantation was in the zone of extremely heavy ice formation during the 1952 storm.

Shortleaf pine (Simpson). This plantation, located in Johnson county near the village of Simpson, 6 miles west of the Dixon Springs Station, was the least damaged of any of the shortleaf pine plantations in the zone of heavy ice formation. The site is rolling and some parts have been severely eroded.

Only about 5 percent of the trees were damaged by the 1952 storm. It is difficult to explain why the damage was so small since, during the storm, the ice formation appeared to be as heavy around the Simpson area as at the Dixon Springs Station. It will be interesting to observe this plantation closely in future glaze storms.

Shortleaf and loblolly pine (Elizabethtown). These plantations were established in 1932 at the Elizabethtown soils experiment field, Hardin county, on land considered unsuitable for agriculture.

Much of the land was badly gullied. Two permanent sample plots, ¼ acre in size, were established in the loblolly pine and shortleaf pine in 1944. Crop trees were marked and one plot of each pair was pruned and the other left as a check. A light thinning was made on the pruned loblolly pine plot in 1946. Two additional plots were established in the loblolly pine plantation during the spring of 1949. The plots were thinned as follows (2):

Plot No. 8 (0.25 acre) — thinned to 80 square feet basal area per acre
Plot No. 8A (0.46 acre) — thinned to 90 square feet basal area per acre
Plot No. 8B (0.42 acre) — thinned to 100 square feet basal area per acre
Plot No. 8D (0.25 acre) — not thinned

Table 8. — Glaze Damage to Shortleaf Pine and Loblolly Pine at Elizabethtown Soils Experiment Field

(Trees per acre)

Type of damage	Loblolly pine				Shortleaf pine	
	Unthinned	Thinned to 80 sq. ft.	Thinned to 90 sq. ft.	Thinned to 100 sq. ft.	Unthinned	Thinned
Bent[a]						
B1	4	...	2	10	...	4
B2	4	16	2	7	...	...
B3	40	8	9	19	...	24
Broken						
1-5 feet	72	28	2	36	72	12
6-10 feet	104	28	67	78	112	48
11-15 feet	48	20	4	38	24	16
16-20 feet	24	24	3	19	...	...
21 feet and over	8	12	20	2	...	...
Branches stripped	8	24	13	...	...	...
Total damaged trees	312	160	122	209	208	104
Total undamaged trees	128	84	104	123	488	408
Percent trees damaged	70.9	65.6	54.0	62.9	29.9	20.3

[a] Determination of damage done by bending explained on page 8.

One of the shortleaf pine plots was thinned to 80 square feet basal area per acre in 1950 (4); the other was left as a check.

Growth of the loblolly pine was quite rapid during the first year following thinning (3). Basal area increases as high as 17 square feet per acre were recorded. There was no net growth during the 1951 growing season due to mortality from the extremely cold weather (see section under Cold Weather Damage, pages 4 to 5).

Although there was some damage to the loblolly pine by the 1950 glaze storm, many more trees were damaged in 1952. Table 8 shows the damage to both shortleaf pine and loblolly pine in 1952.

In both the shortleaf and loblolly pine plantations, the unthinned plots were hurt more than those that had been thinned. There was no damage to the unthinned shortleaf pine from bending. In comparison, on the unthinned loblolly pine plot, 48 trees per acre were bent, 40 of which were in the B-3 classification.

Many loblolly pine trees were broken at a point halfway or more down the stem (Fig. 6). The most severely damaged trees were

Damage from the 1952 glaze storm to a 20-year-old loblolly pine plantation at the Elizabethtown soils experiment field in Hardin county. The bent tree in the center was classified as a B-3 tree. (Fig. 6)

salvaged. Many trees that probably should have been cut were left standing so that their recovery or mortality might be followed.

Shortleaf and loblolly pine (Women's Club). This memorial plantation, established in 1935, gave additional opportunity for direct comparison of glaze damage to shortleaf pine and loblolly pine. The two species occur in pure and mixed plantings.

About 60 percent of the loblolly pine were bent or had broken tops, but only 30 percent of the shortleaf pine were damaged. Practically all of the damage to loblolly pine was from breaking, but 60 percent of that suffered by shortleaf pine was from bending.

The proportion of damage to the two species was about the same in the pure and mixed plantations. In the mixed planting, loblolly pine made up about one-fourth of the total stand and were mostly dominants, having a 5- to 10-foot height advantage over the shortleaf pine. The exposed tops of the loblolly pine, deprived of the support of the shortleaf pine, generally broke off at 6 to 10 feet from the top, the amount they extended above the general crown level.

Loblolly pine (Massac). This plantation in Massac county, established in 1942, had been almost destroyed by a combination of the two glaze storms and the 1950-51 cold weather. It is growing on an excellent site and growth had been rapid. During the 1948 and 1949 growing seasons, the trees increased 0.8 inch in diameter and 6 feet in height.

Damage to the plantation has been as follows:

Number of trees per acre, December 30, 1949	780
Trees damaged by 1950 glaze storm	150
Trees killed by 1950-51 freeze	235
Additional trees dead July, 1952	80
Trees damaged by 1952 glaze storm	245
Total trees dead or damaged	710
Trees relatively undamaged July, 1952	70

The 80 trees listed as dead in July, 1952, probably died largely as a result of injuries received in the 1952 glaze storm. This plantation was in the zone of very heavy ice formation. About three-fourths of the trees damaged in 1952 should have been salvaged.

Loblolly pine (Quarry). This plantation at Dixon Springs Station has been destroyed in a manner almost parallel to the Massac creek planting discussed above. At present about 15 percent of the trees in the stand are in a relatively undamaged condition. A view of this plantation during the 1950 storm is shown in Fig. 7.

A loblolly pine plantation at the Dixon Springs Experiment Station (Quarry plantation) during the 1950 glaze storm. (Fig. 7)

Loblolly pine (Johnson and Williamson). An analysis of damage to these two plantations is important since they are among the oldest loblolly pine plantings in southern Illinois, that in Johnson county being 20 years old in 1952 and that in Williamson, 24 years old. They are located near the limits of the two glaze storms.

The plantation in Johnson county, located about 4 miles southwest of Goreville, is about one acre in size and is growing on a medium to poor site. Growth of the plantation has been previously reported (2). There was little damage from the 1950 storm; that from the 1952 storm, which extended farther north, is shown in Table 9.

The Williamson county plantation is a small planting, less than ½ acre in size. It is located at the entrance to the Marion Country Club, about 7 miles south of Marion on Illinois Highway 37. The soil type is Wynoose silt loam. This is a gray soil found extensively throughout the claypan area of southern Illinois on slopes of 0.5 to 1.5 percent.

Growth of the plantation has been very good. The basal area per acre was 150 square feet in September, 1950, and the the height of the average dominant tree about 50 feet.

Table 9. — Number and Percent of Trees Bent and With Broken Tops in a 20-Year-Old Loblolly Pine Plantation in Johnson County

Diameter class (inches)	Total trees per acre	Trees bent	Trees broken, top-length indicated[a]				Total bent or broken
			6-10 ft.	11-15 ft.	16-20 ft.	21 ft. and over	
4.....	24	2 (8.3%)	2 (8.3%)	2 (8.3%)	.....	.....	6 (25.0%)
5.....	40	4 (10.0%)	4 (10.0%)	.....	.....	2 (5.0%)	10 (25.0%)
6.....	64	6 (9.4%)	4 (6.3%)	6 (9.3%)	2 (3.1%)	2 (3.1%)	20 (31.2%)
7.....	82	2 (2.4%)	14 (17.1%)	8 (9.8%)	2 (2.4%)	6 (7.3%)	32 (39.0%)
8.....	108	.....	12 (10.3%)	14 (12.1%)	6 (5.2%)	.....	32 (29.6%)
9.....	76	.....	18 (23.7%)	4 (5.2%)	.....	.....	22 (28.9%)
10.....	22	2 (9.1%)	.....	2 (9.1%)	2 (9.1%)	.....	6 (27.3%)
11.....	4	.....	.....	.....	.....	.....	.....
12.....	..	.....	.....	.....	.....	.....	.....
13.....	2	.....	.....	.....	.....	.....	.....
All classes...	422	16 (3.8%)	54 (12.8%)	36 (8.5%)	12 (2.8%)	10 (2.4%)	128 (30.3%)

[a] There were no trees broken in the 1-5-foot class.

There was no damage to the trees in 1950 as the storm barely reached this area. In 1952 about 18 percent of the trees had their tops broken by ice. Half of the broken tops were in the 11- to 15-foot class; a third in the 6- to 10-foot class; and the remainder in the 1- to 5-foot class. It should be stressed that this plantation was near the limit of the 1952 storm.

Loblolly pine (Tooley and Collie). These two plantations have been established as part of the forest research program at the Dixon Springs Experiment Station. They have been observed closely.

The Tooley plantation, three years old in 1951, is part of a spacing study which includes both loblolly and shortleaf pine. Although about 40 percent of the loblolly pine was injured by the 1952 glaze storm, there was no breakage. A greater part of the damage was from trees tipping over without much actual bending; trees appeared as "leaners" rather than as bent. This resulted in some root pulling, since the soil was very wet and soft at the time of the storm. Where roots were not broken completely loose on one side, the trees have continued to straighten throughout the growing season. There was practically no damage to the shortleaf pine plantings.

The Collie plantation, six years old at the time of the first storm, was established in 1945 on an abandoned field, parts of which were badly eroded. About 30 percent of the trees were damaged by bending or breakage; 25 percent were bent, and 5 percent were broken. Another type of injury, however, was evident several months after the storm. Severe bending was accompanied by a separation of the bark from the wood on the underside of the bend. This condition was found on many

trees which are now completely straight. As the loosened bark sloughs off, the sapwood will be exposed to decay. At the very best, a severe "bend scar" will result.

Species other than shortleaf and loblolly pine. Other plantations observed included pitch pine (*Pinus rigida* Mill.), red pine (*P. resinosa* Ait), white pine (*P. strobus* L.), sweetgum (*Liquidambar styraciflua* L.), yellowpoplar (*Liriodendron tulipifera* L.), pin oak (*Quercus palustris* Muench.), green ash (*Fraxinus pennsylvanica* var. *lanceolata* (Borkh) Sarg.), and black locust (*Robinia pseudoacacia* L.). Pitch pine was damaged considerably in areas where ice accumulation was heavy, such as the Pounds Hollow recreational area in Hardin county. In these localities damage was about equal to that of shortleaf pine.

Both red pine and white pine were observed at the Elizabethtown soils experiment field in Hardin county and at the Union County State Tree Nursery in Union county. There was no evidence of damage to these species at either location.

Black locust was severely damaged throughout the area, in many cases more so than loblolly pine. Breakage was increased by the fact that most black locust plantations in this area have been riddled by the locust borer.

Exceedingly heavy damage was also observed in native timber stands. Although in general bottomland species were damaged more severely than upland hardwoods, the damage was, in many cases, equally heavy.

Discussion

Under the same conditions loblolly pine is more susceptible to glaze damage than shortleaf pine. This susceptibility is probably related to the fact that on comparable sites in southern Illinois loblolly pine grows more rapidly, both in height and diameter, than shortleaf pine. This advantage is partially offset by the associated brashness of the wood, a characteristic that helps make loblolly pine easily damaged by ice storms.

The ease with which loblolly pine is injured by glaze seriously threatens the successful growing of the species in southern Illinois. As previously noted, cold weather damage can be largely averted by a careful selection of the seed source. However, the effect of seed source on resistance to ice damage is not known. It is a subject worthy of investigation.

Branch stripping in loblolly pine is directly related to the angle made between the branch and the main stem of the tree. Stripping is more likely to occur as this angle approaches 90 degrees. Trees having a branch-stem contact angle of near 90 degrees are superior, from the standpoint of self-pruning, to those trees on which the angle is more acute (5).

Stand density is an important factor in the amount and type of damage done to pine plantations by glaze. In the thinning studies at Elizabethtown, and in the Trammel plantation, the thinned plots were not so heavily damaged as the unthinned. Weak and poor quality trees had been removed earlier and those that were left were strong enough to withstand the storm. Among the unthinned plantations, those that were overstocked were damaged more than those that had fewer trees per acre but were still adequately stocked.

There are not enough data available to determine a relationship between degree of thinning and amount of ice damage. General observations have shown that the amount of bending is greatest around plantation edges and natural openings in the stand. This should point out the danger in thinning too heavily. The best thinning intensity, from the standpoint of ice damage, is not known. Experiments have already been established to determine this point.

To develop strong, stocky trees plantations should be thinned as early as merchantable (or usable) products can be removed. By thinning early, weak trees which contribute heavily to the total damage in ice storms can be used before their salvage is required. A stand of codominant trees — where all the crowns are about the same level — should be maintained. In thinnings this would require the removal of some of the larger dominant trees along with those of other crown classes.

The danger of glaze damage introduces an element of risk into planting shortleaf and loblolly pine in southern Illinois, particularly in the case of the latter. This risk, however, is not peculiar to this section as it exists in the natural range of these and other species of southern pine. Wakeley (8) reports heavy and frequent damage from glaze in central and northern Alabama, Georgia, Louisiana, Mississippi, and eastern Texas. The senior author has observed damage to loblolly pine in the lower piedmont of North Carolina, and in central and northern Mississippi. In spite of the glaze hazard, planting shortleaf pine should be encouraged in southern Illinois. Also, the possibilities

of growing loblolly pine should not be discounted. The present performance of this species in southern Illinois should encourage extensive research in management and in the selection and possible breeding of strains of loblolly pine better adapted to conditions in this area.

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