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For several years a decline of hackberry (*Celtis occidentalis* L.) leading to eventual tree mortality has been evident in northwest Iowa. A search for the cause of the decline in trees in and near Odebolt, in Sac County, Iowa, has included investigation of soil abnormalities, nutrient deficiencies, pathological or viral vectors, entomological agents, climatological extremes, and physiological or environmental factors. The decline could not be attributed to any disease or insect problem. Recurring symptoms were those of herbicide damage. Indications of herbicide damage included cupped, chlorotic leaves, lack of apical dominance, enlarged bud size, and epinastic twigs. In addition, increased soil nitrate levels may indicate abnormal plant nitrite levels caused by herbicidal action.
INDEX DESCRIPTORS: Hackberry Decline, Herbicide Drift, *Celtis occidentalis*.

Hackberry (*Celtis occidentalis* L.) occurs over nearly all of the northeastern states and as far south as Arkansas and Tennessee. Its western range includes most of Kansas and Nebraska and the eastern half of North and South Dakota (Fowells, 1965). It grows satisfactorily on high lime soils and can be seen filling voids caused by Dutch elm disease in the loess hill woodlands of western Iowa. However, in recent years there have been numerous examples of gradually dying individual hackberry trees even on good sites in western Iowa.

The first sign of hackberry decline is a change in color from normal verdant foliage to a chlorotic yellow-green. Late leaf expansion and early abscission (Figure 1) are also characteristic symptoms. Poor color, which is most evident in July and August, may persist for a period of two years prior to the appearance of the second stage, a thinning of the entire crown (Figure 2). The final stage of the decline, involving leaf, twig, and branch mortality, occurs approximately five years following initial signs and ends with death of the tree. The purpose of this investigation was to determine the cause of premature mortality of hackberry in northwest Iowa.

Figure 1. Three hackberry at 12th and Center, Le Mars, Iowa, 9/10/72. The tree at the left appears normal; two on the right are exhibiting premature loss of leaves common to hackberry decline. The one in the center was removed in 1975.

Figure 2. Hackberry at the Fred Ducommun residence in Cleghorn, Iowa, exhibiting the thin crown characteristic of hackberry decline. Photo taken 7/12/72. Death of the tree occurred the following year.

POSSIBLE CAUSES OF DECLINE

In May, 1971, the study was initiated in the town of Odebolt, in Sac County, Iowa. Also in June, 1973, a survey was conducted to determine the extent of decline on Odebolt street and park trees. Affected hackberry were those exhibiting chlorotic leaf color, thin crowns, or branch mortality. Healthy trees were those exhibiting verdant foliage and normal crown density.

Six soil samples were taken at three depths (5 to 8 inches, 20 inches, and 32 to 36 inches) around hackberry exhibiting

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varying signs of decline, and apparently healthy trees. Tests were conducted at Iowa State University on all samples to determine pH, water-soluble salts, nutrient excess or deficiency, and foreign matter not found in an undisturbed or cultivated soil.

Nebraska University conducted analyses for N, P, K, Ca, Mg, Zn, Cu, and Fe, on leaf samples from 15 trees. Comparisons were made between healthy and affected trees.

On-site investigation was conducted for both insect and disease problems associated with hackberry. Diseases of hackberry, according to Hepting (1971), are not numerous. Leaf, twig, and root samples were examined at Iowa State University, Nebraska University, and the U.S. Forest Service pathology laboratory in St. Paul, Minnesota.

Weather data for the Odebolt area, 1956-1971, were obtained from records for the Sac City U.S. Weather Bureau station. These data were compared to growth rates of both healthy and affected Odebolt hackberry. Twelve cross-sectional samples of root and limb wood were examined in an attempt to correlate the decline with climatic conditions.

Signs of air pollution damage to trees via ambient herbicide drift have been described by Phipps (1963) and Sherwood *et al.* (1970). Since hackberry was mentioned by Phipps as being sensitive to herbicide drift, this study attempted to correlate any signs of decline with known signs of herbicide damage.

RESULTS

Data obtained from the survey of Odebolt hackberry (Table 1) indicated that all age and size categories were vulnerable. The extent of decline would discount the possibility of a physiological explanation such as improper planting or girdling roots. Overall, 53.5% of the Odebolt hackberry appeared to be affected; 41.6% of the hackberry in the north half of town appeared affected while 57.9% in the south half appeared affected. Trees in varying stages of decline were observed on streets, in parks, and along back alleys of town. This variation would discount the probability of injury caused by lawn fertilization.

TABLE 1. OCCURRENCE OF HACKBERRY DECLINE IN ODEBOLT, IOWA*

	dbh	*North Number*	*%*	*South Number*	*%*	*North and South Number*	*%*
Healthy	≤10″	9	58.4	33	42.1	42	46.5
	>10″	85		147		232	
Affected	≤10″	0	41.6	8	57.9	8	53.5
	>10″	67		240		307	
Total		161		428		589	100.0

* Approximately 12 additional trees were dead and had been removed prior to this study.

Investigation of psyllids (gall producers), bark beetles, leaf-feeding caterpillars, and root nematodes revealed no contributory relationship to hackberry decline. Though some defoliation by leaf-feeding insects was evident, it was insufficient to result in a 10% crown loss. Nipple galls were present on both healthy and affected hackberry, as were witches' broom and *Eriophyde* mites, as described by Herrick (1935).

This study also included a search for destructive cankers, root rots, leaf or stem pathogens, viruses, fungi, or other potentially destructive agents associated with hackberry. No disease problems were identified. Samples submitted to Iowa State University, the U.S. Forest Service, and Nebraska University revealed no *Ganoderma* or *Armillaria* wood rots; Iowa State University reported no disease organism in its cultures, and repeated cultures of hackberry samples at Nebraska University have yielded only *Penicillium* mold.

No correlation was found between weather extremes and decline of hackberry. Ring-growth examination indicated that deficiencies were occurring within the crown of hackberry trees as early as 1960. Growth rings of root samples suggested that decreases in radial root growth occur only late in the decline of trees. This indicates that the decline is more closely associated with the top of the tree than with the roots, or that the decline is more readily expressed within the crown. All limb samples reflected, by reduced radial growth, the adverse weather of 1955. All samples showed variable growth rates occurring after this adverse weather until the 1960's, when growth rates became poor. In general, normal ring-growth reflected changing climatic conditions. Decline was characterized by persistent, continuing reduction in ring-growth, not correlated with meteorological extremes.

Soils of the town of Odebolt are Sac and Galva Series, found most frequently between 0-5% slope. Both are formed in loess or aeolian silts. They are moderately permeable, well-drained, and have dark surfaces characteristic of soils formed under prairie vegetation. Water availability is high to very high, and the depth to water table is five feet or more. Soil pH is neutral to medium acid in the topsoil and subsoil, and calcareous in the substratum. Both Galva and Sac soils are friable and silty clay loam in texture. Sac soils typically have a loess thickness of 20 to 40 inches; Galva loess thickness may be from 40 to 130 inches (SCS, 1970).

Soil samples examined showed no extremes in pH, water-soluble nutrients, or foreign matter. No chlorides were found, a fact which would discount the possibility of winter road salt causing damage to the hackberry trees. The nitrate level at a 6-inch depth was high in the soil beneath three of six trees examined, and medium beneath three others. The one sample site which had high nitrate levels at both 6- and 20-inch depths supported a tree that was nearly dead. Kahler and Sherwood (1971) found higher amounts of nitrates, phosphorus, and calcium in the soil around trees under "stress." They suggest that these increased nutrient levels may be due to the "stressed" tree's inability to absorb nutrients, or to lawn fertilization.

It is also possible that higher nitrate levels in the soil are due to herbicide activity within the tree. In explaining a mode of action of some herbicides, Klepper (1974) states, "The processes for nitrate reduction and nitrite reduction are separate. Energy needed for nitrite reduction is blocked by photosynthetic inhibitors but nitrate reduction can continue, resulting in nitrite accumulation within the plant." Klepper further states, "In other studies when plant roots were furnished nitrite as their nitrogen source, losses of nitrogen from the roots were recorded."

Phipps (1963) attributed the annual yellowing and blighted leaves of box elder to 2,4-D drift. He also claimed a simultaneous appearance of damage on hackberry and other species across the Great Plains states. The chlorosis common to the first stage of hackberry decline is identical to the chlorotic appearance of blighted box elder in northwest Iowa and elsewhere. Sherwood *et al.* (1970) attributed the loss of the box elder and redbud growing apex to 2,4-D exposure. This characteristic of reduced terminal growth was common to hackberry examined during this study (Figure 3). Cupped leaves, increased lateral bud size, and nastic growth (Figure 4), typical of herbicide injury, were also found in Odebolt trees.

Assumption of a combination of insects, disease, weather, and nutrient deficiencies suddenly killing hackberry in western Iowa is unrealistic. Hackberry survived insects, disease, weather, and low-nutrient soils prior to 1960. However, the variable showing a gross increase within the past 20 years is herbicide usage. In 1950, U.S. herbicide production totaled 26 million pounds. In 1960, this figure had increased to 63 million pounds, and by 1970 it had increased to 370 million pounds (CEQ, 1972). In 1973, herbicide production reached 496 million pounds, with 23% of this amount being exported (USDA-ASCS, 1975). Although these figures do not reflect amounts involved in inventory adjustment, or Odebolt-area usage, it can safely be inferred that herbicide usage in the Odebolt area has increased during the past 20 years along with national trends. Iowa ranks second only to Illinois in total acres treated for weed control (USDA-ASCS, 1973). It has been estimated that up to 10 million pounds of 2,4-D alone are used in Iowa each year (Sherwood *et al.* 1970). Herbicide damage has been observed on sensitive plants such as grape and redbud throughout Iowa each year.

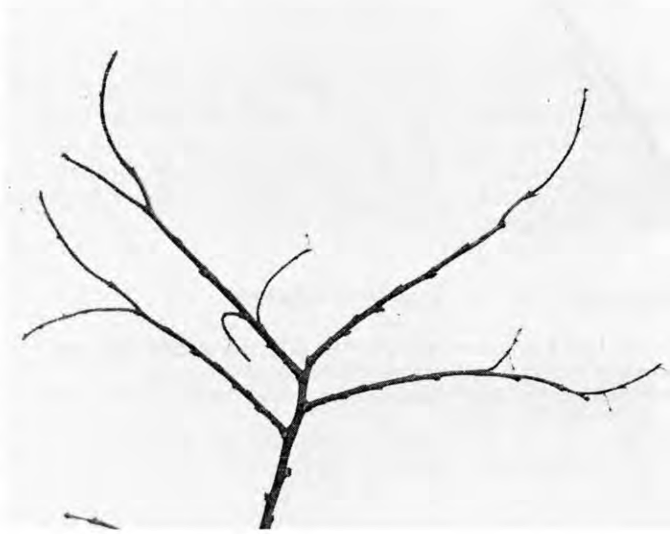

Figure 3. Crown twig showing reduction of terminal growth in hackberry, from street tree at 416 Locust, Odebolt.

DISCUSSION

The study suggests that decline of hackberry can be attributed to herbicide drift. This assumption is justified on the basis of repeated observations of herbicide injury coupled with an absence of any other identifiable causal agent. An absence of hackberry decline within forest stands where tree crowns are protected by other trees is strong evidence supporting herbicide pollution as the major factor involved. A greater percentage of affected trees in the south half of Odebolt (Table 1) also supports the conclusion that drift is a causal agent because prevailing growing season winds are generally southwesterly.

Odebolt, situated in an intensive corn-growing region, undoubtedly receives much herbicide drift. Corn receives more herbicide treatment than does the more sensitive soybean plant. In 1966, corn accounted for 41% of all herbicides applied in agriculture (CEQ, 1972).

Though no correlation was noted between weather conditions and hackberry decline, weather may be contributing to the damage done by ambient herbicide drift. Herbicides tend to reduce the winter hardiness of plants, increasing the likelihood of winter damage. With winter-weakened buds, trees would tend to leaf out late the following spring, as do affected trees in Odebolt. And with tender, late-maturing leaves, the tree would be increasingly susceptible to repeated drift exposure.

The findings of this study suggest further research to monitor the levels of ambient herbicide pollution and to identify effects of repeated herbicide exposure on forest tree species. It appears that herbicide pollution is playing a major role in decline of hackberry in the town of Odebolt.

Figure 4. Vigorously growing crown twig showing nastic growth, from street tree at 4th and Maple, Odebolt.

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