HONEYLOCUST (GLEDITSIA TRIACANTHOS L.)

IN FIELD SHELTERBELTS OF WESTERN

OKLAHOMA

By

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CHAPTER I

INTRODUCTION

The term shelterbelt as used in this thesis applies to plantings consisting of one or several rows of trees and having as their primary purpose protection of fields against the wind. The term in its general usage might also mean narrow and relatively short plantations established near farm buildings, to provide more comfortable living and to save on the cost of fuel and feed. Trees around the farmhouse also have a high esthetic importance.

Planting of shelterbelts in Oklahoma as in the other Prairie States began with the arrival of early settlers in this region. The Clarke-McNary Act of 1925 served to accelerate farm tree planting by providing trees, labor, and technical assistance to the early settlers. However the large scale organized planting of shelterbelts was undertaken only in the middle 1930's as a result of extremely destructive windstorms.

Economic depression stimulated the Government to relieve unemployment by initiating large scale planting in critical areas of the Prairie States. The Prairie States Forestry Project was authorized by the Congress in 1934, and in the spring of 1935 the first shelterbelt was planted near Mangum, Oklahoma.

The area in which the project became effective, known as the shelterbelt zone, comprises a belt of land approximately 100 miles wide and 1,150 miles long, stretching from the Canadian border southward into northwestern Texas. The axis of the shelterbelt zone roughly follows the 99th meridian touching Devils Lake, North Dakota; Mitchell, South

Dakota; Lexington, Nebraska; Kinsley, Kansas; Mangum, Oklahoma; and ending in Fisher County, Texas (Figure 1).

The shelterbelt zone is confined to the area of transition between the true prairie and the short grass plains (Figure 2). The climate of this region ranges from semiarid to subhumid (13). Precipitation in the western part of the zone varies between 16 inches in the north and 22 inches in the south, and occurs mostly during the growing season (34, 51). In the Oklahoma part of the zone, distribution of precipitation is quite variable. Much of the rainfall occurs either in very small amounts or in form of heavy storms. Both types of precipitation are of little benefit to the trees. Failures of crops and tree plantings can often be attributed to lack of moisture brought about by unfavorable distribution of precipitation. Variations in precipitation tend to run in cycles, with years of above average precipitation followed by years of drought (13).

The average annual rate of evaporation from free surface in the shelterbelt zone varies from 29 inches in the north to 56 inches in the south. The average annual temperature ranges from 70° F. in Texas to 37° F. at the Canadian border.

Natural growth of trees in the shelterbelt zone is confined to stream courses, canyons, and ravines, and may be divided into two types: the hydrophytic type and the upland type. Hydrophytic plant communities, immediately bordering water, as along permanent or intermittent streams, resemble the lower flood plain communities of the eastern United States. They are more uniform as to species and general character throughout the zone than are those of the other type. The borders of streams which have an abundance of water for at least a few months of

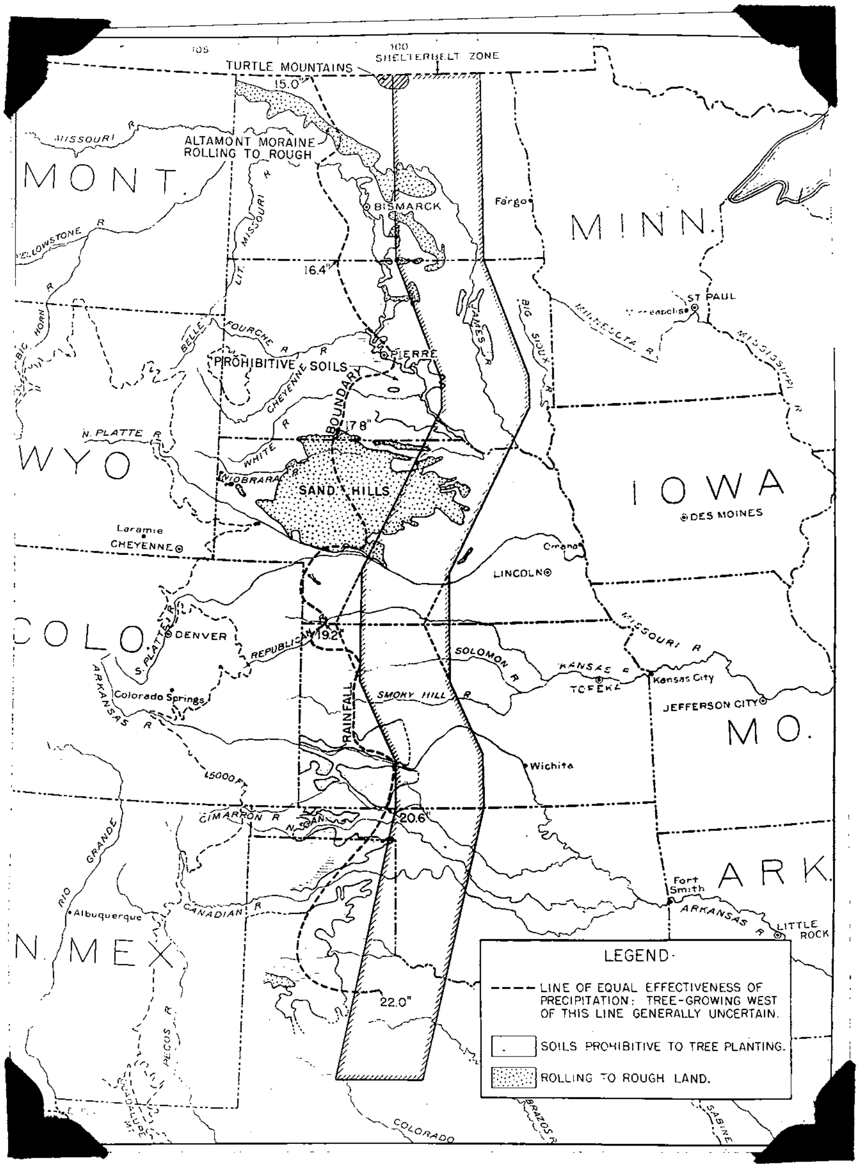

Figure 1. Location of the shelterbelt zone, with factors limiting its westward extension.*

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*R. Zon, What the Study Discloses. Possibilities of Shelterbelt Planting in the Plains Region. p. 6.

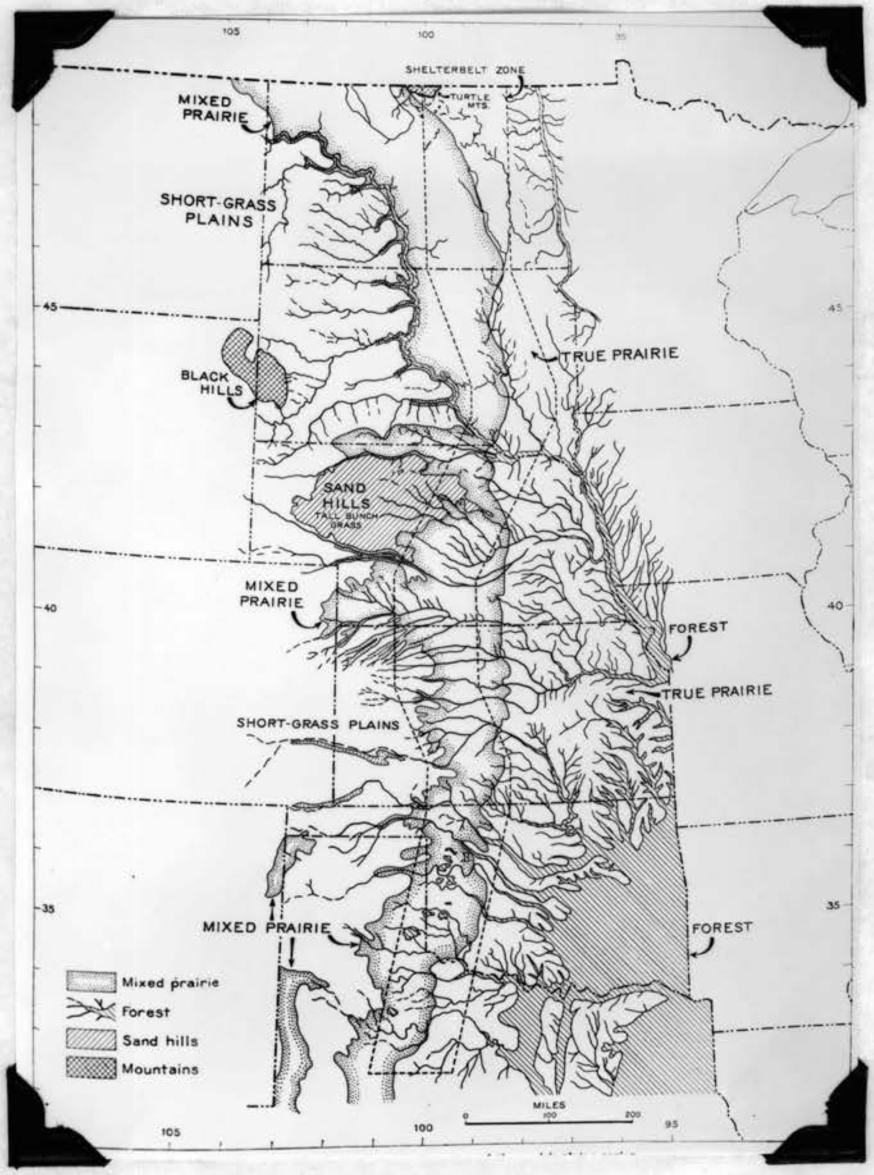

Figure 2. Principal vegetative zones of the prairie-plains region.*

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*J. M. Aikman, Native Vegetation of the Region. Possibilities of Shelterbelt Planting in the Plains Region. p. 157.

the year are lined with a mixture of sandbar willow *Salix interior* Rowlee, black willow *Salix nigra* Marsh, peachleaf willow *Salix amygdaloides* Anderss., eastern cottonwood *Populus deltoides* Bartr., plains cottonwood *Populus sargentii* Dode, false indigo *Amorpha fructicosa angustifolia* Pursh, boxelder *Acer* negundo L., common buttonbush *Cephalanthus occidentalis* L., and an early escape five-stamen tamarisk *Tamarix pentandra* Pall.

Woody vegetation of the upland type is limited to the upper flood plains of streams and bordering slopes. Trees and shrubs of ecological importance in woodland communities of the upland type of the southern part of the zone (Oklahoma, Texas) are American elm, *Ulmus americana* L., netleaf hackberry *Celtis reticulata* Torr., western soapberry *Sapindus drummondii* Hook. and Arn., skunk brush *Rhus nortonii* (Greene) Rybd. et *Rhus trilobata* Nutt., honey mesquite *Prosopis juliflora var. glandulosa* (Torr.) Cockerell, and Havard oak *Quercus havardii* Rydb. Less abundant or rare in occurrence are eastern red-cedar *Juniperus virginiana* L., little walnut *Juglans microcarpa* Berlandier, bur oak *Quercus macrocarpa* Michx., post oak *Quercus stellata* Wangenh., typical post oak *Quercus stellata var. stellata*, blackjack oak *Quercus marilandica* Muenchh., green ash *Fraxinus pennsylvanica* Marsh., black walnut *Juglans nigra* L., hackberry *Celtis occidentalis* L., American plum *Prunus americana var. americana*, gum bumelia *Bumelia lanuginosa* (Michx.) Pers., Chickasaw plum *Prunus angustifolia* Marsh., Mohrs oak *Quercus mohriana* Buckl., and common chokecherry *Prunus virginiana* L.

Artificial planting of trees, first as independent undertakings by individual farmers, and later in cooperation with the Government resulted in introduction of a number of species into the Prairie States.

Planting has also brought about more extensive use of some native species. Among the frequently planted species were: cottonwood *Populus sargentii* Dode, American elm, Siberian elm, *Ulmus pumila* L., honeylocust *Gleditsia triacanthos* L. black locust *Robinia pseudacacia* L., hackberry, netleaf hackberry, boxelder, black walnut, northern catalpa *Catalpa speciosa* Warder, white mulberry *Morus alba* L., red mulberry *Morus rubra* L., silktree *Albizia julibrissin* Durazz., ailanthus *Ailanthus altissima* (Mill.) Swingle, apricot *Prunus armeniaca* L., osage orange *Maclura pomifera* (Raf.) Schneid., green ash, desert willow *Chilopsis linearis* (Cav.) Sweet, eastern red cedar, ponderosa pine *Pinus ponderosa var. ponderosa*, and Austrian pine *Pinus nigra* Arnold.

As a result of experience gained during the last 20 years, the original list of recommended species for shelterbelts has been considerably modified. Some species (American elm, hackberry, desert willow) have not been used in recent years, while the use of some others (catalpa, Siberian elm) has been drastically curtailed.

Thornless honeylocust *Gleditsia triacanthos* f. *inermis* (L.) Zabel, continues to be planted in large numbers. However deterioration of this species in recent years has created serious doubt in regard to its qualities and value in Oklahoma shelterbelts.

Since honeylocust constitutes the object of this study some information on the natural range, distribution, silvicultural requirements and the use of this species is offered.

According to Harlow et al. (37), the natural range of honeylocust *Gleditsia triacanthos* L. covers the eastern half of the United States with the exception of the South Atlantic and Gulf Coastal Plains. It lies almost entirely outside the shelterbelt zone. The western boundary of the range is located in the southeastern part of South Dakota, eastern half of Nebraska, and the eastern part of Kansas and Oklahoma. It is quite probable that the original natural range of honeylocust was not as extensive as that described by Harlow but has been extended to its present area through planting and through seeding from cultivated trees (36). Honeylocust is nowhere abundant. It is commonly found along streams or on bottomlands, on fertile soil. It occurs singly, or scattered in small groups. Nearly pure stands are found only in small areas, especially in southern Indiana and Illinois.

A thornless variety of honeylocust <u>Gleditsia triacanthos</u> f. <u>inermis</u> (L.) Zabel which is preferred for propagation and planting in shelterbelts occurs naturally in the Tennessee Valley (45). Honeylocust has been one of the most favored shade trees in the eastern United States. It also has been used widely in shelterbelts, where, in most cases, it makes one of the tallest rows, along with cottonwood, Siberian elm and black locust.

<u>The Problem</u>

In general, the results of shelterbelt planting indicate the possibility of growing trees on many naturally treeless sites (59). However serious losses among the trees planted in the Plains during the last 20 years point to the necessity for careful selection of species and planting sites as well as to the need for more information on the subject of tree planting in the shelterbelt zone of Oklahoma. One of the immediate problems in the western part of the state is that of honeylocust survival.

During the last few years higher-than-average mortality and loss of vigor among honeylocust in shelterbelts have been observed by field foresters. Mortality among shelterbelt trees in general, particularly in belts established some 15-20 years ago has at times been very heavy. It has been accepted by many observers as an inevitable result of lack of experience in the choice of trees and sites in the early days of the Shelterbelt Program, and perhaps to the overemphasis on the quantity rather than the quality of work done in the days of economic emergency. Such species as black walnut, pines, desert willow, and others are not used now as commonly as before. On the other hand honeylocust has been considered as one of the more reliable species able to withstand unfavable growing conditions, poor land, and climatic extremes of this region. Elimination of honeylocust from the list of species available for planting would be a serious loss to shelterbelt planting in Oklahoma.

Observers reporting deterioration of honeylocust in Oklahoma shelterbelts could find no cause and have given no reason for high mortality of this species in recent years.

Because of the importance of honeylocust in Oklahoma shelterbelts and of its potential qualities as a farm tree, the problem of determining the cause or causes of the decline in quality of honeylocust was undertaken in 1953. More specifically the problem with which this thesis is concerned deals with a study of the comparative behavior of honeylocust, with the possible causes of mortality and lessened vigor, and with the means of improving survival and growth of this species under conditions of southwestern Oklahoma.

CHAPTER II

REVIEW OF LITERATURE

Despite the existence of extensive literature devoted to shelterbelts, very little has been written on the subject of behavior of individual species of trees used in shelterbelt planting. Since occasional poor performance of honeylocust in the last few years might have been caused by any of a number of environmental factors, this review includes literature which deals with various aspects of shelterbelt growth.

Rapid deterioration of entire rows of honeylocust in some shelterbelts in Oklahoma has been attributed by a few observers to exceptionally severe droughts during the years of 1952 and 1953. The majority of shelterbelts in Oklahoma are located in a zone of low precipitation (13) and it is conceivable that lack of sufficient moisture has been one of the important direct or indirect causes of death and disintegration of trees. However, abundance or lack of moisture depends not only on the amount and distribution of annual precipitation, but also on other elements of climate as well as on soil, topography, exposure, competition, and probably other factors. Observations of shelterbelts by H. P. Wells* for many years indicate that the high rate of honeylocust mortality in Oklahoma began several years before the occurrence of the serious drought of 1952.

Observations on detrimental effects of inadequate precipitation on

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*Personal communication, May, 1954.

the establishment and growth of shelterbelts have been reported by many workers. Munns and Stoeckeler (59) found direct correlation between the quality of belts and precipitation, and reported that growth rate of trees in the regions of higher precipitation was from 30 to 50 percent better than in more arid parts of the shelterbelt zone. The Soil Conservation Service (76) recommended that shelterbelts be restricted to those areas of the High Plains where annual precipitation is at least 21 inches. According to the Soil Conservation Service, the High Plains of Oklahoma and Texas are generally unsuited for windbreaks because of low annual precipitation, which makes tree planting extremely hazardous.

Planting of shelterbelts west of a zone delimited by 16 inches of rainfall in the north and 22 inches in the southern part of the Plains is considered unsafe (95), although with special care, good results have been obtained in Colorado, Wyoming, and Montana (95, 75) as well as in Arizona and New Mexico (77).

The need of a certain minimum in the quantity of annual precipitation for tree growth is universally recognized, yet within a zone of precipitation above the minimum, differences in the amounts of annual rainfall are not necessarily of much significance in regard to the survival and growth of trees. Thus in Oklahoma, Afanasiev (2) found no correlation between survival of trees and the amount of precipitation when the latter varied between 24 and 44 inches. He considers, as do others, distribution of precipitation and particularly the availability of moisture during and immediately following planting, primarily responsible for the initial success or failure of planting. Average annual precipitation alone does not indicate the adequacy of available moisture. This is particularly true in the southern Plains where there are great extremes in the range of annual precipitation. Drought in Oklahoma occurs rather frequently. During the forty-year-period between 1895 and 1934, twenty-six drought periods, each lasting four months or longer, have been recorded (9).

Prolonged rainless periods invariably result in death of many trees and the reduction in vigor of many others (2, 34). Reduced vigor, in turn, results in greater susceptibility to injury by insects and fungi (5). Bennet et al. (13) consider droughts as occurring in cycles, but Kellog (50) failed to find periodicity in their occurrence. Whether occurring regularly or not, drought periods have been responsible for death of a large number of trees in Oklahoma shelterbelts.

Difficulties encountered in establishing shelterbelts in the zones of low precipitation in the Great Plains are well recognized by those engaged in shelterbelt work (32). Trees growing under these conditions are smaller in size, lower in vigor, and have less resistance to adverse conditions than trees growing on sites with more adequate amount of precipitation (11).

In the Great Plains, soil conditions apparently have much greater influence on growth and survival of trees than the climatic features of the region, although according to Zon (95) only 5 percent of the soils in the shelterbelt zone were found incapable of supporting tree growth, and 39 percent were classified as "difficult". Soils designated as "unsuitable" or "difficult" do not form large areas but are found scattered throughout the entire zone (95, 43). Typical of these are excessively heavy soils and alkali spots (34).

Texture and depth of the permeable layer of soils have a strong influence on tree vigor (84). Pronounced differences in the rate of growth and survival attributable to differences in soil texture were observed by Afanasiev (1, 2) in his survey of Oklahoma tree plantations. Harper (38) studied the relationship between soil characteristics and tree development and found that high clay content is detrimental to tree growth. Similar observations on the effects of heavy soils were made by other workers (1, 2, 51, 59).

Wells (84) has observed that permeability of soil is one of the principal factors affecting behavior of trees in the shelterbelt zone of Oklahoma. He states that to assure successful tree growth at least six feet of permeable soil are needed, and therefore field windbreaks should be confined to soils of classes I, II, and III (76).

Stoeckeler and Bates (69) consider sandy soils as providing greater stability of moisture supply than heavier types of soils. In periods of abundant rainfall water is stored in larger amount and at a greater depth in sandy soils than in fine textured soils. Movement of water from the surface downward to deeper layers in heavy soils is slow. When the top layer of heavy soil dries out it might take a long time before moisture becomes again available to the trees. This view is also shared by Bodrov (14) who observed that the quality of tree growth in the lower region of the Volga depends entirely on the mechanical properties and moisture content of the soil. According to Bodrov the soil-moisture relationship becomes particularly important when plantations attain the age of 20 years, and the demand for moisture has markedly increased. Wilde (87) on the other hand points to the importance of fine soil material for tree growth. He states that the higher the amount of silt and clay, the greater is the moisture holding capacity of the soil. This observation was made in areas bearing natural tree growth.

Plant growth is closely correlated with chemical properties of forest soils. Wilde (87) considers chemical properties of soil to be more important than soil moisture. However in the Great Plains fertility of soil is seldom, if ever, a limiting factor in the survival of shelterbelt trees (2).

Alkali spots have already been mentioned as incapable of supporting tree growth. In this connection it might also be worth mentioning that in Oklahoma soil reaction ordinarily is not unfavorable to deciduous trees. Adverse effects of soil reaction on deciduous shelterbelt trees begin to be felt when pH exceeds 8.0 (21). Significantly, honeylocust is one of the most alkali tolerant species used in Oklahoma shelterbelts (21, 38).

The element of competition plays an important part in regard to the problem of available moisture in the shelterbelts of Oklahoma. As pointed out earlier, the shelterbelt zone lies in a region of low annual precipitation (22 inches to 28 inches) and high rate of evaporation. Loss of moisture through transpiration by the competing plants is likely to reduce the amount of moisture which otherwise would be available to shelterbelt trees. Cultivation of young plantations in western Oklahoma, especially in the early stages of growth, is necessary to establish successfully shelterbelt trees. Literature on shelterbelts repeatedly illustrates failures of tree growth caused by lack of care and cultivation. According to Munns and Stoeckeler (59) "adequate cultivation is the most important single factor in determining success or failure of tree planting in the Plains."* Data from 293 belts,

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*How are the Great Plains Shelterbelts.

collected by these two workers, show a definite superiority of properly cultivated windbreaks over those which have been neglected. Comparison of growth and survival of green ash in cultivated and noncultivated plantings, made by George in the northern Great Plains (30) also indicates the value of cultivation. Survival of green ash under cultivation was 85 percent, whereas in noncultivated belts it was only 51 percent. In addition, height growth of trees in cultivated plantations was almost twice that of trees in the noncultivated belts. Despite strong emphasis by the Forest Service and the Soil Conservation Service (61) on the need for cultivation, many farmers failed to care for young trees, and this resulted in complete or partial failure of the plantations.

Control of competing vegetation is not confined to cultivation after planting. All agencies charged with technical assistance to the farmer recommend a thorough preparation of the planting site well in advance of actual planting. One of the phases of this preparation consists of plowing and in some cases of subsoiling of the ground, followed by periodic discing. Such preparation, to be effective must be made at least one year in advance of planting (11, 48). The aim of this practice is to create a more abundant reserve of soil moisture and later to reduce its loss by eliminating competing vegetation.

Spacing of trees and shrubs, another important factor in the problem of making more moisture available to the trees, has been receiving considerable attention by shelterbelt technicians. Solution of this problem is complicated by the fact that an increase in spacing while favoring individual trees reduces the effectiveness of the belt and certainly lengthens the period necessary to create a closed wind barrier. It also lengthens the period during which cultivation of the plantation must be maintained.

The spacing of trees cannot be viewed in proper perspective unless certain characteristics and growth habits of various species are also considered. Failure to consider these factors has undoubtedly contributed in the past to excessive competition among trees. Up to now spacing of trees in shelterbelts has ranged from 2 feet by 4 feet to 8 feet by 15 feet (33, 34). Close spacing of 4 feet by 9 feet was suggested by Yeager for North Dakota (94). Bates (11) recommended spacing of 6 feet by 6 feet and 6 feet by 8 feet in preference to wider spacing because the former would shorten cultivation period and induce faster height growth and earlier crown closure. Data based on experimental evidence and reported by George (33) show that in the northern Plains growth and survival of green ash decreased with the increase in spacing from 4 feet by 8 feet to 6 feet by 15 feet. Excessively close spacing (2 feet by 4 feet and 4 feet by 4 feet) of ponderosa pine on the other hand resulted in poorer growth and survival of trees as compared with those of trees spaced 4 feet by 8 feet (33). Spacing of 6 feet by 8 feet, and 8 feet by 8 feet has been recommended by Johnson and Cobb (48). Strong sentiment against close spacing was voiced by Harrington and Morgan (39) and Deters and Schmitz (20). Spacing averaging 8 feet by 10 feet, or somewhat wider has been recommended by several workers (76, 59). In Oklahoma there has also been an increase in tree spacing. The first shelterbelt planted in 1935 by the Forest Service near Mangum, contains rows of trees spaced 5 feet apart, while in more recent plantings the average distance between two adjacent rows is from 8 to 10 feet. According to Johnson (47) even this wider spacing needs to be increased in the drier parts of the shelterbelt zone. One hundred square feet of space per tree is the minimum suggested by Johnson for many species. In eastern Colorado windbreaks are being planted with rows spaced from 12 to 16 feet apart (77).

Requirements of trees for space can hardly be expected to be uniform. Spacing should depend on the characteristics of the species in question as well as on the aggressiveness of trees in the adjacent rows. Aggressive trees with widely spreading crowns or roots, such as Siberian elm or Osage Orange are likely to interfere strongly with growth of other closely located trees (47, 6). Honeylocust being an intolerant species, might be adversely affected by competition with aggressive neighbors.

Choice and arrangement of trees in shelterbelts have been governed mainly by two factors; adaptability of species to the prospective planting site and rate of growth (61, 59). Considerable importance has been attached to the arrangement of species within an individual shelterbelt. This was based not so much upon the possible effects of the species on each other, as upon the expected rate of growth and the ultimate height of trees. The shortest, slow growing plants (often shrubs) made up the edge row while the potentially tallest trees were planted at or near the middle of the belt, thus giving the belt the form of a dam with the highest point somewhat off center (61). Structure of this type was thought to be particularly effective in lifting the wind current and carrying it over the protected field.

Honeylocust being one of the faster growing species, was usually planted next to such trees as Cottonwood, Black Locust and Siberian elm (61). Being outgrown by its neighbors, intolerant honeylocust often failed to develop as vigorously as it would have if planted next to less aggressive species.

From the very outset of tree planting on the Plains, and long before the official inauguration of the Shelterbelt Project, honeylocust has been one of the most popular species for planting on the Plains. A report of 1894 from Nebraska lists honeylocust as one of the species that proved to be well adapted to planting in that State (42). Another old report from Kansas tells of the rapid growth of honeylocust, of the value of its timber, and its freedom of borers (42).

Observations of 1930 at the U.S.D.A. Belle Fourche (South Dakota) Field Station, showed that of 14 species planted in 1909 only four species survived. These were honeylocust, Russian olive, Siberian pea tree, and red cedar (89).

In the original outline of the Shelterbelt Project (61) honeylocust was recommended for Texas, Oklahoma, Kansas, Nebraska, and South Dakota, but only on experimental basis for the southern half of North Dakota. The species was suggested for planting on all kinds of soil except sand. In 1932 the Forest Service recommended the use of honeylocust in every state of the shelterbelt zone (74). During the same period Ware (81) suggested even more general use of honeylocust in South Dakota. However in a recent publication by the U.S.D.A., honeylocust was dropped from the list of recommended species for the northern Great Plains because of the heavy losses and severe injuries caused by the susceptibility of honeylocust to early fall freezes (34).

Honeylocust as a shelterbelt tree appears to be popular abroad. In Hungary and Russia this species is favored for hedgerows because of its resistance to drought and because of the presence of long sharp thorns on its branches. Lack of hardiness prevents its use in the northern steppes of Russia (64). An additional incentive for planting honeylocust in Russia lies in the possibility of harvesting fence posts at an early age of the trees. At the Mariupol Experiment Station (southern Russia) honeylocust was cut five years after planting. Harvested stems were soon replaced by vigorously growing sprouts and suckers (79). Honeylocust was recommended also for the Pampas in Argentina (88).

Honeylocust is considered to be adapted to a very wide range of site conditions. "If a prospective planting site is at all suitable for trees, honeylocust is as likely to succeed as any other species." (3)

According to Harlow et al. (37) honeylocust prefers rich moist bottomland or soils of limestone origin, but is able to survive when planted elsewhere, especially in the Plains and Prairie States. Illick (45) went so far as to say that this tree will grow almost anywhere. Adaptability of honeylocust to heavy soils of uplands and bottomlands was reported by Johnson and Cobb (48). Honeylocust is not exacting in its requirements, however on poor gravelly soils growth of honeylocust is slow, and the tree never attains large size (36). Moderate growth of honeylocust on uplands also has been observed by Ware (81). Vyssotsky (80) advised against planting honeylocust on land characterized by dryness or alkalinity. Such extreme dryness seldom occurs in the Great Plains shelterbelt zone. Shelterbelts as a rule are not planted on alkaline soil. Vyssotsky (80) also found, that after a period of 10 to 30 years in the field honeylocust windbreaks begin to dry out as a result of weed and grass invasion. Usually the trees are then cut down, and sprouts provide the start of a new windbreak.

Honeylocust adaptability to variety of site conditions and drought resistance is also stressed by the Soil Conservation Service which lists it among the tall hardy trees in the southern part of the northern Great Plains region (75).

Observations by Bunger and Thomson (17) of the root development of windbreak trees in the southern High Plains resulted in placing honeylocust into the group of medium rooted trees, while the Soil Conservation Service for the northern Great Plains region cites it as a deep rooted species (75). Bunger and Thomson found that the depth of root penetration of honeylocust was 11 feet, and the length of the longest lateral roots 28 feet. Siberian elm in comparison, is a deep rooted species with a penetration of 27 feet and a lateral root extension of 43 feet. The lateral roots of an 18 year-old well cultivated honeylocust tree completely occupied the soil in which they extended. Comparison of a living tree and a drought-killed tree showed root penetration of the living tree slightly over 11 feet and spreading of the roots over 480 square feet. The longest roots of the drought-killed tree were slightly less than 7 feet and the whole root system was spread over an area of only 369 square feet. A comparison of survival in old shelterbelts after the drought of 1930 to 1937 reveal a much higher survival of deep-rooted trees than of medium or shallow-rooted trees (17). Honeylocust is one of the least aggressive species. Bates (12) observed three honeylocust trees with an average height of 35 feet and lateral root spread of 38 feet. Ratio of horizontal penetration of the root system to the height of these trees is 108.6 to 100, as compared to ratios of 218 to 100 and 157.3 to 100 for mulberry and osage orange respectively.

Until a few years ago honeylocust was one of the most favored trees in windbreak planting. In 1942, a survival of 79 percent in 605 rows of honeylocust averaging 7 years in age, was reported by Munns and

Stoeckeler (59). On the strength of their examination of 1,079 shelterbelts, Munns and Stoeckeler consider honeylocust among the best hardwoods for widescale use. In 1944, Bates (11) reported good results with honeylocust in Nebraska, Kansas, Oklahoma, and Texas, but poor behavior of this species in South Dakota. At the same time Rockwell (62) reported that in South Dakota experiments were carried out with hardy specimens. In 1943 Rockwell (63) recommended planting honeylocust and hackberry next to the tall row composed of either Siberian elm, cottonwood or boxelder. To the leeward of honeylocust, Rockwell (63) proposed planting a row of shrubs followed by a row of evergreens. Planting of shrubs, although intended to benefit evergreens by reducing competition would also be of benefit to honeylocust because the latter would less likely be overtopped by more aggressive neighbors. According to the Soil Conservation Service (75) honeylocust in the northern Great Plains does much better on the south and west sides of Siberian elm and cottonwood rows, where it can receive afternoon light. Adaptability of honeylocust to Oklahoma conditions was reported also by Afanasiev in 1947 (3). He noted the high survival of this species and recommended its wider use in the state (2). Honeylocust was one of the relatively few tree and shrub species recommended by Wells for shelterbelt planting in 1946 (84). In 1947 the Soil Conservation Service (76) suggested planting of honeylocust with nine other tree and shrub species in the southern Plains. In the east central zone of the northern Great Plains, which forms the northernmost area for successful honeylocust growth, honeylocust was reported as occasionally freezing back, but it was felt, "That it occupies an important place in soil conservation plantings and therefore should be used to a limited extent."[1] Stoeckeler and Williams in 1949 included honeylocust among the most promising species for the Great Plains (70). Johnson, as late as 1950, lists honeylocust as one of the most useful species for average planting sites in Oklahoma (47).

Only very recently doubt began to be felt about the use of honeylocust in shelterbelts.[2] Heavy losses of this species were reported by field foresters and farmers from western Oklahoma. Johnson as recently as October, 1954 expressed doubt in the future of honeylocust.[3] Although an exceptionally good drought resistant thornless honeylocust has been bred at the U.S.D.A. Southern Great Plains Field Station at Woodward, Oklahoma, heavy current losses among these selections, which in 1953 still rated as good windbreak trees, make their value rather questionable. The cause of mortality is unknown.

Honeylocust Diseases and Insects

Very few articles deal directly with insect damage or disease of honeylocust. Most statements made on these subjects are negative in character. Only a few minor injuries to honeylocust have been reported. Since disease was suggested as a possible cause of deterioration of honeylocust in belts in western Oklahoma and also because evidence of considerable insect damage has been observed by the writer in his field study of shelterbelts, it might be of interest to review the problem of insects and diseases in greater detail.

As already mentioned, honeylocust was believed to be very resistant

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[1] U.S.D.A. Soil Conservation Service, Farm Forestry for the Northern Great Plains, p. 142.

[2] H. R. Wells and H. E. Engstrom, personal communications. May, 1954.

[3] E. W. Johnson, personal communication.

to injury by diseases and insects, and to have generally few natural enemies (45). Ware (81) reported particular freedom from the attacks by insects and diseases in honeylocust. Afanasiev (3) after examining a large number of shelterbelts in western Oklahoma also noted lack of injury to honeylocust by insects and diseases. A statement concerning the resistance of honeylocust to many defoliating insects which damage other trees in the shelterbelt zone was made by Rockwell (62). Comparative freedom from insects and disease troubles together with a good drought resistance of honeylocust in Oklahoma was reported by Chester, Harper, Monosmith, and Fenton (19). Similar statements come also from Europe, where Schedl (62) found, that honeylocust and Sophora japonica in windbreak plantations in the Ukraine suffer less than any other species from insect injury.

Most papers mentioning insects and diseases of honeylocust do not provide conclusive evidence on their detrimental effects, but merely note their presence. According to these reports, diseases and insects on honeylocust are rare or of minor importance. A rare fungus, Nectria vauillotiana Rg. and Sacc. has been reported by Weese (83) on the bark of honeylocust in Europe. Thyronectria austro-americana (Speg.) Seeler causes canker on smaller branches (67, 68). Although honeylocust is generally resistant to the disease, some trees die from multiple branch infection. The fungus was observed in the eastern half of the United States, from Nebraska to Massachusetts and southward to the Gulf States (15). Originally the fungus has been considered as saprophytic, however Seeler observed signs of parasitism on many trees, following severe winters. In some instances fatalities resulted.

Miller and Wolf (58) found leaf spot on honeylocust, caused by

Linospora gleditsiae Miller and Wolf. The leafspots develop on leaves which have overwintered on trees. The disease is widely distributed in the south. Honeylocust is also the host of the fly-speck fungus *Microthyriella rubi* (8). Dieback of honeylocust has been noticed by several workers (34, 10). Boyce inferred that this dieback is more often caused by fungi than by the indeterminate growth of honeylocust. Species of *Coniothyrium*, *Cytosporina*, *Sphaeropsis*, and other genera are associated with both dieback and canker (10).

In Europe honeylocust is often invaded by mistletoe, *Viscum album* (72, 73). Trees with tender cambium are particularly susceptible (40, 41).

Witches brooms of various intensities, caused by a virus have been found on honeylocust (35). Infected, yet healthy looking trees, sometimes develop symptoms when cut back or defoliated. The brooms are short lived and branches bearing them die back from the tip (15). Friesner (29) examined roots of honeylocust taken from infected trees in the field. The roots had swellings 10 to 18 mm. long and bore dense persistent root hairs. Nodules resembling those of other legumes were not found. Microtome sections showed presence of bacteria within the cells of the central cylinder in the region of the swollen zone. Feher and Bokor (22) identified these as *Bacterium radicicola*, which lives in tumors produced by the primary bark. *Bacterium radicicola* is facultative aerobe and becomes parasitic when air is wanting (Feher, 23). Leonard (56) denied the presence of these bacteria. He stated that seedlings and trees showed no consistent formation of terminal cylindrical root swellings and contained no bacteria within the root tissues.

Some soils in southwest Oklahoma (Tillman, Kiowa, and Comanche

Counties) are infested by cotton root-rot (84). The latter is also known as Phymatotrichum root-rot, Ozonium root-rot and Texas root-rot. This root-rot is caused by Phymatotrichum omnivorum (Shear) Duggar, and is limited to the southwest region of the United States. Both conifers and hardwoods are susceptible to the fungus, and only a few species have shown resistance (71). Wright (90) pointed out the importance of this fungus in regard to shelterbelt plantations in Texas and Oklahoma. Surveys carried out by Wright and Wells (92) in shelterbelts of Oklahoma over a period of six years showed that of 5,942 honeylocust trees, 237 or 4 percent have been killed by the root-rot. Of 25 species studied, honeylocust, in its susceptibility to root-rot is exceeded by Eleagnus angustifolia with 9 percent loss, American elm 8.5 percent, osage orange 6.8 percent, and Siberian elm 6.0 percent. According to Wright and Wells honeylocust is not suitable for planting on root-rot infested soils. On sandy soils the chances of infection are less. The soils, in the counties of southwest Oklahoma, where the field studies were made by the writer, are free of cotton root-rot.[4]

Algae have been found on bark of honeylocust by Briscoe (16). The bark was placed in culture bowl with tap water. Two days later numerous Euglenae were present.

Few papers deal with insect damage on honeylocust. Wygant (93) observed borer damage on honeylocust growing on dry sites. This was caused by Agrilus difficilis Gory, and only very occasionally by Chrysobothris femorata (Oliv.) to which honeylocust is nearly immune. According to Wygant (93) the most serious insect problem is that caused

[4] H. R. Wells, personal communication.

by borers. The weakening effect of the drought on trees appears to increase borer damage and greatly complicates insect control. A similar statement is made by George (32) who considers leafeaters and borers as the most serious enemies of trees. The former may be controlled by spraying, while there is no practical control against the borers according to George. He also states that insects and diseases have not caused a serious problem in shelterbelts. [Yet some trees suffer considerable insect damage in the shelterbelts.] The worst offenders are borers which mostly infest black locust, green ash, and cottonwood. In South Dakota, George observed a honeylocust plantation killed by drought, insects and neglect. [No differentiation made by author.] Another plantation 30 miles away did not show any injury from these causes. No explanation was given by the author (34). Johnson (46) in 1934 reported that honeylocust, although extensively used in early plantings in Kansas, lost its popularity because of the borer. He observed greatest loss due to the borers on sites where the trees have been neglected and lost their vigor through competition for moisture with weeds and grass. Johnson however recommended planting of honeylocust when good care can be given. Ware and Smith (82) observed susceptibility of honeylocust to borers with a survival of less than 50 percent in western and central Kansas prior to 1936.

Champlin and Knull (18) in 1925 recorded for the first time breeding of Agrilus difficilis in dead honeylocust. The insect was also found on willow and prickly ash. Fisher (28) noted, that larvae probably do not live in these trees. Agrilus fallax-- has been reared a number of times by different workers from dead and dying honeylocust and hackberry. Adults of Agrilus egeniformis Champlin and Knull have been collected on honeylocust in Nebraska and Oklahoma in 1917 (18). Two common timberbeetles of the family Scolytidae may also infest honeylocust. *Monarthrum mali* Fitch is known to damage coniferous as well as broadleaf species (44). A twig girdler, *Oncideres* spp. was observed by Kotinsky (55) on a number of tree species including honeylocust. *Cyllene caryae*--, the painted hickory borer was found on devitalized and dead honeylocust trees by Fenton (44) in Oklahoma.

Honeylocust was found to act as a host to Miridae. *Paracalocoris gleditsiae*-- found in Iowa seems to be confined to honeylocust (52). Other Miridae found on honeylocust are *Pilopherus laetus* U. D. and *Pilopherus walshii* Uhl. The former was found in Alabama, the latter in Washington, D. C. (53). A mite infestation was noted by Schuder. *Tetranychus ellipticus* defoliated honeylocust at Lafayette, Indiana during the summer of 1949 (66).

Dasyneura gleditsiae (O. S.) Felt, a gall gnat or gall midge was first observed in 1866 as a honeylocust leaf deformer (25). This insect is believed to be widely distributed. It has been found in several eastern states (26). No statement was made as to the amount of damage done to honeylocust. An undescribed twig gall of the *Neolasioptera* sp. has been observed on honeylocust (24). Alfalfa and locust (presumably honeylocust) are hosts to *Micrutalis calva* Say, as listed by Leonard (57).

The webworm, *Homodaula albizziae* Clarke, described as a new species by Clarke in 1943, was observed by Wester and George (86) on honeylocust in 1947. The moth was discovered for the first time on the silktree in Washington, D. C. in August, 1940. Since that time *Homodaula albizziae* has been observed in Maryland (1944), in Virginia (1945), in North

Carolina (1947), and in Georgia (1947). Honeylocust is subject to greater damage than the silktree because of the slower production of foliage. Smaller trees appeared to be more heavily attacked than the large ones. Honeylocust according to Wester and George (86) is highly resistant to disease and until 1947 has generally been considered very resistant to insects. [Wester and George are referring to the rapid spreading of Homodaula albizziae.] Earlier observations showed that honeylocust may be infested by Tlascala reductella, a moth belonging to the family Phycitidae, but this insect is not considered to be a serious pest (86). The white marked tussock moth, Hemerocampa leucostigma S&A was reported by Kotinsky (55) to attack almost every variety of trees except conifers and was quoted by Kotinsky as "one of our worst shade tree pests."

The reports on honeylocust show rather rare occurrence of diseases with only occasional fatalities with the exception of Phymatotrichum root-rot which caused remarkable losses in Arizona and Texas. Insect damages on honeylocust have been found sporadically with mostly minor injuries. In only a few areas of the United States losses of honeylocust due to insects have been reported.

CHAPTER III

METHODS OF STUDY

Material for this thesis was obtained from data collected in 50 shelterbelts located in Greer, Washita, and Caddo Counties, (Tables I and II in Appendix A) and from laboratory studies on the A. and M. Campus, Stillwater, Oklahoma.

The field studies were carried out in April and May, 1954, after the trees had leafed out and ground vegetation could easily be appraised. Observations during the growing season provided more reliable types of information in regard to mortality, state of health, and the pattern of deterioration of individual trees. Defoliation caused either by insects or other elements of the site were easily observed at that time of the year. Tree crowns in full foliage create a more complete and reliable picture of the situation normally found within a belt when the forces of competition are at their maximum.

Individual belts used as a source of data were chosen on the basis of composition, location and presence of apparent characteristics which could possibly suggest causes of deterioration of honeylocust. Some of the belts were selected because of high honeylocust mortality, while mortality of other species in the same belt was low. However, field studies were not confined to belts containing dead, dying, or unhealthy honeylocust. Stands of healthy trees were also incorporated into this study so as to provide a sound basis for possible identification of individual elements of site causing variations in the quality of shelterbelts. In this group were included shelterbelts found in close proximity to those of poor quality, on sites of apparently similar nature, yet offering a contrast in the behavior of trees. It was felt that similarity in site characteristics might permit isolation of the factors responsible for the differences in the behavior or trees.

The data obtained in each of the visited belts concerned those factors known to be capable of causing difficulties in growing trees in western Oklahoma. Basic information obtained in the field has been summarized in Tables I and II (Appendix A). In addition to the items listed in the table, field examinations also included observations of apparent injuries to the trees and on possible causes of such injuries. Search for insects and for evidence of diseases and former insect injury constituted a part of examination of each belt.

Measurements of individual trees were taken with an Abney hand level and a diameter tape. Soil samples were obtained by means of a soil auger. The former were taken at various depths, to a maximum depth of six feet.

A few insects and pathological specimens were brought in from the field for identification.

In addition to the items obtainable through observations and measurements, information on the history of each belt was obtained wherever possible, either from the owners or from the records of the Soil Conservation Service and the State Division of Forestry.

The principal laboratory work consisted of the analysis of soil samples brought in from a number of shelterbelts. Chemical analysis was limited to a relatively few samples from belts with different behavior of honeylocust in order to find a response, if any, of too low or too high content of several elements for tree growth.

Mechanical analysis was performed on 75 samples. A modified "Bouyoucos" method of determining percentages of sand silt and clay was employed, utilizing a hydrometer calibrated to read grams of suspended material per liter of liquid. Theoretically, the hydrometer method of analysis measures the density of a suspension at a given depth with time. The procedure was as follows: 50 grams of air-dry soil were placed in a beaker and covered with distilled water for 30 minutes to 12 hours depending upon the soil density. The soil was then transferred into the dispersing machine. Five cc of one normal sodium hydroxide and 5 cc of a saturated solution of sodium oxalate were added. After 15 minutes dispersing the soil suspension was transferred into the one liter graduated cylinder, distilled water added to a volume of 1000 milliliters, and shaken vigorously. The first hydrometer reading was made 40 seconds after placing the cylinder on the table, to determine silt and clay in suspension. A second reading after one hour gave the amount of clay alone. Temperature was recorded both times and a correction of 0.25 plus or minus was applied for each degree centigrade above or below 18 degrees C. The result was multiplied by two since only 50 grams soil were used. The first figure subtracted from 100 gives the percentage of sand.

The collected insects have been identified by Dr. F. A. Fenton at the Entomology Department of A. and M. College, except one specimen which was identified by the Agricultural Research Laboratory in Washington, D. C. Some of the insects were found either in the egg or larval stage and had to be reared for final indentification.

Tree ring studies were made in order to determine the period of stagnation.

CHAPTER IV

RESULTS

The field studies lead to the conclusion that no single factor is responsible for honeylocust mortality in shelterbelt plantings. It is a complex of factors which determines ultimate failure of honeylocust. However, the single feature of insect attack seems to be of primary importance in determining the survival potential of honeylocust in the shelterbelts of southwest Oklahoma.

Weakened trees are much more apt to become the prey of insects. Healthy specimens or plantations can withstand primary insects and partial loss of foliage without suffering invasion of secondary insects. Secondary attacks usually mean complete failure of plantations. Even with a heavy borer attack, the strongest and healthiest specimens are sometimes able to survive and recover. The rows, however, become heavily thinned and the usefulness for wind protection is considerably lessened. This becomes more important in the latest recommendations for design of Oklahoma windbreaks, which consist of very few rows. A sudden partial failure of one row may cause funnel-like holes through which the wind is forced with increased velocity. The results are sometimes worse than having no windbreak at all. Partial or complete failure of one or more rows of honeylocust in wide shelterbelts may cause invasion of grass which weakens the heighboring rows by strong root competition.

The strong influence of insect damage on honeylocust survival has not been mentioned before in literature, except in one instance where honeylocust has been invaded by the webworm, <u>Homodaula albizziae</u> Clarke. This is a newly discovered pest of honeylocust now confined to the eastern portion of the United States, but rapidly spreading. In general, honeylocust is believed to be drought enduring, and insect and disease resistant.

In western Oklahoma, until recently, honeylocust proved to be one of the most reliable species for shelterbelt and windbreak planting. Recent indications are that a heavy infestation of primary and secondary insects is detrimental to honeylocust plantations which have been weakened by recent drought conditions. The lack of sufficient precipitation during the years 1951 to 1953 alone is not responsible for the weakened conditions of the trees. It is true that rainfall in western Oklahoma is a limiting factor. With an abundance or optimum of moisture, soil characteristics such as permeability and soil texture, and plant competition become less important to the survival of honeylocust. However, in areas with semiarid and subhumid climate soils and plant competition become critical factors controlling tree survival.

<u>Competition for Light and Soil Moisture</u>

Soil characteristics may be considered less important than plant competition for moisture availability. However, under adverse soil conditions a high loss of honeylocust has been observed. Until the recent insect invasion honeylocust was more likely to succeed than some of the other species used in windbreak planting. The mere fact that high losses and failure of honeylocust has been observed even on the most favorable soils lead to the conclusion that other factors are chiefly responsible for mortality. As previously mentioned these factors include competition between adjacent tree rows, and competition with herbaceous plants, and more important with grass and soddy plants.

Honeylocust is an intolerant tree with medium height and medium root expansion. If bordered by taller trees with strong root development, honeylocust suffers from root competition as well as from suppression. In many instances the foliage of this tree becomes so sparse when bordered by cottonwood or Siberian elm, which both outgrow honeylocust, that after invasion of defoliating insects or only of leaf-folding midges, the tree is not able to recover entirely and thus becomes extremely weakened. In such cases borer infestation is extremely hazardous. Once the plantation is invaded by borers death of the trees mostly occurs in a rather short period of time. Many of the visited belts gave evidence of this typical reaction. Some of the examples are very striking, especially when areas of favorable growth with high survival are located near high mortality areas containing similar soil conditions.

The intolerant character of honeylocust makes difficult its successful establishment next to species with more rapid height growth such as cottonwood or Siberian elm. Proper light conditions are as important as space for root development. When bordered on both sides by either cottonwood or Siberian elm, honeylocust usually shows signs of suppression. Stagnation of growth is evidenced by appearance of dead limbs in the top portions of the trees. In severe cases of suppression, with overtopping from both sides, entire rows of honeylocust die out. In several narrow windbreaks one row of honeylocust was planted next to a row of cottonwood but mostly on the east or north side where honeylocust cannot receive the afternoon light. In these cases, as following examples will illustrate, vigor of honeylocust depends upon the growth form of the bordering cottonwood trees. Honeylocust receiving top light showed good growth and form, but when interfered with by overhanging limbs of trees in adjacent rows, crown deformation and high mortality was observed.

A three-row belt has been established in a north-south direction on 27 inches of A horizon of medium texture and moderately freely permeable soil and permeable subsoil. It contains thorny honeylocust 25 feet tall, cottonwood 65 feet tall, and osage orange and mulberry in the same row 25 feet tall. Cottonwood is suppressing the honeylocust along the east edge (Figure 3). The honeylocust trees show stem deformation in their upper part with growth trending towards the light on the east side, which is a typical reaction of intolerant species. Most of the trees died recently. On many trees a few green limbs still may be observed. In this case a honeylocust mortality as high as 95 percent has been noted as compared to a 100 percent survival of cottonwood, osage orange, and mulberry. All the dead honeylocust trees were found infested by a flat-headed borer, Agrilus difficilis Gory in larval stage. Another part of the same belt with apparently better soil conditions, greater soil depth, and straighter growth of cottonwood showed only 20 percent mortality of honeylocust. The larger loss in the first example cannot be assigned to soil conditions. When it is possible to establish cottonwood, it is also possible to gain good growth of honeylocust. In several shelterbelts where cottonwood partially failed because of too shallow soil conditions, honeylocust showed excellent growth and survival.

Another belt (No. 5) quite similar to the above mentioned in structure and site conditions, and located only a short distance from the

Figure 3 (belt No. 4a). Very poor behavior of honeylocust as a result of severe competition and suppression by cottonwood. Entirely overtopped dead honeylocust trees are to be seen in the right half of the picture.

first, showed only 2 percent mortality of honeylocust. The orientation again is from north to south. The windbreak consists of three rows, from east to west— thorny honeylocust, cottonwood, and mulberry and green ash. The mortality of mulberry and green ash was 15 percent while the survival of cottonwood was more than 95 percent. Cottonwood however showed much straighter growth form and had less dense crowns. Honeylocust was somewhat influenced from the side but only in very few instances overtopped (Figure 4).

Relatively straight growth of cottonwood was observed in an east-west belt consisting of three rows. An important feature of this belt is the care which has been taken in cleaning and thinning the rows properly, thus preventing too strong competition between the trees. The old saying "Good farmers have good crops" can also be applied for windbreaks. Carelessness is the worst offender of shelterbelts. This has been pointed out repeatedly by the United States Forest Service, the Soil Conservation Service, and authors dealing with the establishing of windbreaks. But only few farmers realize the value of proper care. This belt is an example of careful management as seen in Figure 5. Even the sapzone (zone of root extension of trees) has been put into use by planting sand love-grass, Eragrostis trichodes (Nutt.) Nash, which was one of the very few examples the writer observed.

It is very difficult to determine the amount of root competition. As long as honeylocust is not overtopped and suppressed, the adjacent rows do not have a detrimental effect on its growth. Since there is a close relationship between crown form and root development of trees, the root competition may also count for the suppression. In other words, the suppression can be the evidence of root competition. In one

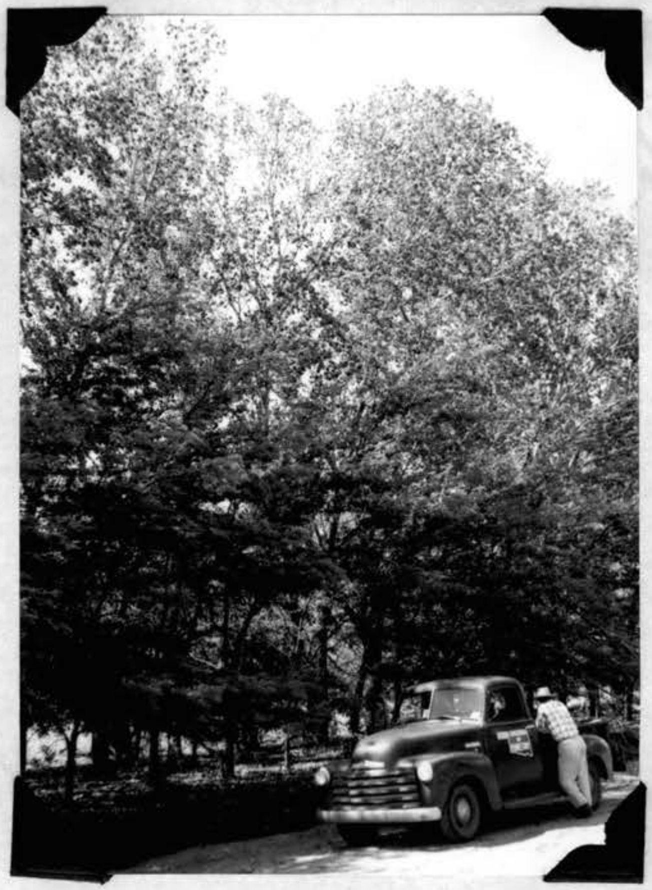

Figure 4 (belt No. 5). Straight growth of cottonwood allows more space for the development of honeylocust which is of good vigor.

Figure 5. Well managed three-row belt in excellent condition. Honeylocust forming the outside row is only very slightly suppressed by cottonwood and shows good survival. The sapzone (foreground) has been put into use with sand lovegrass.

instance it was possible to observe the influence of a row of mature cottonwood trees upon the zone of root extension as shown in Figure 6. A single row of old cottonwood trees alongside a road is bordered on the north by a ten-row shelterbelt. The first row consisting of desert willow and the second row consisting of black locust showed 100 percent mortality. A survival of 30 percent was noted in the third row containing honeylocust and black locust. This apparently is the end of the zone of influence of the cottonwood trees, for the next two rows of honeylocust as well as the remaining 5 rows showed fair to good vigor and a 100 percent survival. Honeylocust, although bordered to the north by Siberian elm, showed no signs of suppression. A better vigor of honeylocust has been observed in row four then in row five, and this is due to a larger space for development and better light conditions.

The best example of the results of suppression observed by the writer is belt No. 49 (Figure 7). This ten-row belt with a uniform composition throughout its whole length clearly indicates the danger of too great competition. The belt was planted in 1942, oriented from east to west with a spacing of 10 feet by 6 feet. The ground is covered by debris. The 2nd, 3rd, and 4th rows were cut in 1953 for fence posts. The first survey was made in the eastern part of the belt on a length of 500 feet. Green ash in the 5th row in excellent condition with a height of 35 feet is followed by honeylocust of very good vigor and 40 feet tall showing only very slight damage by leafeating insects and midges. Following are two rows of cottonwood of the same height, with highly reduced vigor and 40 percent mortality (Figure 7). Within a very short distance this picture changes rapidly (Figure 8). Cottonwood showing much better growth, a height of 50 feet and 100 percent survival

Figure 6 (belt No. 9). Zone of influence of a mature cottonwood row. The first three rows of the bordering belt disappeared. Row No. 4 and No. 5 consisting of honeylocust show fair to good vigor and 100 percent survival.

Figure 7 (belt No. 49). A row of catalpa sprouts is followed by a green ash row (35 feet high) and a row of honeylocust (40 feet high).

Figure 8 (same belt as Figure 7). Favorable soil conditions allow excellent growth of cottonwood (right background). Honey-locust (center) died as result of severe suppression.

entirely suppressed the honeylocust row which only gained a height of 25 feet until the trees died. The cause of better growth of cottonwood is most likely greater soil depth, which the writer was not able to prove because of lack of means.

Early overmaturity as a cause of high mortality in honeylocust as indicated by Russian authors (80) cannot be responsible in this case. Even under more extreme conditions of the Kamenaiya steppe honeylocust plantations reached an age of at least 15 to 20 years until they started to dry out, and this partly due to sod invasion. The good soil conditions, the excellent growth of green ash, 5 feet taller than honeylocust, and cottonwood which almost completely overtops honeylocust, and the absence of grass clearly indicate the causes for the weakened condition of honeylocust. Death presumably occurred through insect damage. There was no evidence of primary insects left, however traces of a heavy borer infestation have been observed. This flatheaded borer attacks devitalized trees but not dead trees, therefore death of honeylocust in this case must be attributed rather to the borer attack than to the suppression which is only responsible for the weakened condition.

One of the most aggressive species is Siberian elm, which has been noted by Bunger and Thomas (17) and by Bates (12) and which the writer could observe in various instances. By no means is honeylocust alone affected by this aggression. Other species also show the effects of suppression and root competition in the higher mortality and the poorer vigor. Yet the greatest effects are observed in honeylocust. Species like mulberry, hackberry, osage orange, catalpa, and green ash are more shade enduring than honeylocust. Comparisons made with these above mentioned species are not conclusive because the visited shelterbelts usually are of such a design that the tallest species (cottonwood or Siberian elm) are bordered by honeylocust or black locust. Black locust cannot serve as comparative species, as its poor behavior is well known.

Comparisons of growth of honeylocust bordered on one or both sides by Siberian elm or cottonwood show the same results. Honeylocust located between two rows of Siberian elm showed the highest mortality among all other species, 65 percent in a ten-row belt (No. 21) oriented from east to west with a spacing distance of 10 feet by 6 feet. Honeylocust forming the fourth row also showed poor vigor while the bordering rows of Siberian elm ranged from fair to good with 100 percent survival and exceeded honeylocust 15 feet in height growth. Good vigor of honeylocust was observed only on the west end of the shelterbelt, where it was free on one side, and there was enough room for its development. The failure of honeylocust in this case is of no great importance for the benefits of the windbarrier. It could easily have been avoided by a different arrangement of species and by proper thinning. The latter also would have resulted in a greater effective height.

The influence of root competition, as well as crown suppression, can be studied easily in belts which contain more than one row of honeylocust under uniform soil conditions. There it can be seen that when one honeylocust row is bordered by a row of vigorously growing tall trees, honeylocust shows greatly reduced vigor, whereas another honeylocust row in the same belt is of good vigor when next to a row of a tall species in poor condition. A typical example is belt No. 25, where honeylocust in row No. 7 is located next to a row of healthy and rapidly growing Siberian elm trees. Honeylocust was found suppressed with a height of only 25 feet. Honeylocust in row No. 10 gained a height of 38 feet and showed very good vigor. This row is bordered by cottonwood trees (50 feet high) of fair to poor vigor. The difference between the two honeylocust rows is very striking, 50 percent better height growth and 25 percent better diameter growth in row No. 10, and is due to the difference in the behavior of the bordering tall species.

In many cases mortality itself gives only a fair or sometimes no idea at all about the present situation. High mortality shows that something in the past has affected the plantation. The causes may be competition, insect damage, soil conditions or various other factors. The results however are very striking: percentage of survival may be low, poor vigor in evidence, or entire rows may have died. The same reasons for mortality still hold in the present. They do not necessarily result in mortality, as the trees are somewhat better in general vigor. Good vigor might also be misleading. Single trees which show unfavorable effects and slight damage indicate an unhealthy condition of the plantation. It may take years before this becomes evident in the percentage of mortality, depending upon the rapidity of increase of the insect population.

Single honeylocust trees in a three row belt (No. 39) are dying from the top and show borer damage. The east row is formed by Siberian elm 36 feet high, 7.5 inches dbh., and 5 percent mortality, evidencing very good vigor. Osage orange on the west is of good vigor and is 15 feet tall. A general good vigor also has been observed in honeylocust which gained a height of 30 feet and 6.5 inches dbh. Those honeylocust trees which were overtopped by Siberian elm are by no means in poor condition. Twigs of the top branches of lightly suppressed trees were found dying off. This slightly reduced vigor results in a greater susceptibility to attack by secondary insects. If such reduced vigor is recognized early enough, the plantation easily can be saved if the infested trees or the whole row of honeylocust are cut. The sprouts soon would be effective as a part of the wind barrier.

A more advanced stage of deterioration was observed in belt No. 24. There it was already evident in the fair to poor vigor of honeylocust in row No. 7. The 20 percent mortality was no obvious indication of the general behavior.

Unfortunately most of the farmers do not have the necessary understanding for these problems and do not apply proper care at the proper time. If care cannot be given, it would be better not to plant windbreaks at all, or at least no honeylocust. Honeylocust in particular needs care if heavy competition with adjacent rows and competition with grass are to be avoided. These observations are also supported by Johnson (46) in early plantations of Kansas, where severe competition for moisture was the principal factor for borer invasion and loss of honeylocust.

Effects of Grass Cover on Growth of Honeylocust

Within the study area trees generally were not able to compete successfully with grass. Soddy conditions usually result in complete failure of the whole plantation. Only honeylocust, red cedar, and osage orange show some resistance to competitive grasses (Figure 9).

Until the recent borer invasion honeylocust has been by far the best species in regard to survival under soddy conditions (Figure 10, see also Figure 19 and 20). In several visited belts dead rows of honeylocust form the only remnants of the former plantation. These trees died one or two years before the survey was made. In all instances traces of a heavy borer infestation was observed. The sudden failure of

Figure 9 (belt No. 50). Honeylocust (foreground) 14 years after planting. Generally poor behavior of the belt because of soddy condition. Only red cedar (background) did well.

Figure 10 (belt No. 26)

Recent high mortality of honeylocust caused by too severe competition with grass and heavy borer infestation. Note the fair to good behavior of osage orange (background).

honeylocust in grass invaded belts was very striking to the observer and apparently accounts to a great degree for the recent reports on honeylocust loss in southwest Oklahoma. The mortality of these trees can be attributed to borer damage as well as to the effects of drought since the insect invasion coincides with a period of rainfall far below the average.

The ground cover of 18 of the visited belts was 90 percent or more grass. The average mortality of honeylocust in these belts is 48 percent whereas the average weighted mortality of all species is 59 percent. The percentage of mortality here is somewhat misleading. Honeylocust in these belts was found heavily infested by borers and showed far more reduced vigor than some of the other species.

In several belts a heavy grass cover occurred in single spots. Honeylocust in these small areas was either dead or heavily infested by borers. The grass spots sometimes were so small that only one or two trees have been affected (Figure 11). Johnsongrass Sorghum halepense (L.) Pers. was found as the greatest competitor. In all instances where Johnsongrass occurred mortality of trees was 100 percent. Other species frequently found were six weeks fescue Festuca octoflora Walt. and junegrass Hordeum pusillum Nutt.

Grass invasion is not limited to shallow soil conditions, although shallow soils usually are invaded by grass. Heavy grass cover also was found on deep sandy soils (Figure 12).

Where dense grass is found among shelterbelt plantings, it severly affects honeylocust. This is not a feature peculiar to honeylocust behavior. The status of all species in such belts is rather poor. The high mortality of honeylocust which occurred in recent years seems

Figure 11 (belt No. 27). Dead honeylocust (center) in small patch of grass. Siberian elm (stump in right foreground) died several years before competition with grass became fatal to honeylocust.

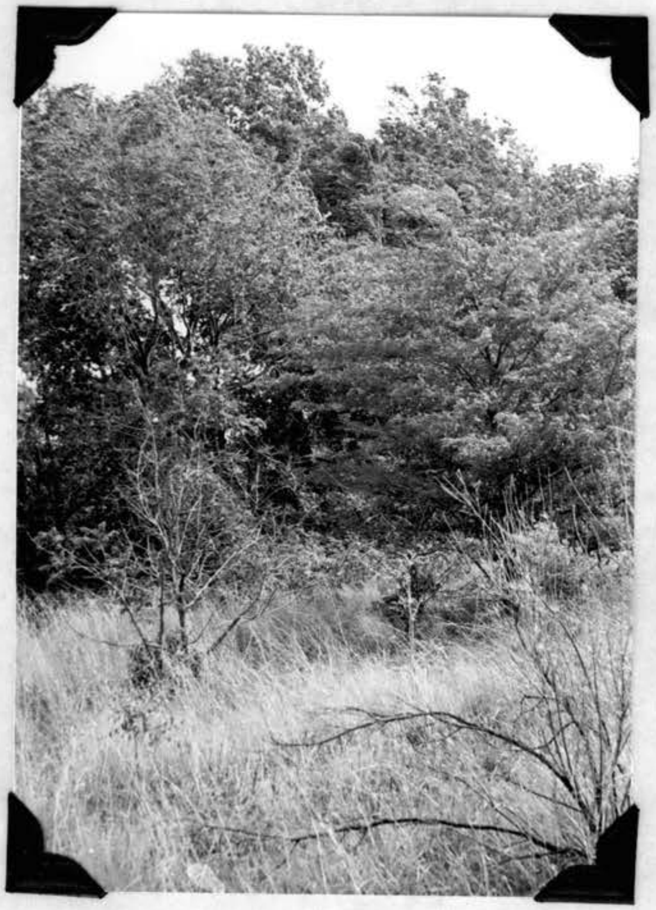

Figure 12 (belt No. 8).

Shelterbelt without management. Honeylocust in foreground is unable to compete with grass even on deep sandy soil. Siberian elm and cottonwood in the background are situated in a shallow depression which is not invaded by grass.

Figure 13 (same belt as Figure 12). Careful management for fencepost production close to the owners house resulted in vigorous growth of honeylocust.

especially apparent.

Optimum Spacing for Honeylocust

The optimum spacing distance for trees in shelterbelts is closely related to the competition between adjacent rows. This is by no means the only influencing factor. There are others which are highly responsible such as the amount of precipitation, and soil conditions. Various authors have dealt with this problem and contradictory statements have been given. The importance of rainfall as pointed out by Werner (85) and Johnson (47) can be minimized in this case. The amount of precipitation in each of the counties visited might be considered as equally distributed, especially when comparisons can be drawn in the very same belt. The same observations as stated by George (33) and Johnson (47), that the growth habit of the adjacent row influences the spacing distance, were made by the writer in various instances. The behavior of the adjacent species again depends mostly upon soil texture, soil depth, and available soil moisture. If these variables are eliminated to a great extent, the response of the mutual influence of the different species or rows becomes more visible.

In the area visited there were no great differences in spacing. The distances used vary from 10 feet by 10 feet, to 8 feet by 6 feet. Honeylocust did not show response to these small differences. In only a few instances a smaller spacing was made, as for instance a seven-row belt (No. 16) with a spacing distance of 4 feet by 3 feet. Honeylocust with 100 percent survival is bordered by cottonwood and catalpa with 80 percent and 90 percent mortality respectively. Only two rows, honeylocust and Siberian elm had very good vigor, the other species—black locust, cottonwood, and catalpa—ranged from fair to poor. Another close spacing due to replanting in the second year because of presumed failure was found in the first belt planted in the United States under the Great Plains Shelterbelt Project. The average spacing of this belt in the present time is 68 inches by 68 inches in some parts trees are as close together as 34 inches. Honeylocust in the thirteenth row of this seventeen-row belt shows 100 percent survival and a height of 38 feet. It is however bordered to the north by a row of pine trees which almost completely disappeared followed by a 46 feet tall row of Siberian elm. To the south it is bordered by a row of black locust sprouts. The close spacing of the honeylocust trees and the short spacing distance to the south, where black locust apparently had gained a considerable height, considering the stump diameter, did not effect growth and vigor of honeylocust. Excellent soil conditions, deep sandy loam, are most likely responsible for the good behavior of the belt.

A demand for wider spacing in regard to honeylocust can be observed and recognized in belts where this species is bordered on one or both sides by at least two rows of either cottonwood or Siberian elm. A different behavior of honeylocust was observed when the bordering row was alive and in good vigorous condition, than when this row has entirely disappeared, thus doubling the spacing distance. The following examples will prove that in an area with a certain limited amount of rainfall and under almost equal soil conditions, spacing is highly influenced by the competition of the adjacent rows. This by no means proves that precipitation and soil conditions are not the most responsible factors. Comparisons of the required spacing distance due to the amount precipitation could not have been made because of only small differences for which the gathered material cannot be considered as conclusive. The observations show, that with the given amount of rainfall, the spacing distance in many instances is too short. In belt No. 14 honeylocust is bordered to the north by two rows of cottonwood. The spacing distance between the rows is 116 inches and between the trees in the row 8 feet. Soil conditions are favorable with a high watertable. Wet sandy loam was found at a depth of 4 to 6 feet with steadily increasing moisture content. The cottonwood rows in the western part of the belt each show a mortality of 20 percent, good vigor and a height of 42 feet. Honeylocust on the average has a height of 33 feet, fair to good vigor, and 100 percent survival. In places where the row of cottonwood next to honeylocust disappeared, honeylocust is of very good vigor and gained greater height. Another example is belt No. 27 (Figures 14, 15, 16, 17), a belt with changing composition. Honeylocust shows excellent growth and vigor when bordered by a first row of black locust of very poor vigor, and a second row of cottonwood. Similarly, the honeylocust performance is good if the first border row is dead cottonwood and the second is cottonwood in which the mortality has been from 10 to 20 percent. The doubled spacing distance allows honeylocust entire freedom for development. Where the adjacent cottonwood row is thrifty, honeylocust shows poor results. A doubled spacing distance which in this case is 19 feet is not necessary and is not desirable from the standpoint of wind protection. The single spacing distance of 9½ feet however is too short as to allow sufficient growth of honeylocust.

Spacing distances as carried out in the shelterbelt of southwest Oklahoma are insufficient since the growth habits of the different tree species are not taken into consideration. The common distance of 8 to 10 feet between two rows is too short when a row of cottonwood or

Figure 14 (belt No. 27). Stagnation of growth of honeylocust which is overtopped by a cottonwood tree. Notice the dead limbs in the top of the honeylocust tree.

Figure 15 (belt No. 27). Honeylocust free from competition shows very good vigor and growth. The row of dead trees in right center is Siberian elm which was suppressed by cottonwood already in an early stage.

Figure 16 (belt No. 27). Good height growth and vigor of honeylocust. The neighboring two cottonwood rows failed entirely.

Figure 17 (belt No. 27b). Honeylocust in very good condition. The two bordering rows, black locust and cottonwood show 100 percent mortality. Following is another row of cottonwood with fair vigor (upper left).

Siberian elm is planted next to a row of honeylocust. In this case the minimum required spacing distance between rows would be 12 to 14 feet in order to secure vigorous growth of honeylocust. Such wide spacing would increase the period before the shelterbelt becomes effective as a wind-barrier, and would also increase the cultivation period. Therefore it is not advisable to plant honeylocust next to taller tree species. The present spacing distance of 8 to 10 feet between rows is sufficient when honeylocust is bordered by trees which do not exceed honeylocust in height growth.

Honeylocust Survival and Behavior in Relation to Soil Texture and Soil Depth

Successful growth of trees in the Great Plains largely depends upon the water economy of the soil. Soil moisture maintenance, as pointed out in the review of literature, is primarily determined by soil texture and depth of the permeable layer. Clay soils are usually considered as detrimental to tree growth in semiarid regions. These findings can be only partially supported by the writers observations. Considerably increased mortality of trees was found only when an impenetrable layer occurred at a depth of less than 3 to 4 feet. Such extreme cases of shallow soil have been observed in very few instances. The cause was either a hardpan at a shallow level or sandstone. The affects on tree growth are the same. Those soils either barely support a poor growth of trees or fail entirely to produce tree growth. Honeylocust is no exception in such extreme cases.

Trees in shallow soils start to stagnate when their roots are no longer able to penetrate into greater depths and expand horizontally where they have to compete with the neighbors for moisture supply. In drought years this problem is far more serious than in years with high precipitation. Tree ring studies showed good growth of honeylocust until 1952 in several plantations, then the diameter growth almost stopped. In 1954 when the survey was made, the trees were already dead, only a few still showing some green limbs. This sudden stagnation of honeylocust growth coincides with a period of precipitation far below the average. In all cases a dense ground cover of grass increased the competition for moisture. The weakened trees have been attacked by borers in either 1952 or 1953. At the time the survey was made the borers had already abandoned the trees.

The following examples will illustrate the above statements. A two row honeylocust windbreak (No. 7, see Appendix A, Tables I, II, III, and Figure 18) was found recently killed by borers. Stagnation of growth in 1952 was traced through the growth rings. Death occurred one year later. Until 1952 very good diameter growth was observed. The trees were growing in shallow soil with a permeable layer of only 39 inches. The ground cover was formed by a heavy sod. Although the direct cause of death was the result of a borer infestation, honeylocust was not able to maintain a vigorous growth during the drought period, chiefly because of the shallow depth of the permeable layer. Clay content was 18 percent at 18 inches depth, and 26 percent at 39 inches depth, which is less than that found in several other belts with high survival and good behavior of honeylocust.

Soil types were quite variable in the visited counties. Belts with a length of one-fourth or one-half mile may include several soil classes. This very often accounts for the different behavior of the shelterbelt trees in a relatively small area. The changes are sometimes very obvious, especially where one part of the belt was planted on deep

Figure 18 (belt No. 7). Competition with grass in shallow soil and a heavy borer infestation are the cause of death of this two-row honeylocust windbreak. A slight slope in foreground increases the water runoff.

loamy sand, and the other on a shallow clay soil. This was observed in a nine-row belt (No. 15) where a sudden change in the behavior of honeylocust was found due to an abrupt change of soil conditions. In the western part of this belt (Figure 19) for a distance of 200 feet a sandy and gravelly soil layer extends to a depth at least 6 feet, an almost impenetrable layer at 18 inches in the remaining windbreak (Figure 20) prevents successful tree growth. The clay content at 10 inches depth is as high as 35.5 percent and at 18 inches 43 percent. The amount of silt is 32.5 percent and 30.6 percent respectively. Mortality of honeylocust in the good portion of the belt is 2.5 percent indicating good to fair behavior, honeylocust being the most vigorous species in this lot. The average mortality of the other species is 42.8 percent. The only severe competition for honeylocust is a 90 percent grass cover. In the other part of the belt honeylocust survived the longest except that osage orange with a survival of 40 percent, and a few red cedars still remain. The two rows of dead honeylocust trees formed the only relic in the center of the belt, some trees still having several green limbs. Similar findings were made in belts on shallow soils which have been invaded by grass, honeylocust always being one of the last surviving species. In all these cases evidence of a heavy borer infestation was observed.

There is no doubt about the responsibility of the permeable soil depth as to survival and vigor of the different tree species. There are only two species which show fair results in very shallow soil. These are osage orange and red cedar. All other trees, including honeylocust, are unable to gain sufficient growth to fulfill the purpose of wind protection.

Figure 19 (belt No. 15).

Good results of honeylocust in very coarse sand despite a 90 percent grass cover.

Figure 20 (same belt as Figure 19).

Dead honeylocust in shallow clay soil. Extreme soddy condition and overgrazing.

No connection has been observed between the amount of clay in the various layers and the survival of honeylocust. A comparison of the mortality of honeylocust and the mortality of all species in different soils show that honeylocust reacts less to soil texture than most of the other tree species.

In clay soils honeylocust had better vigor and higher survival than most of the other planted species. A high clay content was found in the soils of an eleven-row belt (No. 12). Clay content was 50.5 percent at a depth of three feet. Two rows of honeylocust forming the tallest species were of very good form and good vigor with 100 percent survival, whereas the other species had an average mortality of 45.6 percent. Honeylocust growing in a soil with relatively high clay content was found second best species in a nine-row belt (No. 6) with fair to good vigor and only 5 percent mortality. However at the time the survey was made it showed slight infestation by borers.

Honeylocust on the other hand may show reduced vigor and high mortality on good sandy soils, if competition with grass or other trees is severe. For example, in belt No. 20 one row of honeylocust bordered by cottonwood is in a rather poor condition and is invaded by borers and caterpillars. The other row, being less suppressed, is of better vigor and has no mortality.

Grass cover was found on heavy soils as well as on sandy soils. The grass vegetation competed rather severly with tree growth on both kinds of soils.

Trees in southwest Oklahoma in general grow better on the sandy soils, but in many instances other factors are more important than the soil components. Honeylocust very often is planted next to the tallest row which is either Siberian elm or cottonwood. These species do better in deeper soils with less fine material. Cottonwood is especially exacting in its requirements. In deeper and more sandy soils cottonwood reaches larger size and has maximum vigor. In this situation it is more able to suppress honeylocust. As a result one often finds higher mortality of honeylocust in better and deeper soils as shown in following example.

In a ten-row belt (lot No. 49a) a mortality of 23.9 percent (excluding honeylocust) was observed; the clay content being 23.5 percent at 10 inches depth, 20.5 percent at 20 inches depth, 13.5 percent at four feet, and 9.25 percent at six feet depth. Honeylocust in 12 years attained a height of 40 feet and had 100 percent survival. The bordering cottonwood however was only of fair vigor with a mortality of 40 percent. In lot No. 49b, only 300 feet away from the first, a better appearance of the belt in general has been noticed, the mortality being 5 percent less than in lot No. 49a. The clay content also was far less with 11.0 percent at 10 inches depth, 14.5 percent at 20 inches depth and 5.0 percent at five feet. The honeylocust row in lot No. 49b however, was completely dead at the time the survey was made. It only gained a height of 25 feet and was entirely overtopped by cottonwood which was growing vigorously due to the better soil conditions.

Growth of honeylocust did not show any remarkable response regarding the differences in soil texture. Honeylocust in shallow soil with a permeable layer of less than 3 to 4 feet is unable to maintain vigorous growth. This suggests that permeability depth is of greater importance than soil texture, especially during the last drought period the trees were not able to satisfy their moisture requirements and became extremely weakened. This resulted in a heavy borer infestation.

Insect Damage to Honeylocust

Heavy insect damage on honeylocust as observed by the writer seems to be of rather recent origin. Honeylocust is usually described as one of the most resistant species to insect attacks. Various other species used in shelterbelt planting are quite susceptible, even from the time of establishment of plantations. The susceptibility of black locust, green ash, American elm, cottonwood, and others to insect attacks, especially to borers, is well known. Borer occurrence, however, in many cases is localized. For instance, green ash was found by the writer to be heavily infested by borers in Greer County, whereas it was completely free from insects in most of the belts in Caddo County. Such a sporadic occurrence seems to be the case with honeylocust, for insects have been found in the past on this tree in some areas of North Dakota and Kansas. In Oklahoma so far only one species has been mentioned to attack devitalized or dead honeylocust trees in recent years, namely the hickory borer, Cyllene cariae Gahan (27).

In southwest Oklahoma the greatest part of the mortality of honeylocust observed, occurred in the last few years. Early stages of wood decay are just beginning. In several belts which were completely invaded by grass, rows of dead honeylocust trees formed the only evidence of a former shelterbelt. These observations of a rather recent death of honeylocust are confirmed by statements of farmers. For instance, one farmer observed a two-row honeylocust windbreak (No. 7, Figure 18) dying in the summer of 1953 during a short period of time. As direct cause of mortality the writer found an extremely heavy infestation of borers. In this case thrifty growth was followed by stagnation in 1952, a period of precipitation below the average. Soddy condition, shallow soil and a moderate slope are most likely responsible for the weakened condition. In May 1954 the insects had already completely abandoned the trees. The infestation therefore must have occurred not later than 1953, and probably even earlier. The borer in the larval and in the adult stage which was found by the writer in several instances, has been identified as Agrilus difficilis Gory. This species was first recorded by Champlin and Knull (18) to breed in dead honeylocust, in willow, and in prickly ash. Fisher (28) however noted, that the larvae probably do not live in these trees. The writer found this species in southwest Oklahoma entirely confined to honeylocust. The same species was found by Wygant (93) to injure honeylocust in the Great Plains. Wygant gives no statement of damage.

Agrilus difficilis is a flatheaded borer and in its life history closely resembles Chrysobothris femorata (Oliv.), the flatheaded apple tree borer, which usually attacks devitalized trees. The same can be said of Agrilus difficilis. In only one instance a slight infestation was observed on thrifty growing trees. Honeylocust in weakened condition was heavily attacked by this borer. The same observations were made by Johnson (46) who noted losses of honeylocust due to borers on sites where the trees, because of neglect and competition with weeds and grass, failed to make thrifty growth. These causes are described in previous chapters. The borers were mostly found in trees with greatly reduced vigor, trees which were at least partly alive. Borers abandon completely dead and dried honeylocust.

Another devitalizing factor for honeylocust are primary insects, which were found by Fenton (27) and Monroe and Riddle (60) as highly responsible for lowering the resistance of trees to borer attacks. The most serious problem is that of the leafeating caterpillars. Two species were found on honeylocust by the writer. They inflicted severe damage in several cases. The eating patterns of the two species are identical, therefore the amount of damage done by either insect cannot be definitely ascertained. Presumably responsible for the defoliation in May 1954 is an unidentified species of the family Tortricidae, which was found in the larval stage on the bark of the trunk or larger limbs, where it found shelter from the unfavorable weather conditions at that time. The other species was found in the egg stage only, on uninjured leaves. It was reared by the writer and identified by Dr. F. A. Fenton as the plum borer, Euzophera semifuneralis Walker of the family Phycitidae. Since this species has not been found in the larval stage, the first species was most likely responsible for the defoliation. The plum borer has been found on peach and plum trees (57). The infestations in several instances are rather heavy. Devitalized trees were attacked as well as thrifty growing trees. The only difference is that specimens in good vigorous condition with a large leaf surface were more able to withstand damage than trees with poor vigor. Honeylocust in a two-row windbreak (No. 41) of very good vigor may endure partly defoliation much more successfully than the honeylocust row in belt No. 43 which shows greatly reduced vigor. Both were heavily attacked by the caterpillars. The honeylocust in belt No. 41, being excellent in vigor, is much more apt to recover than the same species in belt No. 43 where vigor runs from fair to poor. In the two-row windbreak only slight borer damage was observed, but a heavy borer infestation was found in the belt with the poor condition. Honeylocust mainly is affected by this defoliation. Only in a few instances slight damage was found on Siberian elm and hackberry, when these species were located next to the infested honeylocust row.

Dasyneura gleditsiae Felt, a gall gnat is also damaging honeylocust to some extent. This species according to Felt (26) is evidently widely distributed. It deforms the leaflets of honeylocust. Cook[5] states, that the two halves of the leaflet, which forms a characteristic pod-like swelling inhabited by two or three pale orange larvae, never have an opportunity to unfold, though there is a growth of cells allowing the leaflet to enlarge and form the larval chamber between the two halves. This insect greatly reduced the active leaf-surface of honeylocust trees in many of the visited belts. Since only one generation commonly is presumed by Felt, the trees are likely to recover from these injuries. This insect alone for itself would not be of any great danger, yet as a typical primary insect, it attacks very healthy trees, thus weakening them and permitting borer invasion. This was observed in several belts. Recent borer infestation was found on trees which showed a great number of deformed leaves. Trees only slightly damaged by Dasyneura gleditsiae and in good vigorous condition have not been attacked by Agrilus difficilis. These observations were made in belts which were not invaded by the caterpillars, although in other instances gall gnat and caterpillar damage was found on the same tree. The gall gnat in southwest Oklahoma was far less important than leafeaters in 1954. It is, however, able in extreme cases to weaken the trees to such an extent as to allow borer invasion. This gall gnat also occurred at the campus of

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[5]E. P. Felt, 29th Report of the State Entomologist on Injurious and Other Insects of the State of New York. p. 163.

A. and M. College in Stillwater to a rather small extent in 1954. The well cared trees at the campus are too vigorous and thrifty growing as to allow greater damage.

Pseudodiaspis yuccae (Ckll.), a scale insect, was found for the first time in Oklahoma by the writer in one of the younger belts. The principal host for this insect is Yucca sp. It is not uncommon in Texas. On honeylocust trees 10 to 12 feet tall, the bark of the trunk and larger limbs was entirely covered by this insect. The trees showed greatly reduced vigor. Munroe and Riddle (60) consider scale insects as very dangerous enemies of tree plantations in the Great Plains. A similar statement was made by Chester, Harper, Monosmith, and Fenton (19), who inferred that scale insects are one of the two worst enemies of shade trees in Oklahoma, the other being the flatheaded borers.

Micrutalis calva Say, a membracid, was occasionally found infesting honeylocust. This insect is a leaf-sucker whose actions cause the margins of the leaves to turn brown and curl upwards. The amount of damage done by this insect cannot be stated. Other seemingly less important insects found on honeylocust are: Thyridopteryx ephemeraeformis (Haw.), or bagworm; Leiopus variegatus (Hald.), a longhorned beetle, in dead trees; engravings of bark beetles, presumably a species of the family Scolytidae, also in dead honeylocust; and a tussock moth feeding on green leaves.

Insect damages in recent years are a serious problem to honeylocust survival in shelterbelts of western Oklahoma. The most dangerous is Agrilus difficilis Gory, a typical secondary insect, which infested a great many honeylocust plantations of reduced vigor. The devitalizing factors are drought effects on shallow soils, competition with other trees and competition with grass, and to some extent the effects of primary insects. Unless the general condition of the plantations can be improved by proper management, greater losses of honeylocust by borers will have to be expected.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The ultimate mortality of honeylocust in Oklahoma shelterbelts is mainly caused by insects, the most important of which is Agrilus difficilis. It usually attacks trees devitalized by lack of soil moisture and by inability to compete for light requirements. This becomes more evident in years with low precipitation, like the present drought period existing between 1951 and 1955. In areas invaded with grass, honeylocust was one of the most resistant species. More recently, this resistance may be questioned. The results of defoliation of primary insects are also more severe in drought years than in years with high precipitation. Ample precipitation would allow the trees to recover.

The general status of honeylocust in Oklahoma shelterbelts points to the necessity for more careful management. Most important for successful development of honeylocust is maintenance of its vigor. Therefore precautions should be taken in eliminating the weakening factors such as competition and suppression. Sites should be carefully selected.

Honeylocust should not be planted next to cottonwood or Siberian elm because too severe competition for light and soil moisture weakens it. A row of shrubs or lower trees planted in between honeylocust and these more aggressive species will be sufficient to prevent suppression. It is not advisable to plant honeylocust together with cottonwood or Siberian elm in one-, two-, or three-row windbreaks. Extremely shallow soil with a permeable layer less than 3 to 4 feet should be avoided for planting. Honeylocust, like most of the other species cannot maintain good vigor in competition with a heavy grass stand. Special care must be taken to avoid grass invasion.

There are no practical means to control borer damage. Heavily infested trees should be cut and burnt before the insect reaches the adult stage. Spraying against leafeating insects is practical for young belts. Bear grass should be eradicated close to honeylocust in order to prevent infestation of honeylocust by Pseudodiaspis yuccae.

In conclusion it can be said that honeylocust did not fulfill its expectations of believed immunity to insect attacks. Honeylocust still may be planted on selected sites. Regular observation for borer attack in future will be necessary. Insects may be only of sporadic occurrence as previously observed, but they also may develop as a serious menace to honeylocust, especially when belts are not managed properly.

LITERATURE CITED

1. Afanasiev, M. A Study of Red Cedar Plantations in North Central Oklahoma. Oklahoma Agricultural Experiment Station Technical Bulletin T-34, 1949.

2. Afanasiev, M. Preliminary Study of Tree Plantations in Oklahoma: Relative Survival by Species and Factors Affecting Survival. Oklahoma Agricultural Experiment Station Technical Bulletin T-29, 1948.

3. Afanasiev, M. Trees and Tree Planting for Posts Windbreaks and Erosion Control. Oklahoma Agricultural Experiment Station Bulletin B-314, 1947.

4. Aikman, J. M. "Native Vegetation of the Region." Possibilities of Shelterbelt Planting in the Plains Region. Washington, D. C.: U. S. Government Printing Office, pp. 155-175, 1935.

5. Albertson, F. W., and J. E. Weaver. "Injury and Death or Recovery of Trees in Prairie Climate." Ecol. Monogr. Vol. XV. pp. 339-433, 1945.

6. Anonymous. "A Survey of Past Plantings." Possibilities of Shelterbelt Planting in the Plains Region. Washington, D. C.: U. S. Government Printing Office, pp. 39-47, 1935.

7. Aune, B., L. A. Hurst, and A. Ochsenbrug. Agricultural Investigations at the Belle Fourche (South Dakota) Field Station 1926-1932. U.S.D.A. Technical Bulletin 454, 1934.

8. Baines, R. C. "Pathogenecity and Hosts of the Flyspeck Fungus of Apple." Phytopathology Vol. XXX, No. 2. Abstract of Papers, 1940.

9. Bates, C. G. "Climatic Characteristics of the Plains Region." Possibilities of Shelterbelt Planting in the Plains Region. Washington, D. C.: U. S. Government Printing Office, pp. 83-111, 1935.

10. Bates, C. G. "Shelterbelt Influences, I. General Description of Studies Made." Journal of Forestry, Vol. XLIII. No. 2, pp. 88-93, 1945.

11. Bates, C. G. The Windbreak as A Farm Asset. U.S.D.A. Farmers Bulletin 1405, 1944.

12. Bates, C. G. Windbreaks, Their Influence and Value. U.S.D.A. Forest Service Bulletin 86, 1911.

13. Bennet, John B., F. R. Kenney, and W. R. Chapline. "The Problem: Subhumid Areas." Soils and Men, The Yearbook of Agriculture 1938. Washington, D. C.: U. S. Government Printing Office, pp. 68-76.

14. Bodrov, B. A. "Possibilities of Shelterbelt Planting on Chestnut Soils of the Volga Region." Shelterbelts VI. Issue. Moscow: State For. Tech. Printing Office in Russian with English Summary, pp. 38-40, 1936.

15. Boyce, J. S. Forest Pathology. New York and London: McGraw Hill Book Company, pp. 38, 117, 254, 287, 290, and 449, 1938.

16. Briscoe, M. S. "A Source of Euglena." Trans. Amer. Microsc. Soc. Vol. LVIII. No. 3, p. 374, 1939. Biol. Abstr. No. 1670, 1940.

17. Bunger, M. T., and H. J. Thomson. "Root Development as A Factor in the Success or Failure of Windbreak Trees in the Southern High Plains." Journal of Forestry Vol. XXXVI. No. 8, pp. 790-803, 1938.

18. Champlin, A. B., and J. M. Knull. "Notes on Coleoptera." The Canadian Entomologist Vol. LVII. No. 5, p. 113, 1925.

19. Chester, K. S., H. J. Harper, R. O. Monosmith, and F. A. Fenton. A Program for Shade Trees in Oklahoma. Oklahoma Agricultural Experiment Station Bulletin 234, 1938.

20. Deters, M. E., and H. Schmitz. Drought Damage to Prairie Shelterbelts in Minnesota. Minnesota Agricultural Experiment Station Bulletin 329, 1936.

21. Engstrom, H. E., and J. H. Stoeckeler. Nursery Practice for Trees and Shrubs Suitable for Planting on the Prairie-Plains. U.S.D.A. Misc. Publ. 434, 1941.

22. Feher, D., and R. Bokor. "Untersuchungen ueber die bakterielle Wurzelsymbiose einiger Leguminosenhoelzer." Zeitschrift Wiss. Biol. Abt. E Planta Archiv F, pp. 406-413. Berlin: Verlag von Julius Springer, 1926.

23. Feher, D., and R. Bokor. "Investigations on the Root Symbiosis of Some Woody Legumes." In Hungarian with German Summary. Math es Term. Ertesitoe (Budapest) Biol. Abstr. No. 7141, 1927.

24. Felt, E. P. Key to American Insect Galls. New York State Museum Bulletin 200, p. 152, 1917.

25. Felt, E. P. Key to Gall Midges. (A Resume of Studies I-VII, Itonididae). New York State Museum Bulletin 257, 1925.

26. Felt, E. P. 29th Report of the State Entomologist on Injurious and Other Insects of the State of New York. New York State Museum Bulletin 175, pp. 124, 163, 1913.

27. Fenton, F. A. Control of Shade Tree Borers. Oklahoma Agricultural Experiment Station Circular 84, 1939.

28. Fisher, W. S. "A Revision of the North American Species of Buprestid Beetles Belonging to the Genus Agrilus." Smithsonian Institute. U. S. Nat. Mus. Bulletin 145, pp. 39-42, 1928.

29. Friesner, G. M. "Bacteria in the Roots of Gleditsia Triacanthos." Proc. Indiana Acad. Sci. Vol. XXXV, pp. 215-224, 1925. Biol. Abstr. 1928, No. 17944; 1927, No. 11350.

30. George, E. J. "Effects of Cultivation and Number of Rows on Survival and Growth of Trees in Farm Windbreaks on the Northern Great Plains." Journal of Forestry, Vol. XLI, 1943.

31. George, E. J. Growth and Survival of Deciduous Trees in Shelterbelt Experiments at Mandan, North Dakota, 1915-1934. U.S.D.A. Technical Bulletin 496, 1936.

32. George, E. J. "Some Silvicultural Problems of the Northern Great Plains." Journal of Forestry, Vol. LII, No. 7, pp. 511-515, 1954.

33. George, E. J. Spacing Distances for Windbreak Trees on the Northern Great Plains. U.S.D.A. Circular 770, 1948.

34. George, E. J. Thirty-One Year Results in Growing Shelterbelts on the Northern Great Plains. U.S.D.A. Circular 924, 1953.

35. Grant, T. J. "Systematic Brooming of Robinia Pseudacacia and Other Viruslike Diseases of Trees." Phytopathology, Vol. XXIX, No. 8, Abstract of Papers, 1939.

36. Green, G. R. Genus Gleditsia. Trees of North America Vol. II The Broadleaves. pp. 201-203, 1938.

37. Harlow, W., M. Harrar, and S. Ellwood. "Genus Gleditsia." Textbook of Dendrology. New York and London: McGraw Hill Book Company, pp. 425-427, 1941.

38. Harper, H. J. Preliminary Survey of Important Factors Which May Affect the Development of Trees in Western Oklahoma. Mimeographed Publication.

39. Harrington, F. M., andC. W. Morgan. Dryland Shelterbelt Tests at the Northern Montana Branch Station. Montana Agricultural Experiment Station Bulletin 235, 1930.

40. Hartig, R. Lehrbuch der Baumkrankheiten. Berlin: Verlag von Julius Springer, 1882.

41. Hartig, R. The Diseases of Trees. London and New York: McMillan and Company, 1894.

42. Hatton, J. H. "A Review of Early Tree Planting Activities in the Plains Region." Possibilities of Shelterbelt Planting in the Plains Region. Washington, D. C.: U. S. Government Printing Office, pp. 51-57, 1935.

43. Hayes, F. A., and J. H. Stoeckeler. "Soil and Forest Relationship of the Shelterbelt Zone." Possibilities of Shelterbelt Planting in the Plains Region. Washington, D. C.: U. S. Government Printing Office, pp. 111-115, 1935.

44. Hopkins, A. D. Catalogue of West Virginia Forest and Shade Tree Insects. West Virginia Agricultural Experiment Station Bulletin 32, 1893.

45. Illick, J. S. Tree Habits. How to Know the Hardwoods. Washington, D. C.: American Nature Association, 1924.

46. Johnson, E. W. Hardy Trees and Shrubs for Western Kansas. Kansas Agricultural Experiment Station Bulletin 270, 1934.

47. Johnson, E. W. "Tree and Shrub Investigation in the Southern Great Plains." Journal of Forestry, Vol. XLIX, No. 10, pp. 716-719, 1951.

48. Johnson, F. R., and F. E. Cobb. Tree Planting in the Great Plains Region. U.S.D.A. Farmers Bulletin 1312, 1923.

49. Keller, J. W. "Shelterbelts in the Great Plains." Soil Conservation, Vol. X, No. 12, pp. 259-263, 1945.

50. Kellog, E. R. "The Shelterbelt Scheme." Journal of Forestry, Vol. XXXII, No. 9, pp. 974-977, 1934.

51. Kneipp, L. F., and A. A. Simpson. "Land Acquisition." Possibilities of Shelterbelt Planting in the Plains Region. Washington, D. C.: U. S. Government Printing Office, pp. 29-33, 1935.

52. Knight, H. H. "Description of Seven New Paracalocoris With Keys to the Nearctic Species and Varieties (Hemiptera, Miridae)." Ann. Ent. Soc. Am. Vol. XIX, No. 4, pp. 367-377, 1926.

53. Knight, H. H. "Notes on the Distribution and Host Plants of Some North American Miridae." Canadian Ent. Vol. LIX, No. 2, pp. 34-44, 1927.

54. Knight, H. H. "The Fourth Paper on New Species of Plagiognathus (Hemiptera, Miridae)." Ent. News, Vol. XL, No. 8, pp. 263-268, 1929.

55. Kotinsky, J. Insects Injurious to Deciduous Shade Trees and Their Control. U.S.D.A. Farmers Bulletin 1169, 1921.

56. Leonard, L. T. "Bacteria Associated With Gleditsia Triacanthos." Trans. Third Comm. Internat. Soc. Soil Sci. Vol. A, pp. 64-70, 1939. Biol. Abstr. 1940, No. 3123.

57. Leonard, M. D. A List of the Insects of New York. New York Agricultural Experiment Station Ithaca Memoir 101, 1928.

58. Miller, J. H., and F. A. Wolf. "A Leaf Spot Disease of Honeylocust Caused By A New Species of Linospora." Mycologia, Vol. XXVIII, pp. 171-180, 1936.

59. Munns, E. N., and J. H. Stoeckeler. "How Are the Great Plains Shelterbelts." Journal of Forestry, Vol. XLIV, No. 4, pp. 237-257, 1946.

60. Munroe, J. A., and H. W. Riddle. Insect Pests of Trees and Gardens. North Dakota Agricultural Experiment Station Circular 42, 1930.

61. Olson, D. S., and J. H. Stoeckeler. "The Proposed Tree Plantations, Their Establishment and Management." Possibilities of Shelterbelt Planting in the Plains Region. Washington, D. C.: U. S. Government Printing Office, pp. 15-27, 1935.

62. Rockwell, F. I. Attractive Farmhouses. Improving the South Dakota Landscape With Trees and Shrubs. South Dakota Agricultural College Extension Circular 412, 1944.

63. Rockwell, F. I. Planting Windbreaks to Survive Drought in South Dakota. South Dakota Agricultural College Extension Circular 397, 1943.

64. Rudolf, P. O., and S. R. Gevorkiantz. "Shelterbelt Experiences in Other Lands." Possibilities of Shelterbelt Planting in the Plains Region. Washington, D. C.: U. S. Government Printing Office, pp. 59-76, 1935.

65. Schedl, K. "Der Forstliche Pflanzenschutz in der Ukraine." Forstarchiv, Vol. XIX, 3/8, pp. 85-95, 1943.

66. Schuder, D. L. "A Mite Infestation of Honeylocust." Journal of Economic Entomology, Vol. XLIII, No. 3, p. 397, 1950.

67. Seeler, E. V. "Thyronectria Denigrata (Winter) Seaver, the Cause of Disease in Gleditsia." Journal of Arnold Arboretum, Vol. XX, No. 1, pp. 114-115, 1939.

68. Seeler, E. V. "Two Diseases of Gleditsia Caused by A Species of Thyronectria." Journal of Arnold Arboretum, Vol. XXI, pp. 405-424, 1940.

69. Stoeckeler, J. H., and C. C. Bates. "The Advantage of Porous Soils for Trees." Journal of Forestry, Vol. XXXVII, No. 3, pp. 205-222, 1939.

70. Stoeckeler, J. H., and R. A. Williams. "Windbreaks and Shelterbelts." Trees, The Yearbook of Agriculture 1949. Washington, D. C.: U. S. Government Printing Office, pp. 191-199.

71. Streets, R. B. Phymatotrichum (Cotton or Texas) Root Rot in Arizona. Arizona Agricultural Experiment Station Technical Bulletin 71, pp. 298-410, 1937.

72. Tubeuf, C. von. "Gaertnerische Kultur der Mistel." Mitt. d. Deutsch. Dendr. Gesellschaft, pp. 188-196, 1917. Zeitschrift fuer Pflanzenkrankheiten, Vol. XXIX, p. 57, 1919.

73. Tubeuf, C. von. "Ueber die Begrenzung der Mistelrassen und die Disposition ihrer Wirtspflanzen." Zeitschrift fuer Pflanzenkrankheiten, Vol. XXVII, pp. 241-263, 1917.

74. U.S.D.A. Forest Service. Forestry for the Great Plains. Washington, D. C.: Prairie States Forestry Project, 1937.

75. U.S.D.A. Soil Conservation Service Northern Great Plains Region. Farm Forestry for the Northern Great Plains. Regional Forestry Division, Region IX, 1946.

76. U.S.D.A. Soil Conservation Service Southern Gulf Region. Tree Windbreaks for the Southern Plains. Fort Worth, Texas: Regional Forestry Division, 1947.

77. U.S.D.A. Soil Conservation Service Southwest Region. Forestry Handbook. Albuquerque, New Mexico: Regional Forestry Division, 1947.

78. U.S.D.A. Southern Great Plains Field Station. Tour Bulletin of Seventeenth Annual Range Improvement Field Day. Woodward, Oklahoma, October 3, 1953.

79. Vyssotsky, G. N. The Role of the Forest in Raising the Yield of Farmland. (U.S.F.S. translation No. 62 from "Lessnoye Khoziaistvo", Moscow, No. 10-11, pp. 19-44, 1929).

80. Vyssotsky, G. N. "Shelterbelts in the Steppes of Russia." Journal of Forestry, Vol. XXXIII, No. 9, pp. 781-789, 1935.

81. Ware, E. R. Planting and Care of Trees in South Dakota. South Dakota Agricultural College Extension Circular 356, 1936.

82. Ware, E. R., and L. F. Smith. Woodlands of Kansas. Kansas Agricultural Experiment Station Bulletin 285, 1939.

83. Weese, J. "Beitraege zur Kenntnis der Hypocreaceen, 1. Mitteilung." Sitzungsbericht Akad. d. Wiss. Wien, Vol. CXXV, No. 1, pp. 465-575, 1916. Zeitschrift fuer Pflanzenkrankheiten, Vol. XXVIII, pp. 187-188, 1918.

84. Wells, H. R. "The Status and Use of Shelterbelts in Western Oklahoma." Oklahoma Crops and Soils 1946. Oklahoma Agricultural Experiment Station Bulletin 295, pp. 104-108, 1946.

85. Werner, H. O. The North Dakota Farmstead, Its Arrangement and Adornment. North Dakota Agricultural College Extension Circular 10, 1916.

86. Wester, H. V., and R. A. St. George. "Live History and Control of the Webworm, Homodaula albizziae." Journal of Economic Entomology, Vol. XL, No. 4, pp. 546-553, 1947.

87. Wilde, S. A. Forest Soils and Forest Growth. Waltham, Massachusetts: Chronica Botanica Company, 1946.

88. Williamson, J. "La acacia negra en La Pampa." Montes (Madrid), Vol. IV, No. 24, pp. 523-525, 1948. Biol. Abstr. 19617, 1949.

89. Wilson, R., and F. E. Cobb. Development of Cooperative Shelterbelt Demonstrations on the Northern Great Plains. U.S.D.A. Bulletin 1113, 1923.

90. Wright, E. "First Progress Report on the Phymatotrichum Root Rot Losses in Experimental Windbreaks of Oklahoma and Texas." U.S.D.A. Plant. Dis. Rpt. 24, pp. 13-20, 1940.

91. Wright, E., and T. W. Bretz. "Shade Trees for the Plains." Trees, The Yearbook of Agriculture. Washington, D. C.: U. S. Government Printing Office, pp. 65-72.

92. Wright, E., and H. P. Wells. "Tests on the Adaptability of Trees and Shrubs to Shelterbelt Planting on Certain Phymatotrichum Root Rot Infested Soils of Oklahoma and Texas." Journal of Forestry, Vol. XLVI, No. 4, pp. 256-263, 1948.

93. Wygant, N. D. "The Relation of Insects to Shelterbelt Plantations in the Great Plains." Journal of Forestry, Vol. XXXVI, No. 10, pp. 1011-1019, 1938.

94. Yeager, A. F. Shelterbelts for North Dakota. North Dakota Agricultural College Extension Circular 43, 1921.

95. Zon, R. "What the Study Discloses." Possibilities of Shelterbelt Planting in the Plains Region. Washington, D. C.: U. S. Government Printing Office, pp. 3-10, 1935.

APPENDIX

APPENDIX A

TABLE I

SUMMARY DATA ON SAMPLE SHELTERBELTS IN CADDO, GREER, AND WASHITA COUNTIES, OKLAHOMA (1954)

Belt	Location				Spacing					Ground Cover		No.
No.	S	T	R	County	Rows	Trees	Orient.	Topogr.	Aspect	Grass	Weeds	Rows
1 a				Washita	10'	8'	NS	level				6
1 b				Washita	10'	8'	NS	level				6
2 a				Washita	8'	8½'	NS	level				16
2 b				Washita	8'	8½'	NS	slight slope	W	10		16
3	SE SW 10	9	18	Washita	3'	3'	EW	slight slope	S	90		9
4 a	S½ SE 3	9	19	Washita	10'	6½'	NS	level				3
4 b	S½ SE 3	9	19	Washita	10'	6½'	NS	level				3
5	SE 3	9	19	Washita	10'	6½'	NS	level				3
6	S 3	9	19	Washita	11'	8'	EW	level				9
7	SE 32	9	20	Washita	12'	10'	NS	10% slope	S	100		2
8 a	SE 30	7	21	Greer	9'	6½'	EW	slight slope	N	50		10
8 b	SE 30	7	21	Greer	9'	6½'	EW	level				11
9	SE 30	7	21	Greer	11'	10'	EW	level		20		10
10	SW 30	7	21	Greer	9'	9'	EW	level				7
11 a	SE 6	4N	21W	Greer	11'	8'	EW	level				9
11 b	SE 6	4N	21W	Greer	11'	8'	EW	level				9
12	NE 7	4N	21W	Greer	10'	6'	EW	level				11
13	NE 29	4	22	Greer	10'	8'	EW	level		90		2
14 a	NE 29	4	22	Greer	10'	8'	EW	level				7
14 b	NE 29	4	22	Greer	10'	8'	EW	level				7
15 a	SW 3	5	21	Greer	11'	10'	EW	level		90		9
15 b	SW 3	5	21	Greer	11'	10'	EW	slight slope	E, W	100		9
16	NW 13	6	21	Greer	4'	3'	EW	level		20	20	7
17	SW 6	6	20	Greer	10'	3'	EW	level				7
18 a	NE 1	6	21	Greer	10'	6'	EW	level				10
18 b	NE 1	6	21	Greer	10'	6'	EW	level				8
18 c	NE 1	6	21	Greer	10'	3'	EW	level				8

TABLE I--Continued

Belt No.	Location				County	Spacing		Orient.	Topogr.	Aspect	Ground Cover		No. Rows
		S	T	R		Rows	Trees				Grass	Weeds	
19	S½	26	7	21	Greer	5½'	5½'	EW	level				17
20 a	NE	19	7	21	Greer	10'	8½'	EW	slight slope	E, S			13
20 b	NE	19	7	21	Greer	10'	8½'	EW	level				11
21	SW	26	5	22	Greer	10½'	6'	EW	level				10
22	SW	10	5	22	Greer	10'	8'	NS	level		100		2
23	W	10	5	22	Greer	9'	7½'	EW	level		100		15
24						10'	8'	EW	level				15
25						9'	8'	NS	level				16
26	NE	5	7	14	Caddo	10'	8'	EW	level		100		10
27 a	NW	2	7	12	Caddo	10'	9'	EW	level		20	180	10
27 b	NW	2	7	12	Caddo	9'	8'	EW	level				10
28	SW	36	8	12	Caddo			EW	level				10
29		13	8	12	Caddo	10'	7'	EW	level		90		9
30	NE	24	8	12	Caddo	10'	6'	NS	level		40	40	3
31	SE	21	7	12	Caddo	10'	6'	NS	level		90		3
32	NE	3	7	12	Caddo	9'	8'	EW	level		40	10	10
33	SW	25	8	13	Caddo	9'	8'	NS	level		100		3
34	SW	1	8	13	Caddo	9'	7'	EW	level		30	10	10
35	NE	10	8	13	Caddo	10'	8'	EW	level		100		10
36	SW	10	8	13	Caddo	9'	8'	NS	level		100		2
37	SW	10	8	13	Caddo			EW	level		100		10
38		4	8	13	Caddo	10'	8'	EW	level		60	40	10
39		32	8	10	Caddo	10'	8'	NS	level			50	3
40 a		5	8	10	Caddo	10'	8'	EW	slight slope	S, W	90		8
40 b		5	8	10	Caddo	10'	8'	EW	moderate slope	S, SW, SE	100		8
41	SW	31	8	10	Caddo			NS	moderate slope				2

TABLE I--Continued

Belt No.	Location S	T	R	County	Spacing Rows	Trees	Orient.	Topogr.	Aspect	Ground Cover Grass	Weeds	No. Rows
42	18	8	10	Caddo			EW	moderate slope		90		9
43	SW 27	6	11	Caddo			EW	moderate slope		80		10
44				Caddo	10'	8'	EW	moderate slope		20		9
45	NW 27	6	11	Caddo	10'	5'	NS	moderate slope				3
46				Caddo			NS	moderate slope				3
47				Caddo			NS	moderate slope				3
48				Caddo			EW	moderate slope				10
49 a	SE 18	6	11	Caddo	10'	6'	EW	moderate slope				10
49 b	SE 18	6	11	Caddo	10'	6'	EW	moderate slope				10
50	24	8	12	Caddo	9'	6½'		moderate slope		90		6

TABLE II

GENERAL INFORMATION ON THE VISITED SHELTERBELTS IN SOUTHWEST OKLAHOMA

Belt No.	Percent Average Mortality	Honeylocust No. Rows	Honeylocust Mortality	Honeylocust Bordered By S or E	Mortality	Honeylocust Bordered By N or W	Mortality
1	33	4	100	cottonwood	100	red cedar	
		5	0				
1 b	18	4	0	cottonwood		red cedar	
		5	0				
2 a		6	71	hackberry	20	cottonwood	
		9	13	cottonwood		mixed	30
2 b	30	7	11	hackberry	10	maple	20
		10	10	maple	30	mixed	30
3		5	95			osage orange	40
4 a	30	1	90			cottonwood	
4 b	7	1	20			cottonwood	
5	4	1	2			cottonwood	5
6	28	6	5	black locust	10	cottonwood	30
7	100	1	100				
		2	100				
8 a	42	5	95	black walnut	30	Siberian elm	
8 b		4	no evidence	mulberry			60
		5	0				
		6	0				
9	28	3	no evidence	black locust	100	Siberian elm	
		4	0				
		5	0				
10	29	3	10	osage orange	5	black locust	90
11	26	2	0	cottonwood	70	black locust	20
		5	0	black locust		black walnut	60
11 b	36	2	80	cottonwood	100	black locust	20

TABLE II—Continued

Belt No.	Percent Average Mortality	Honeylocust No. Rows	Honeylocust Mortality	Honeylocust Bordered By: S or E	Mortality	N or W	Mortality
		5	0	black locust		black walnut	60
12	37	5	0	black locust	70	blacl locust	
		8	0	black locust	20		
		9	no evidence				
13	75	1	75				
		2	75				
14 a	55	4	30	cottonwood	100	hackberry	100
		5	30				
14 b	23	4	0	cottonwood	20	hackberry	50
		5	0				
15 a	34	4	0	Siberian elm	50	hackberry	90
		6	5	hackberry	90	black locust	10
15 b	90	4	100	no evidence	100	no evidence	100
		6	100	no evidence	100	no evidence	100
16	48	5	0	cottonwood	80	catalpa	90
17	6	4	0	cottonwood	15	catalpa	0
18 a	30	4	10	cottonwood	50	black locust	0
18 b	48	5	0	cottonwood	90	black locust	0
18 c	4	5	0	cottonwood	10	black locust	0
19		13	0	black locust		pine	100
20 a	18	5	0	American elm	25	cottonwood	40
		8	30	Siberian elm	0	osage orange	40
20 b	22	5	0	American elm	30	cottonwood	70
		8	0	Siberian elm	0	osage orange	30
21	14	4	65	Siberian elm	0	Siberian elm	0
22	20	2	10	black locust	30		
23	56	7	10	mulberry	90	Siberian elm	30
		10	0	no evidence	100	osage orange	20

TABLE II—Continued

Belt No.	Percent Average Mortality	Honeylocust No. Rows	Honeylocust Mortality	Honeylocust Bordered By S or E	Mortality	Honeylocust Bordered By N or W	Mortality
24	25	7	20	mulberry	0	cottonwood	20
		10	10	Siberian elm	0	osage orange	0
25	28	7	20	osage orange	10	Siberian elm	10
		10	10	cottonwood	25	American elm	60
26	63	4	95	osage orange	10	Siberian elm	95
		6	100	Siberian elm	95	ailanthus	95
		9	100	Siberian elm	95	osage orange	0
27 a	47	5	30	Siberian elm	30	hackberry	10
27 b		6	0	hackberry	5	black locust	30
28	25	6	5	hackberry	20	black locust	20
29	57	6	10	hackberry	90	black locust	95
30	30	2	0	mulberry	60	desert willow	30
31	20	2	10	Siberian elm	10	desert willow	30
32	50	6	10	Siberian elm	70	mulberry	90
33	23	2	30	Siberian elm	40	osage orange	0
34	33	4	0	cottonwood	90	black locust	50
35	47	6	10	hackberry	15	Siberian elm	100
		9	20	Siberian elm	100	osage orange	0
36	35	2	35	Siberian elm	35		
37	82	6	100	Siberian elm	100	no evidence	100
		9	95		100	osage orange	20
38		3	60	cottonwood	95	black locust	
		4	45				
39	2	2	0	Siberian elm	5	osage orange	0
40 a	70	5	10	cottonwood	90	black locust	100
40 b	82	5	60	black locust	90	black locust	100
41	0	2	0	Siberian elm	0		
42	54	6	10	no evidence	100	black locust	50

TABLE II—Continued

Belt No.	Percent Average Mortality	Honeylocust No. Rows	Honeylocust Mortality	Honeylocust Bordered By S or E	Mortality	N or W	Mortality
43	41	6	20	hackberry	0	Siberian elm	100
		8	50	Siberian elm	100	Siberian elm	40
44	30	8	30	cottonwood	30	mulberry	20
45	7	2	10	Siberian elm	0	osage orange	10
46							
47	0						
48	20	6	5	Siberian elm	0	cottonwood	50
		9	0	cottonwood	50	mulberry	0
49 a	21	6	0	green ash	0	cottonwood	40
49 b	27	6	100	green ash	0	cottonwood	0
50	58	3	100	Siberian elm	80	black locust	30

TABLE III

SOIL TEXTURE DATA IN SAMPLE SHELTERBELTS OF CADDO, WASHITA, AND GREER COUNTIES, OKLAHOMA

								Honeylocust	
Lot No.	Depth Inch.	Soil Color	Hue	Percent Sand	Percent Silt	Percent Clay	Average Mortality Percent	Mortality Percent	Behavior
5	20	dark reddish brown	5YR 3/4	40.00	39.50	20.50	5	2	very good
	40	dark reddish brown	5YR 3/4	65.50	14.50	20.00			
	62	reddish brown	5YR 4/3	39.00	32.00	29.00			
6	20	dark reddish brown	5YR 3/4	44.00	39.50	16.50	28	5	good
	40	reddish brown	5YR 4/4	49.00	23.75	28.25			
	50	dark reddish gray	5YR 4/2	28.50	31.00	40.50			
	60	yellowish red	5YR 4/6	79.00	11.00	10.00			
7	20	dark reddish brown	2 5YR 3/4	59.50	22.50	18.00	100	100	very poor
	39	red	2 5YR 5/6	51.50	22.00	26.50			
8 a	72	yellowish red	5YR 5/6	77.00	7.50	15.50	93	95	very poor
9	12	reddish brown	5YR 5/3	87.00	6.50	6.50	28	0	good
	48	pinkish gray	5YR 6/2	22.50	33.50	44.00			
11 a	26	dark reddish brown	5YR 3/3	59.25	18.25	22.50	26	0	good
	46	reddish brown	5YR 4/4	54.00	19.00	27.00			
	72	red	2 5YR 4/6	49.00	30.00	21.00			
12	12	brown	7 5YR 5/4	90.50	8.00	1.50	37	0	very good
	36-72	reddish brown	5YR 5/3	33.50	16.00	50.50			
14 a	48	light reddish brown	5YR 6/5	77.75	20.00	2.25	55	30	poor
14 b	12	reddish brown	5YR 4/3	57.00	31.50	11.50	23	0	good

TABLE III—Continued

Lot No.	Depth Inch.	Soil Color	Hue	Percent Sand	Percent Silt	Percent Clay	Average Mortality Percent	Honeylocust Mortality Percent	Honeylocust Behavior
	48	light reddish brown	5YR 6/5	76.25	20.25	3.50			
15 a	12	dark reddish brown	5YR 3/3	77.00	13.00	10.00	34	2.5	good
	35	reddish brown	5YR 4/4	78.75	10.25	11.00			
	72	yellowish red	5YR 4/6	85.50	5.00	9.50			
15 b	10	dark reddish brown	5YR 3/4	32.00	32.50	35.50	90	100	very poor
	18	dark red	2 5YR 3/6	27.00	30.00	43.00			
18 a	28			64.75	19.25	16.00	30	10	fair
	72	reddish brown	5YR 5/4	82.00	5.50	12.50			
18 c	12			87.25	8.75	4.00	4	0	good
	20	red	2 5YR 4/6	79.50	5.75	14.75			
	72	yellowish red	5YR 5/6	58.50	25.75	15.75			
19	10	reddish brown	5YR 5/4	92.00	3.00	5.00	no evidence	0	good
	18	red to dark red	2 5YR 4/6-3/6	80.00	6.50	13.50			
	50	yellowish red	5YR 5/6	71.00	12.75	16.25			
	72	reddish yellow	7 5YR 6/6	65.00	11.75	23.25			
20 a	10	reddish brown	5YR 4/3	81.00	13.00	6.00	18	15	fair
	22	dark reddish brown	5YR 3/4	70.00	10.00	20.00			
	40	reddish brown	5YR 4/4	86.00	7.00	7.00			
	60	reddish brown	5YR 4/4	65.00	12.75	22.25			
22	12	dark reddish brown	5YR 3/3	72.75	17.75	10.00	20	10	poor
	20	dark reddish brown	5YR 3/3	49.50	28.00	22.50			

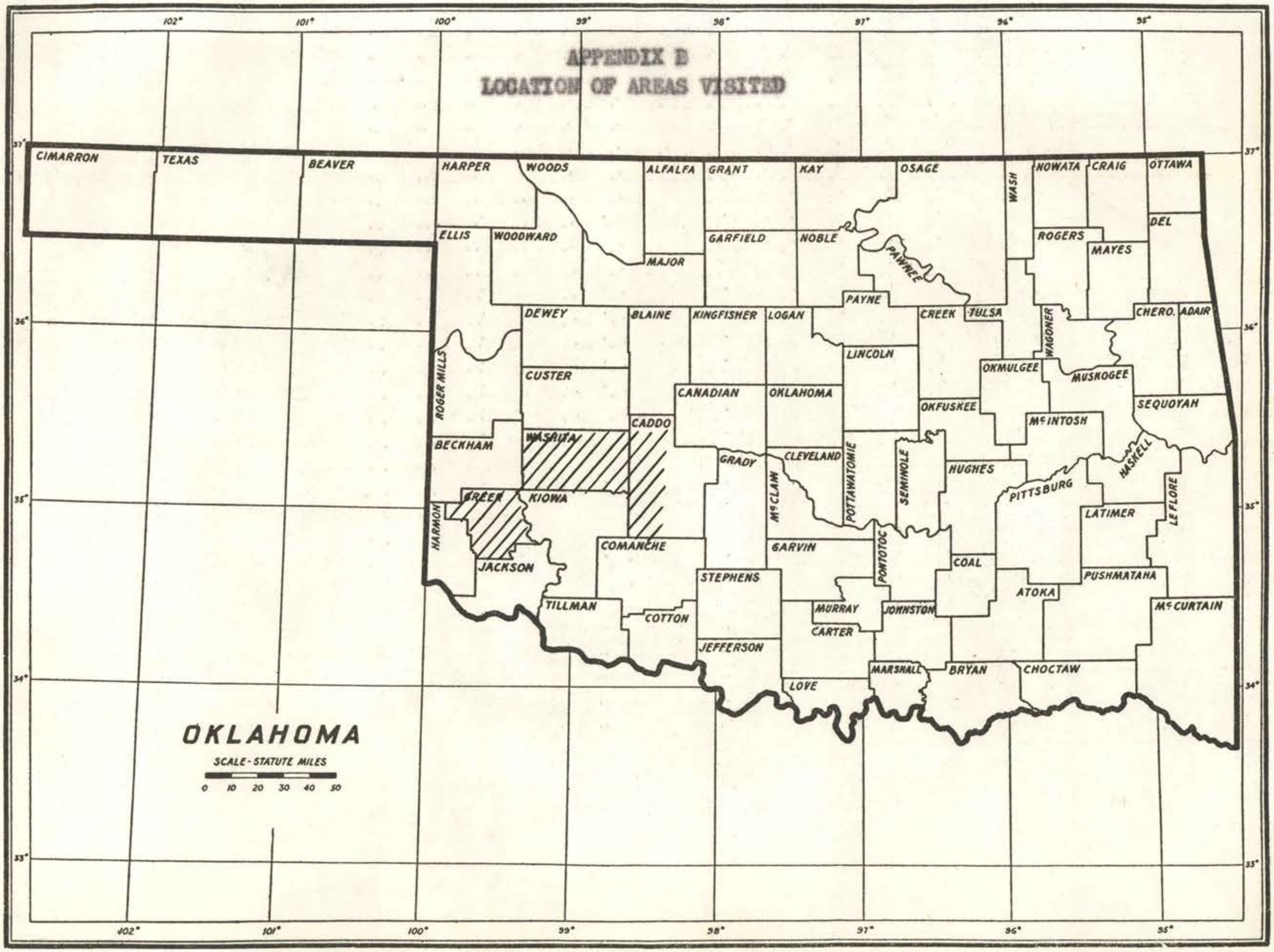
TABLE III--Continued

Lot No.	Depth Inch.	Soil Color	Hue	Percent Sand	Percent Silt	Percent Clay	Average Mortality Percent	Honeylocust Mortality Percent	Honeylocust Behavior
	28	dark reddish brown	5YR 3/4	32.50	32.50	35.25			
27 a	10	reddish brown to yellowish red	5YR 5/5	92.50	6.50	1.00	47	30	good
	30	reddish brown	5YR 4/3	54.00	21.50	24.50			
32	25	reddish brown	5YR 4/4	53.00	19.50	27.50	50	10	fair
	41	yellowish red	5YR 4/6	59.00	19.25	21.75			
34	14	reddish brown	5YR 4/3	80.00	8.50	11.50	33	0	fair
	41	gray brown	10YR 5/2	41.50	32.00	26.50			
36	7	reddish brown	5YR 4/3	37.00	37.50	25.50	35	35	poor
	33	dark reddish dark reddish brown	5YR 4/2 to 5YR 3/2	26.00	35.50	38.50			
37	10	reddish brown	5YR 4/3	36.50	35.25	28.25	82	100	very poor
	41	reddish brown to yellowish red	5YR 4/5	31.50	34.50	34.00			
38	9	reddish brown	5YR 4/4	78.50	8.00	13.50	no evidence	55	very poor
	41	dark red	2 5YR 3/6	76.50	5.50	18.00			
39	11	reddish brown	5YR 4/3	84.50	10.00	5.50	2	0	good
	22	reddish brown	5YR 4/4	6.800	11.00	21.00			
	34	yellowish red	5YR 4/6	76.75	8.75	14.50			
	72	reddish yellow	5YR 6/8	79.00	10.50	10.50			
40 a	9	reddish brown	5YR 4/3	82.00	9.50	8.50	70	10	fair
	25	yellowish red	5YR 4/6	64.50	15.50	20.00			
	42	yellowish red	5YR 5/6	65.00	19.50	12.50			

TABLE III--Continued

Lot No.	Depth Inch.	Soil Color	Hue	Percent Sand	Percent Silt	Percent Clay	Average Mortality Percent	Honeylocust Mortality Percent	Honeylocust Behavior
	72	yellowish red to reddish yellow	5YR 5/6 to 5YR 6/6	66.50	19.50	14.00			
40 b	11	dark red	2 5YR 3/6	63.00	14.00	23.00	82	60	poor
	25	red	2 5YR 4/8	57.50	14.00	28.50			
	37	red	2 5YR 4/8	63.00	17.00	20.00			
	50	red	2 5YR 5/8	65.50	21.50	15.00			
43	10	reddish brown	5YR 4/4	56.50	29.50	14.00	41	35	fair
	76	red	2 5YR 5/8	26.00	48.00	26.00			
48	9	dark reddish gray	5YR 4/2	60.00	24.50	15.50	20	2.5	very good
	72	reddish yellow to yellowish red	5YR 6/8 to 5YR 5/8	67.75	19.75	12.50			
49 a	10	reddish brown to dark reddish brown	5YR 4/4 to 5YR 3/4	64.25	12.25	23.50	21	0	very good
	20	reddish brown	5YR 4/4	64.00	15.50	20.50			
	36	yellowish red	5YR 5/8	77.50	9.00	13.50			
	72	reddish yellow	5YR 6/8	86.00	4.75	9.25			
49 b	10	brown	7 5YR 5/4	76.75	12.25	11.00	27	100	
	20	yellowish red	5YR 4/6	77.50	8.00	14.50			
	60	reddish yellow	5YR 6/8	92.00	3.00	5.00			

APPENDIX B
LOCATION OF AREAS VISITED



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VITA

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