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Urban Land Rehabilitation Using Fast Growing Black Locust

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Charleen Marie Buncic

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URBAN LAND REHABILITATION USING FAST GROWING BLACK LOCUST TREES

By

Charleen Marie Buncic

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

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1994

ABSTRACT

URBAN LAND REHABILITATION USING FAST GROWING BLACK LOCUST TREES

By

Charleen Marie Buncic

Detroit spends more than two million dollars annually maintaining approximately 60,000 vacant lots that it owns. It is an economically depressed city with limited funds for environmental projects. This thesis explores the success of black locust on vacant urban land, and its suitably for use in urban land rehabilitation/vacant lot renewal.

The effects of soil compaction on tree performance was evaluated using a penetrometer. No relationship was found between tree performance and the degree of soil compaction. Direct seeding was evaluated as a possible reclamation method, but its suitability was unable to be determined through this study. Fall planting of containerized seedlings was also evaluated. Black locust planted at later times during the fall had better survival and growth.

For Greg

I am grateful that we have met
in our journey through this life.
Never forget me, for I
will always love you.

ACKNOWLEDGMENTS

I am deeply grateful for the opportunity provided to me by my former advisor, the late Dr. James Hanover. When I needed guidance and support he was there. When I was feeling hopeless, he provided the encouragement to continue with this project. Dr. Hanover was a very special person and he is sadly missed.

To Dr. J. James Kielbaso, thank you for taking on the advisory role after Dr. Hanover's death; I know that it was difficult. For making me laugh when I needed it most, and for your many efforts, your support and encouragement, I thank you.

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For my family who has always supported me; I love you.

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CHAPTER I

INTRODUCTION

THE PROBLEM

Detroit is a large city with a population of 1,027,974 that has many poverty-stricken areas. According to 1989 national census data, the average poverty threshold for a four-person household was $12,674. In 1989, there were more than 143,936 households in Detroit living below the poverty threshold (Bureau of Census, 1990). Monies for urban renewal have been limited, and hopes of receiving funding for projects aimed at environmental enhancement are small. The city currently has approximately 65,000 vacant lots. In accordance with city ordinances for vegetation management on public lands, the lots must be maintained. This is accomplished by mowing them two to three times during the summer months, costing the city more than two million dollars each year (verbal communication with Detroit Department of Public Works). This research was conducted to ascertain some economically feasible alternatives for vacant lot renewal.

OBJECTIVES

The goal of this study was to determine, through several research experiments, the performance of black locust (*Robinia pseudoacacia* L.) trees under urban conditions at a site in Detroit, Michigan. Black locust was chosen because it is a low maintenance species that is able to tolerate weather extremes, such as heat and drought. It grows rapidly, and competes with grasses and weeds, thereby reducing the amount of required maintenance on the vacant land, and money invested by the city. Currently, there is a considerable amount of research being conducted on the multiple uses of black locust. Black locust was chosen to explore its performance under urban conditions.

A compaction study investigated the effect that soil compaction had on the survival and growth of black locust. A direct seeding study evaluated the plausibility of direct seeded black locust. A fall planting time study investigated the best time during the fall season to plant black locust seedlings. A compost study explored the effect of the surface application of compost on the performance of black locust.

TEXT PREVIEW

The characteristics of urban soils and their impact on tree growth will be described in the literature review. Applications for future research and potential vacant lot renewal projects for the city will be proposed in the concluding chapter of this thesis.

Chapter Two contains a literature review on urban soils and their management for planting. Chapter Three provides background information on the project. Chapter Four details a compaction study that looked at the effects of soil compaction on tree growth. Chapter Five focuses on a direct seeding study that determined the success of direct seeded black locust on an urban site. Chapter Six discusses a fall planting study which tested the best time during the fall season to plant black locust. Chapter Seven briefly discusses an additional study which failed to yield reliable results. It has been presented in this thesis for the purpose of documentation. Chapter Eight will summarize all research activities and findings, and present recommendations for Detroit.

PROJECT LIMITATIONS

Anyone conducting research in the urban area should be aware of possible circumstances that they may encounter. Dealing with city politics and bureaucracy will most likely be an issue. Other considerations to be aware of are vandalism, limited funding, quality of materials, level of maintenance and infrequent site visitation which are directly related to project support. Project limitations will become evident throughout this thesis.

CHAPTER II

LITERATURE REVIEW

URBAN SOILS

URBAN SOILS

"Drastically disturbed urban soils are those in which human activities have dominated the soil-forming process" (Short, 1990, p.229). High bulk density, lithologic variation and variable organic matter content are some of the unique characteristics of these soils (Short, 1990).

The ecological environment of an urban area varies tremendously from one site to the next, and is quite different from the ecology of areas outside of a city. Urban ecological factors impacting plant life include: "fifteen to twenty percent less solar radiation, 0.5 to 1.5 degrees Celsius higher mean temperatures, ten to twenty percent less wind speed, two to ten percent less relative humidity, five to ten percent more clouds and five to ten percent more total rainfall" (Craul, 1990, p. 219).

Not only do the atmosphere and plant growth factors differ in the urban setting, but soils, something often neglected when planning for "urban reforestation", also differ, perhaps even more (Craul, 1992). Urban soils are distinct from other soils because they often are completely disrupted by construction and urbanization and they no longer function in a natural way. Urban soils usually have one or more layers about fifty centimeters thick comprised of fill material that often contains contaminants (some of which may be toxic), at levels higher than found in natural, undisturbed soils. This "soil" is a result of construction activities, e.g., mixing, filling, scraping, compaction, and pulverization. In addition to these problems faced by the urban forester, is the scarcity of information pertaining to urban soils and their management. In many urban areas, there is a lack of soil survey data, making soil assessment difficult because there is no information on the original soil conditions (i.e., topography, depth of water table, parent material, depth to bedrock, etc.) (Craul, 1992). Creating a taxonomic system for classifying urban soils has been extremely difficult. The extent of spatial and vertical variability, because of disturbance, makes it difficult to gain an understanding and knowledge of the pedogenic processes which played a role in original soil formation. It takes many years for pedogenic processes to result in profile evolution in disturbed soils. This difficulty in classification and mapping of urban soils was best summarized by Indorante et al. (1984):

> "Pedologists have been slow to define and separate different soils within disturbed land areas because these soils seem inherently too variable; mappable patterns of order were not apparent. The soil genesis model does little to help one perceive spatial order. The time is so short that the active factors of soil formation have had little effect. Lacking an applicable conceptual model, one commonly finds the apparent complexity overwhelming, and fails to perceive order" (In Craul, 1992, p.116).

The District of Columbia Soil Survey has listed a dozen soil associations for urban areas. Two of those associations seem applicable to the majority of Detroit's urban area. Those associations are the "Urban Land Association" and the "Udorthents Association". The Urban Land association is described as "nearly level to moderate sloping areas, most of which are built up and occupied by structures and works; on all landscape positions" (Smith, 1976, p. 9). The Udorthents association is described as "deep to moderately deep, nearly level to steep, well drained soils that consist of cuts, fills, or otherwise disturbed land; on all landscape positions" (Smith, 1976, p. 8). It is possible, with the soil taxonomic system developed thus far, to infer general characteristics of an urban soil. A detailed system has yet to be developed, and may take years to do so.

Common characteristics of urban soils, include "a high degree of vertical and spatial variability, a loss of structure leading to a tendency towards compaction, poor aeration status and generally impeded drainage, presence of a hydrophobic crust on the bare surface, elevated soil reaction (pH), increased temperatures, interrupted cycling of nutrients and organic matter, and the presence of anthropeic (human-made) contaminants and toxic substances" (Craul, 1990).

Vertical variability is characterized by abrupt changes, both chemical and physical, as the soil deepens. The layers may differ in structure, texture, bulk density, nutrients, and pH. Differences in these soil properties can lead to altered aeration, drainage, fertility, and water-holding capacity of the soil. Drastic differences in the soil layers can create a microsite that may not be suitable for plant growth (Craul,1985).

Added to the complexities of vertical variability, is spatial variability. Spatial variability is characterized by horizontal differences that are caused by earlier construction activities that can leave one site very different from another, despite their close proximity (Craul, 1986).

Because natural soil forming processes are lacking in urban soils, they easily become compacted. Urban conditions (such as history of being disturbed, low organic matter content, heavy amounts of surface traffic, infrequency of the structure-enhancing cycles of freezing-thawing/wetting-drying, and low amounts of vegetation), all lead to the destruction of soil structure, rendering them easily compacted (Craul, 1985).

Compaction of the soil impacts the physical, chemical and biological properties of the soil. The extent to which compaction occurs depends on the soil structure, texture, organic matter content, and soil moisture content at the time of the applied force (foot traffic, wheel traffic, and vibrational forces). Soil conditions that lead to compaction are organic matter content, degree of aggregation, moisture content, number of soil layers to which force is being applied and the energy of that force, and compression that has already occurred (Zimmerman et al, 1961). Organic matter can add structure to a soil and aid in reducing compaction. Applied to the surface, organic matter will distribute compactive forces and prevent further compaction. Surface application of organic matter will, after time, decrease the degree of compaction by increasing microorganism activity and enhancing the freezing/thawing cycles. The most efficient way of using organic matter for quicker compaction reduction, is to incorporate it into the soil (Craul, 1992).

Some of the physical changes resulting from compaction are a reduction in pore space, a shift in the distribution of pore sizes, decreased infiltration, and decreased aeration. Because soil particles are closer in compacted soils, there are greater heat conducting capabilities, resulting in longer periods of time in which the soil is cool or warm. The reduction in total pore space creates lower water holding capacity of the soil making less water available to the plant and increasing surface runoff (because of reduced infiltration) (Craul, 1990).

The changes associated with compaction (total pore space and distribution of pore sizes) results in overall changes in the soil which can affect tree performance (Zisa, et al., 1980). Compacted soils cause impeded water drainage and infiltration, decreased aeration, and restricted root growth. Because roots tend to be shorter and thicker and with more lateral branching when grown in compacted soils, there is an increase in the surface area of the root that is present at shallower soil depths, increasing the amount of drought stress (Pittenger and Stamen, 1990).

Soil compaction has a large impact on tree performance because it leads to a decrease in root growth. Because most root growth occurs within the upper thirty inches or less of the soil profile, compaction in this zone is detrimental. Root systems become stunted in dense soils, proportional to the degree of compaction. Roots tend to occupy areas where there is the least resistance, usually towards the surface. This increases the risk associated with drought and windthrow.

Windthrow occurs when trees are shallow rooted making them susceptible to falling during periods of high wind speed. Because of the mechanical impedance faced by the roots, they are unable to penetrate into areas where nutrients are available. As a result, the areas that the roots occupy become depleted in nutrients. The lack of aeration changes the chemical composition of the nutrients, making them less available to the plant. The loss of pore space commonly restricts, and sometimes completely inhibits root penetration through the soil (Craul, 1986).

Limited moisture and aeration also negatively impact the nitrifying processes normally present in soils. Anaerobic conditions created by poor drainage and poor aeration lead to the formation of toxic gases in the soil atmosphere. Gases such as methane, hydrogen sulfide, ethane, nitrous oxide, esters, alcohols, and fatty acids all have harmful effects on soil organisms and plants (Craul, 1985). Inadequate gaseous diffusion results from impeded water drainage which is a result of the loss of total pore space. If macropores become destroyed in a compacted soil, the density of the soil increases with the loss of total pore space. In this situation, the pores usually remain water-filled, leading to slow water movement through the soil, which then leads to anoxia. Anoxic conditions induce reducing reactions, resulting in a soil atmosphere with high, sometimes harmful, levels of carbon dioxide. If a portion of a soil profile does not have sufficient pore space for proper water drainage, the entire profile will be poorly drained. Drainage of the entire soil profile is dependent upon the least permeable layer. The presence of concrete or asphalt, (buried or on the surface), also creates the same results; i.e., a reduction in aeration and drainage (Craul, 1986).

Heavy foot and wheel traffic lead to the destruction of vegetation, compaction and surface crusting of the soil (Craul, 1985). This crust acts as a barrier to the diffusion of gases and the infiltration of water. These crusts can also be water-repellent as a result of the deposition of hydrocarbons which are present in the atmosphere (Craul, 1986). The lack of aeration also leads to a decrease in the decomposition rate of organic matter, which could also lead to the formation of toxic by-products (like fatty acids, methane, nitrous oxide, etc.).

Increased soil alkalinity (pH) is also common in urban soils. The increase in pH is due to three things: 1) exposure of parent material (personal contact with Dr. Boyd Ellis, 1993), 2) the building rubble (e.g., masonry, plaster, cement, etc.) present in the ground releases calcium, and 3) the calcium solutions that are washed from building facades into the soil. The use of de-icing compounds at the site or at the soil originating site, may also contribute to elevated pH. In urban soils, pH values as low as 3.0 and as elevated as 9.0 have been reported (Craul, 1985).

Urban environments are characterized by buildings with reflective surfaces, concrete and asphalt, which reradiate heat. "Heat islands" are common phenomena in urban areas. Heat islands are areas in which there is an increase in ambient temperatures. The combination of an increase in the amount of roads and buildings with a decrease in overall vegetation, results in a heat island with increased temperatures in the urban core of ten or more degrees Celsius. Heat islands also slow surface winds. This further exacerbates pollution problems because pollutant dispersal and ventilation is reduced (Cardelino and Chameides, 1990). This increase in the ambient temperature in such environments results in the following stresses on vegetation: A) soil temperature becomes elevated, causing an increase in the amount of water required by plants, B) metabolism is increased and growing period is extended, which creates disproportional root to shoot ratios, C) the rate of organic matter decomposition increases and root growth can extend into the early winter, leading to improper hardening off of the plants (Craul, 1986). Although the sites in this study were grassy (and relatively distant from buildings and excessive pavement), they still experience elevated temperatures relative to areas outside the city. Even grassy urban areas, the coolest of urban settings, have temperatures that are elevated relative to those temperatures found in a forest floor (Craul, 1985).

Nutrient cycling and microorganism activity are severely disturbed in urban soils. It is difficult for urban soils to support a healthy and balanced soil organism population. The organic matter which helps to maintain healthy and active microorganism populations is low in urban soils. Soil organisms do not thrive in these soils because there is not enough organic matter (i.e., food) to support their populations. Often, soil organism mobility is inhibited, making it difficult for them to obtain food. Even the larger organisms, such as earthworms, (which aid in soil formation, by helping to decrease the degree of soil aggregation, and nutrient cycling), are not able to survive in many urban soils. Because soil formation processes are almost non-existent in urban soils, this process of nutrient contribution does not exist, resulting in a nutrient deficient soil. Although weathering of building facades and rubble in the soil add some nutrients/ions to the soil, the ion balance is usually a problem (Craul, 1985).

Urban soils commonly contain buried rubble (masonry, plaster, cement, etc.), toxic residues, nutrient deficiencies, and are compacted (Cohen, 1986). Typical anthropeic materials found in urban soils are cement/concrete, rubble, bricks, asphalt, metal, wood, plastic, glass, rubber and other anthropogenic materials, as well as chemical contaminants like residual pesticides, heavy metals, and hydrocarbons (Craul, 1990). The presence of these foreign materials have an effect on the soil physical, chemical, and biological properties, which in turn affects plant survival. In addition, anthropeic matter in the form of chemical contaminants add stress. By-products from the decomposition of contaminants, as well as the contaminants themselves, can be detrimental or toxic to soil organisms or the plant. Contaminants show their effect by either being directly toxic to an organism or they may interfere with nutrient uptake and cycling which eventually leads to an unhealthy organism and perhaps death (Craul, 1985).

MANAGING URBAN SOILS FOR PLANTINGS

Planners should aim for sustainable and low management plantings that will be feasible and accepted by the users (i.e., city, community,). The actual methodology for assessing the site depends upon the site and the project, as well as project objectives in conjunction with the future users and the actual area that will be directly influenced by the project. Certain details need to be taken into consideration.

Accurate climatological data from the site can only be obtained by collecting measurements from the site. Information from the local weather bureau is usually generalized data, and may not be accurate for the site, especially given heat islands and the variations found in an urban environment. When assessing an urban site for planting, it is important to pay special attention to the soils and to involve an urban soil scientist.

The soil plays a major role in plant performance, and is often neglected. Consideration should be given to the soil series, structure, texture, water holding capacity, etc. Soil surveys should be reviewed thoroughly, if they are available. As mentioned earlier in this Chapter, many urban areas were already established before the soils were surveyed, rendering information on original soil conditions unavailable. Regardless of whether or not soil surveys are available, soil analyses should be conducted, to gain information on soil conditions at the time of project implementation. The soils should be analyzed for properties such as nutrient content and availability, micronutrient content and availability, alkalinity, contaminants (especially if there are suspect areas), organic matter content, soil strength/compaction, and water holding capacity. Soil analysis must be conducted prior to project implementation.

Biological amendments are useful in enhancing the soil structure and aiding in microfauna populations - mycorrhizae are especially important in aiding rooting and root performance. Amendments to consider for surface application or incorporation are mulches, fly ash, expanded clays, slate, shale, or pumice (Craul, 1992).

Heavily compacted soils could benefit from inducing surface aeration. There are several methods currently in use to increase aeration; these are soil replacement, deep plowing, deep water jetting or air injection, and running tines over the soil. Unfortunately, these methods are costly, and the effects only temporary (Craul, 1992). Sometimes, the method itself creates more compaction further down in the soil profile.

Planting species amenable to a site is important. Unfortunately, this is often not done, resulting in heavy losses (financial and biological). There are several species which are tolerant of compacted soils. These species could be studied on a site to assess their performance and create records for future suggestions.

After careful planning and hard work, it would be sensible to protect the project as much as possible from vandals and curious individuals. Proper site management and site regulation will aid in project success and acceptance.

CHAPTER III

PROJECT BACKGROUND

BLACK LOCUST

In 1990, the late Dr. James W. Hanover of Michigan State University submitted a proposal to Detroit for urban lot rehabilitation using black locust trees. It was proposed that by planting black locust trees at high densities, the need for vacant lot mowing could be eliminated. Because black locust is a fast growing tree species, the canopy would quickly close and suppress weed growth.

Black locust (*Robinia pseudoacacia* L.) is a nitrogen-fixing tree species native to the southeastern United States but widely planted in all states in the U.S., in Canada and throughout the world. A map for the natural range of black locust is shown in Figure 1. It has been planted far beyond its natural range.

The species can be used for many purposes, including lumber, poles, fence posts, pulp because of it excellent decay resistant property. It is also commonly used for fuel, land reclamation, beekeeping, animal fodder, wildlife habitat, barriers and screening (Ashby, et al., 1985). It has one of the highest growth rates for a plant species in North America. Height growth of up to two-and-a-half meters in one growing season without irrigation or fertilization has been observed in the nursery (Hanover, 1989).

Black locust has been widely planted in the United States because of its ability to tolerate extreme environmental conditions, such as droughts, and infertile and acidic soils. It therefore grows well on mine spoils where the subsoil is infertile and where few species will grow.

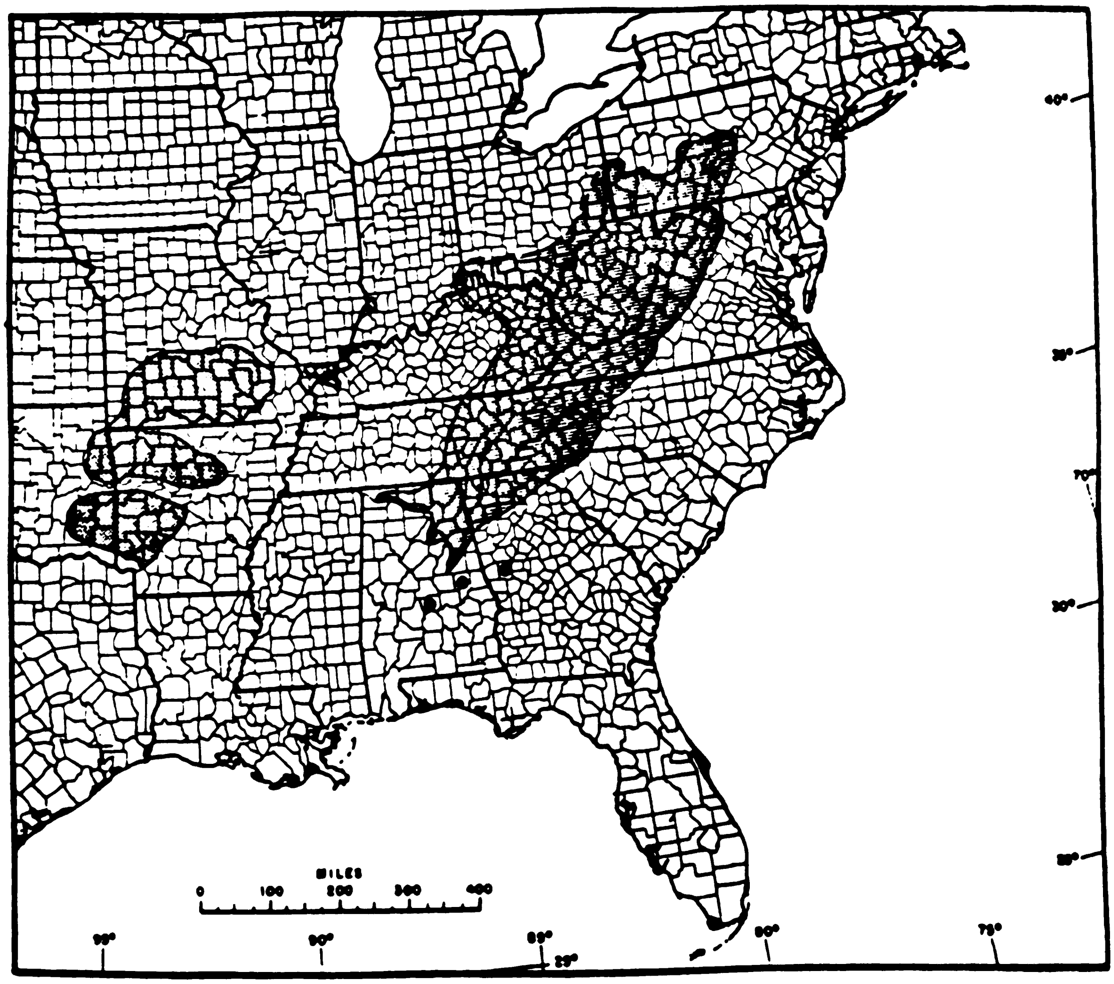

Figure 1. Natural Range of Black Locust (Fowells, 1965, p. 642).

Black locust is able to occupy and stabilize unproductive sites partly because of its nitrogen (N_2) fixing ability; a process where a symbiotic relationship is created between the tree and a bacterium (*Rhizobium sp.*). While the tree supplies nutrients to the bacterium, it in return receives nitrogen (N_2 from the atmosphere) that has been fixed into a useable form for the plant, by the bacterium. This is one of the attributes of the species that makes it ideal for planting under city conditions where harsh environmental conditions and adverse soil conditions can have a negative impact on tree growth.

Because of its ability to fix nitrogen (N_2), it is expected that this species will aid in soil amelioration. Although a species' ability to grow under poor conditions can be studied in the laboratory or greenhouse by simulating adverse conditions, it is preferable to do the study under natural growing condition. The purpose of this study was to do the research and development necessary to make vacant land in the city of Detroit productive and relatively maintenance free using black locust trees.

Hanover (1989) researched many of the physiological attributes of black locust. Some of the characteristics which would allow black locust to be successful on urban site, such as those found in Detroit, are:

1) Rapid growth rate that allows it to outcompete weeds
2) Ability to fix atmospheric nitrogen (N_2)
3) Tolerates low fertility sites
4) Resistant to drought
5) Resistant to pollutants found in the atmosphere

6) Resistant to both high and low temperatures
7) Strong tap root and fibrous root systems
8) High seed viability and longevity
9) Seeds germinate rapidly

Studies have shown that water stress and nitrogen deficiency do not affect black locust. However, one condition that black locust is unable to tolerate is a poorly drained soil (Hanover, 1989). Growing black locust in an urban environment would provide a test for this species under more rigorous stresses like pollution, variations in soil chemical and physical properties, and elevated ambient temperatures (adapted from a proposal written for Detroit by Drs. Hanover and Mebrahtu, 1990).

RESTRICTIONS

The primary focus of the proposed research project was a spacing study. The objective of this experiment was to test what would be the optimal planting density for rapid canopy closure, without creating excessive competition. Closure of the canopy would create shade that would suppress weed growth. For more information about the experimental design for this study, refer to the experimental design section in Chapter Four.

Because of unforeseen events throughout the research period, research objectives had to be modified. In late April, 1991, several vacant city blocks were examined and soil samples collected and the first seedlings planted on May 8, 1991. The trees were inadvertently mowed (to 12.5 centimeters) one day after planting. Planting resumed on the two following days, while the city was being informed about the mowed trees. On July 29, 1992 the trees were accidentally mowed again.

Because one half of the study was completely mowed and several sections from the other half also mowed, it was not possible to make valid comparisons between treatments of the original experimental design. Because of this, the objectives of the spacing study were unable to be met. However, after one growing season, despite the two mowings, there was a noticeable difference in tree growth from one area to the next. Based on tree vigor, there were areas that seemed to be more conducive to tree growth. Given this situation, objectives for the spacing study were restructured during the second growing season, 1992. The new objective was to determine why certain areas were able to support such vigorous growth, while areas adjacent to them were almost void of vegetation. Because of both budgetary and time constraints, it was not possible to perform extensive soil analyses or tissue analyses to gain more detailed information on soil-tree interactions. The new objective of this study, involved a compaction study to investigate if soil compaction had an influence on the performance of black locust trees.

When the spacing study was originally designed, it was evenly divided between two city blocks. Severe vandalism at the end of the second growing season (1992), prevented the collection of total height data from one of the city blocks (or six of the twelve plots comprising this study), decreasing the amount of compaction data by half.

When the city was informed that the site had been mowed, the researcher was instructed to cease all planting and research operations. Apparently because additional authorization was needed, use of these specific lots was not "official" and the researcher was directed to stop all operations. In mid-June, 1991 project continuation was authorized and the direct seeding study (see Chapter Five) was initiated, albeit very late for such a study. Initiating a seeding study late in the season, when weather and soil conditions are not optimal for germination, had an impact on the results from this study.

A lack of project support also impacted the research effort and results. Lack of funding influenced the quality of materials utilized, frequency of site visits, amount and type of research conducted, and the level and quality of maintenance.

CHAPTER IV

SPACING/SOIL COMPACTION STUDY

INTRODUCTION

A majority of soils in an urban environment have at some point been disturbed, usually from construction activities. Disturbed urban soils are primarily characterized by increased alkalinity (pH) with a substantial amount of compaction, the latter being the subject of this study. Soil compaction to any degree can have a negative impact on tree growth.

The soils in the vacant city blocks used for this study were heavily compacted. This was ascertained through gaining information on the history of the lots, understanding urban soils, through observations of the patchy growth patterns of site vegetation, as well as the actual difficulty encountered when working with the soil.

The objectives of the spacing study were revised after the two mowings. The revised objectives considered tree performance at the end of the first and beginning of the second growing seasons. Soil compaction was measured with a penetrometer and these data were correlated with height. The objective of the compaction study was to examine if soil compaction has an influence on the survival and growth of black locust trees on an urban site in Detroit. This study attempted to test the hypothesis that areas displaying poor tree survival and growth have a greater degree of soil compaction than those areas displaying better tree survival and growth.

LITERATURE REVIEW

Levels of compaction can be expressed by both bulk density and penetrometer readings (Pittenger and Stamen, 1990). Past research has shown that the penetrometer, an instrument that measures soil compaction, can be both an effective and inexpensive method for obtaining information on this soil physical property (Thompson, et al., 1987).

The use of a penetrometer is common in agriculture and mineland reclamation. When the penetrometer is inserted into the ground, it faces some resistance. This resistance is an index of several soil physical properties such as structure, texture, moisture content, density, consistency, and degree of compaction (Zisa, et al., 1980). A penetrometer gives a measurement of soil strength. Soil strength is an indicator of the degree of soil compaction. With this information, newly constructed soils can be evaluated for variation, a common condition resulting from soil reconstruction after mining or farming practices. (Hooks and Jansen, 1986).

There are several types of penetrometers available (pocket, procter, cone, standard split-spoon) which have been designed for particular uses. Although designed for specific uses, they can be applied to other uses. The cone penetrometer, used in this study, was created by The United States Army Corps of Engineers. It is used to measure soil compactness (or density) and was used by the Corps to predict the carrying capacity of soils for army vehicles (Davidson, et al., 1959).

The resistance which roots face in the soil is the soil strength, as measured by the penetrometer. Some suggest that soil strength is most important in affecting root growth. It is argued that soil strength is a better measurement for root penetration than is bulk density (Thompson, et al., 1987). In their study on cotton plants, Taylor and Burnett (1964) also mention evidence suggesting that soil strength is the actual controlling factor in root penetration through the soil, and not bulk density or any other soil physical factors.

Both soil strength and bulk density may be reliable methods for measuring root system performance. Unfortunately, measuring bulk density, especially in very large areas, can be time consuming and expensive. According to the results from a study comparing penetrometer and bulk density results on reconstructed mine soils, the cone penetrometer is an effective tool for predicting root performance without obtaining bulk density measurements (Thompson, et al., 1987). Bulk density and soil strength both increase with compaction. It has been shown "that bulk density can be correlated with the soil penetrometer resistance" (Abercrombie, 1990, p.505). Penetrometer data has been correlated to both root growth (Pittenger and Stamen, 1990) and laboratory determinations of soil strength (Zisa, et al., 1980). It is believed that soil strength is the factor that limits root growth, whereas bulk density may be a better predictor for limitations in root growth (Thompson, et al., 1987).

Using the penetrometer is easy, quick, and inexpensive relative to gathering bulk density data, allowing for more observations. Given the variability found in mine soils, as well as urban soils, this could be advantageous (Thompson, et al., 1987), as it would allow one to collect many measurements from a large site, the results being more representative of that site.

It is not recommended to insert the penetrometer into the ground beyond three hundred pounds per square inch (p.s.i.), because it is at this level that growth begins to decline (Paul Swartz, personal communication, 1992). Penetrometer data should be collected when the soil is at field capacity. Field capacity is a condition where all of the small pores and spaces between pores remain water filled against gravity, after soil wetting and drainage of water has occurred (Foth, 1990). Soil moisture is a direct factor in determining soil strength. The relationship between soil moisture content and root resistance is inversely related; in other words, as soil moisture content decreases, the level of resistance increases (Zisa, et al., 1980). Because soil strength is affected by both the soil moisture content and soil texture, the most reliable penetrometer readings are obtained when the soil is a uniform loamy texture, and is at field capacity (Pittenger and Stamen, 1990).

There must be an evenly distributed force applied to the penetrometer at a slow, steady rate to obtain reliable readings. Soils that are hard and dry or with a lot of rubble present, make obtaining reliable measurements difficult (Davidson, et al., 1959).

MATERIALS AND METHODS

This part of the research was initiated in mid-April 1991 and terminated in mid-October 1992.

Site Description

The research was conducted on four vacant city blocks in Detroit, Michigan. State, city and area maps are shown in Figures 2 through Figure 4. The location in which the research was conducted seemed to be an economically depressed area, with new public housing development occurring nearby. The blocks are located adjacent to U.S. Interstate 94, northeast of Wayne State University. The site is exposed to relatively high levels of traffic pollution due to its proximity to the expressway. The city blocks range in size from 100 to 200 feet deep by 275 feet wide, with either a serviceable road or alley separating the city blocks from each other. In order to avoid confusion throughout the rest of this paper, especially the experimental design and statistical analyses sections, the city blocks will be referred to as "lots". Figures 2, 3, and 4 show maps of the city and the location of the research area. Four vacant lots were employed for the purpose of this research. They are located between Brush and Beaubien Roads (these streets run along the east and west sides). Lot one is situated south of the interstate, and north of Hendrie Road. Lot two is situated south of Hendrie Road, and north of a serviceable alley. Lot three is situated south of a serviceable alley, and north of Palmer Road. Lot four is situated south of Palmer Road, with a serviceable alley running along the south side.

Figure 2. Map of Michigan, locating Detroit, the city in which the research was conducted.

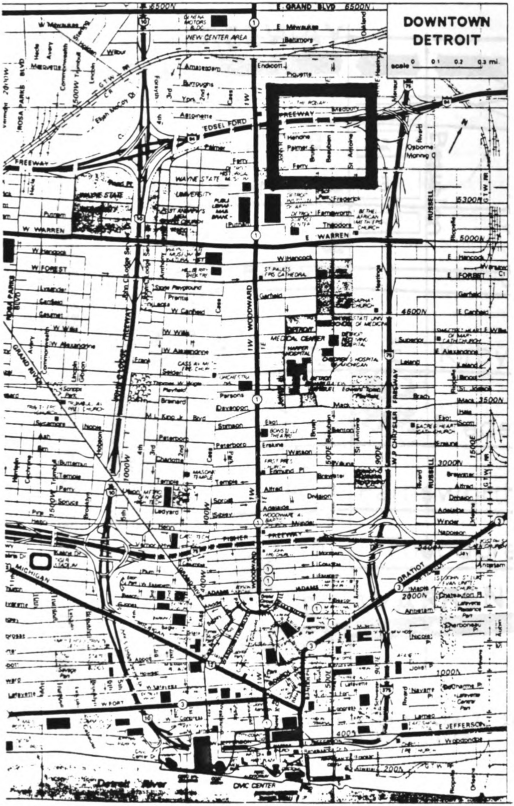

Figure 3. Map of Downtown Detroit, Locating Research Site (in box).

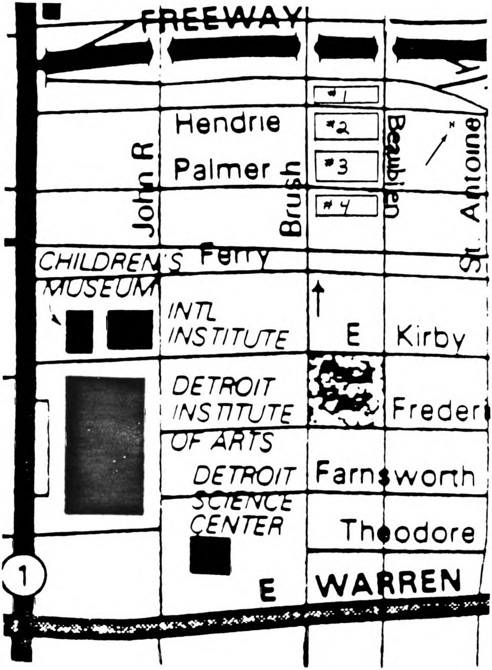

Figure 4. Research area from the box in Figure 3, locating the four (1 through 4) research plots.

The entire research area, including roads and alleys, was about 224,000 square feet (5.14 acres). Buildings, once located in the area were razed about fifteen years ago, but foundations were left in the ground. Miscellaneous fill was brought in to regrade the area. The soil is an "urban land" soil with a Class Two loam texture. Because these soils are derived from miscellaneous fill of varying textures and mineralogies and fertility, they are considerably heterogeneous, with many discontinuities. They are also severely compacted and contain a considerable amount of anthropeic (human-made) materials. Some of the materials that were encountered from the surface to a depth of at least three feet, were glass, metal, plastics, rubber (tires), wood, bricks, rubble, large slabs of concrete, and areas of buried asphalt.

The site supported a generous stand of weeds and grasses. Vegetation on the site consisted of Queen Anne's lace (*Daucus carota* L.), morning glory (*Ipomoea sp.* L.), wild pea (*Pisum sp.* L.), goldenrod (*Solidago sp.* L.), pigweed (*Amaranthus sp.* L.), burdock (*Arctium sp.* L.), dandelion (*Taraxacum officinale* Zinn.), milkweed (*Asclepias sp.* L.), teasel (*Dipsacus sp.* L.), clover (*Trifolium sp.* L.), mustard (*Brassica sp.* L.), boneset (*Eupatorium sp.* L.), chicory (*Chichorium sp.* L.), plantain (*Plantago sp.* L.), day lily (*Hemerocallis sp.* L.), cottonwood (*Populus deltoides* L.), mulberry (*Morus sp.* L.), tree-of-heaven (*Ailanthus altissima*. Desf.) and some grasses.

Composite soil samples revealed varying levels of soil fertility components. The nutrient components from soil analyses in 1991 and 1992 are presented in Tables 1 and 2.

Experimental Design

The experiment was initially designed to study the effect of planting density on weed suppression (spacing study). It was set up as a completely randomized block design. The three treatments were spacings of one meter by one meter, one meter by two meters, and two meters by two meters. The treatments were replicated four times. Diagrams of plot layout for lots two and four are shown in Figure 5 and Figure 6. Because the trees had been mowed two times the original objectives of this study were restructured based on observation made in the field. After one growing season, there was a visible distinction between those areas displaying good tree growth and poor growth. Groups were visually selected and isolated based on vigor. The groups varied in size. There were eight groups of high vigor and five groups of low vigor, giving a total of thirteen groups with a range from six to sixty-eight trees within a single group. Soil compaction and tree height were measured and studied on trees randomly selected from groups characteristic of good growth and poor growth. Diagrams of plot layout with areas of good and poor growth are shown in Figures 7 and 8.

Table 1. Results of twelve composite soil sample analyses collected from all four blocks from the site in 1991.

Parameter	Range	Fertilizer Index
Calcium	5811 - 6720 (lbs/acre)	High
Magnesium	405 - 568 (lbs/acre)	High
Potassium	208 - 303 (lbs/acre)	Med
Phosphorous	10 - 31 (lbs/acre)	Low-Med
pH	7.8 - 8.3	Very high
CEC	17.0 - 19.4 me/100g	High
Organic matter	1.6% - 3.7%	Low (>5% Ideal)
Nitrogen	0.59 - 4.40 (ppm NO_3)	Low

Table 2. Results of twelve composite soil sample analyses collected from all four blocks from the site in 1992.

Parameter	Range	Fertilizer Index
Calcium	5474 - 6232 (lbs/acre)	High
Magnesium	304 - 496 (lbs/acre)	High
Potassium	232 - 320 (lbs/acre)	Med
Phosphorous	4 - 21 (lbs/acre)	Low-Med
pH	8.1 - 8.2	Very high
CEC	15.0 - 17.9 me/100g	High
Organic matter	2.5% - 3.5%	Low (>5% ideal)
Nitrogen	2.6 - 8.45 (ppm NO_3)	Low-Med

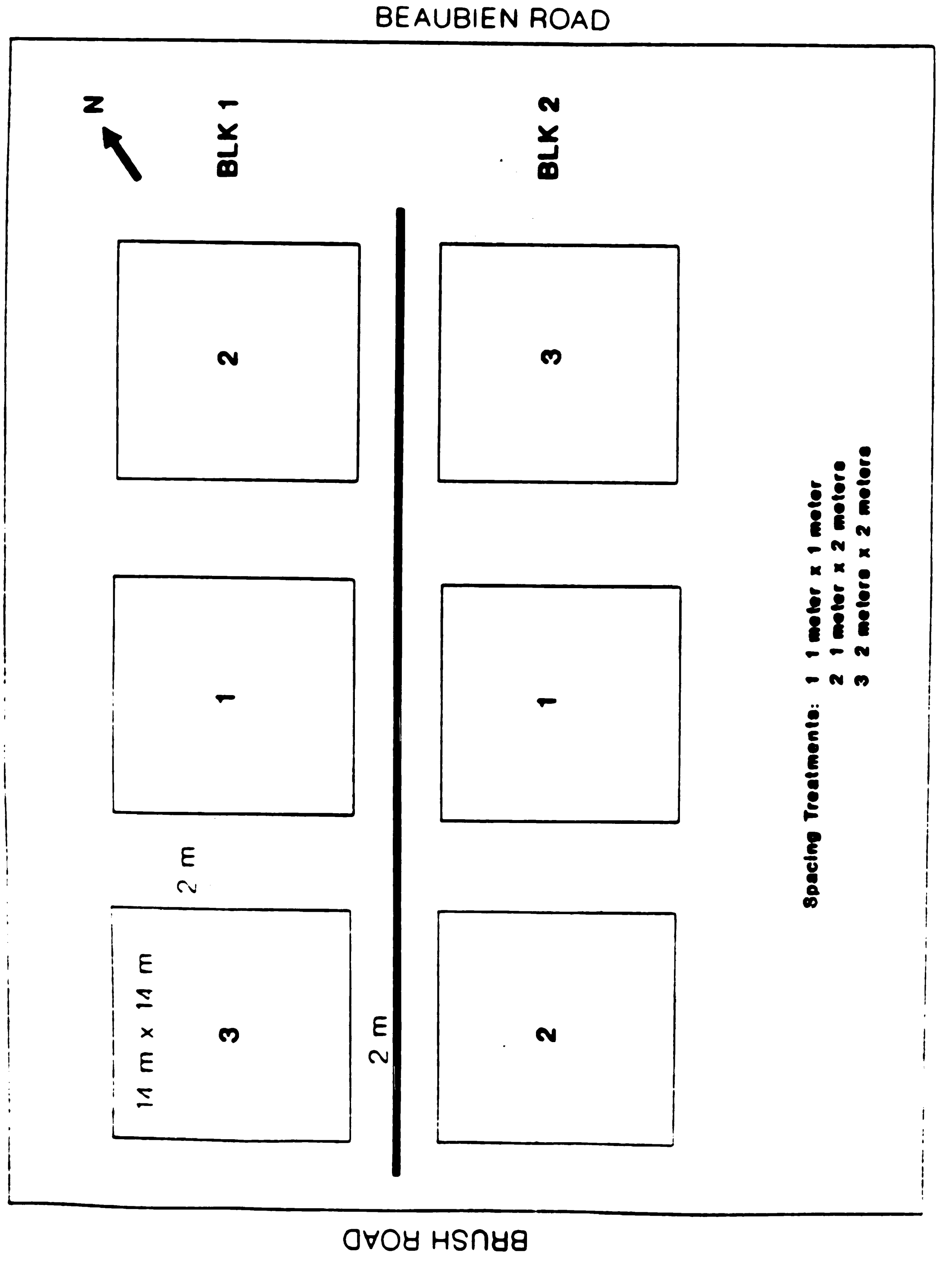

Figure 5. Diagram of the Spacing Study Located on Lot #2

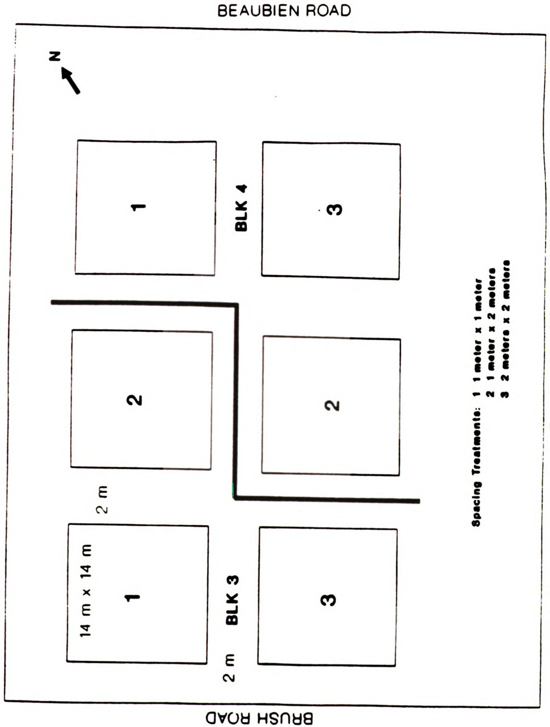

Figure 6. Diagram of the Spacing Study Located on Lot #4

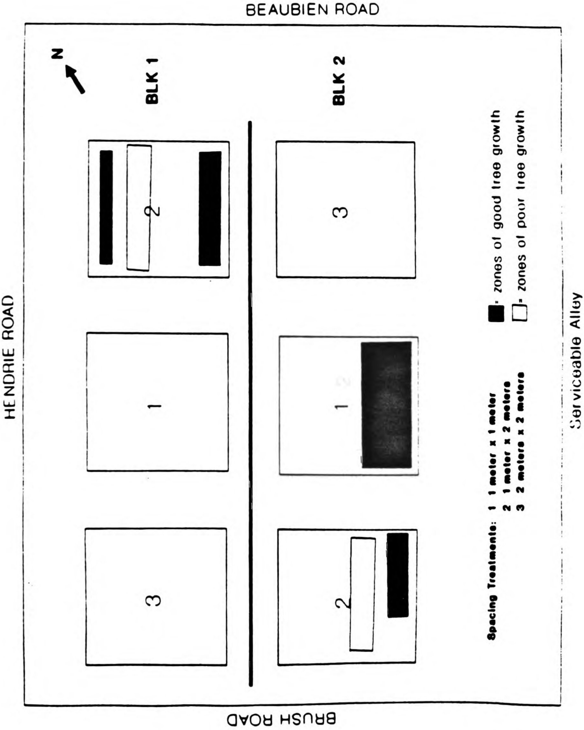

Figure 7. Diagram of the Spacing/Compaction Study Located on Lot #2

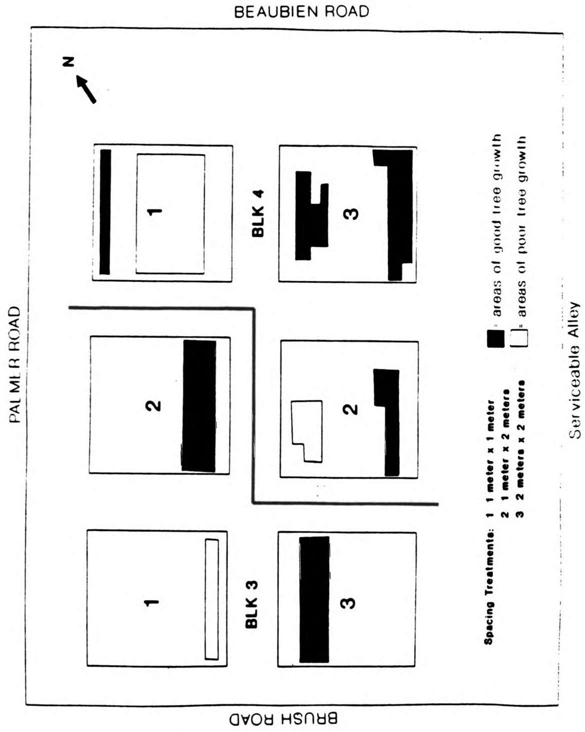

Figure 8. Diagram of the Spacing/Compaction Study Located on Lot #4

Site Preparation

1991 - The twelve experimental plots of the original spacing study were marked. They were fourteen meters by fourteen meters. A two meter buffer zone was left between the plots to minimize the effects of shading. The total size of the study area including buffer zones was 2,760 meters squared.

Soil Sampling

1991 - Three composite samples per lot, each consisting of twenty sub-samples, were collected. Samples were taken to a twelve inch depth. Soil samples were analyzed by the Soil Testing Laboratory located at the campus of Michigan State University, East Lansing, Michigan. All samples were analyzed for calcium, magnesium, phosphorous, potassium, nitrogen, cation exchange capacity (CEC), pH, and organic matter content. Results were presented in Table 1. Fertilizer recommendations were also given based on trees and shrubs as crops. See appendix A.

1992 - Prior to the second growing season, composite soil samples were again collected. They were analyzed for the same nutrients by the soil testing lab at Michigan State University. Results were presented in Table 2.

Weed Control

1991 - Weed control was established by broadcast spraying the experimental plots with the post-emergent herbicide glyphosate at a rate of three pounds active ingredient per acre (a.i.a.).

Three meter buffer zones were left between plots to minimize edge shading effects.

1992 - All experimental plots were spot sprayed to the point of drip with a 1.5 percent solution of glyphosate. Because weed growth was excessive the previous year, the pre-emergent herbicide treflan 5G was applied at a rate of two pounds per 1,100 square feet, or four pounds a.i.a. The herbicide was broadcast to all plots during a rain in order to increase its effectiveness.

Planting

1991 - The planting stock was 1-0 bare root black locust seedlings. The option of using a tree planter was determined to be inappropriate because of heavy compaction and the presence of foreign materials. Using this equipment in these conditions could pose hazards to the equipment and its operators. Therefore, the seedlings were planted by hand using a dibble bar. Seedlings were root-pruned to a uniform length of eight inches (twenty centimeters). They were then placed into buckets containing peat moss and water to keep the roots moist during planting. A total of 1,636 seedlings were planted.

Fertilizer Application

1991 - Because soil nitrogen levels were extremely low, it was decided to broadcast fertilize the plots. Nitrogen-fixing trees may gain some benefits from nitrogen fertilization (Hanover, 1989). Ashby, et al. (1985) also note that planted and seeded locust respond positively to a fertilizer application at the time of planting, unlike many other species. Fertilizing the trees with a very low level of nitrogen may be enough to enhance survival. This was important because the trees were very small (because they were planted at a high density in the nursery beds), and were being outplanted to a harsh site. Along with attempting to increase soil nitrogen levels, the formulation used would also aid in reducing the soil pH. Although it has proven extremely difficult to decrease soil pH as opposed to increasing it, sulphur is used in effort to do so (Foth, et al., 1988).

Ammonium sulfate fertilizer (21-0-0) was broadcast by hand to each of the twelve plots. It was applied at a rate of forty-four pounds per acre (1.01 pounds per 1,000 ft^2) in three separate applications between June and July 1991.

Site Maintenance

1991 and 1992 - The research site was located in a residential area and it was suggested by the city (Department of Public Works) to maintain the aesthetics of the site. The perimeter of all experimental plots as well as the aisles were maintained by periodic mowing throughout the growing seasons. Both a brush hog mower and hand mowers were used. Plots were kept clearly marked with paint and flags.

Data Collection

1991 and 1992 - Following the original design, new growth and total stem height were measured for all trees at the end of the first growing season. On the un-mowed trees, survival, total height and the amount of new growth were measured. For the trees that were mowed twice, survival, height, and new growth after the second mowing were measured. Soil compaction and total tree height were measured on randomly selected trees within the thirteen isolated groups during the second year.

<u>New growth data</u>

1991 - The amount of new growth was measured for all trees in the study. New growth was measured on the longest branch, and was recorded in centimeters. For the trees which were mowed for the second time in August 1991 (those on lot two), new growth was measured from the scar of the second mowing (this was about six inches above ground level).

<u>Total height data</u>

1991 - Total stem height of each tree, from soil level to the terminal meristem, was measured. Total height was recorded in centimeters.

1992 - Total height was recorded in the same manner as the previous year, recorded in meters.

<u>Soil compaction data</u>

1992 - During mid growing season, groups of trees displaying different growth patterns which were located adjacent to each other, were selected. A qualitative scale with two levels was used to measure vigor. Healthy and vigorous trees received one number, while those that appeared chlorotic and less vigorous, received a different number. Height was estimated using a six-level scale ranging from no height to above five feet.

In August, soil compaction was measured using a cone penetrometer (DICKEY-John Soil Compaction Tester) with a half-inch diameter cone-shaped tip and a probe length of twenty-seven inches. The most reliable penetrometer readings are obtained when a soil is at field capacity, therefore readings were collected when the soil was presumed to be at field capacity. Measuring at field capacity minimizes variability in soil moisture, which could affect penetrometer readings. Soil compaction was measured next to random trees within the previously isolated groups. Three subsamples were collected around the base of each chosen tree, each tree being a sample. Because the penetrometer needs to be pushed into the ground at a slow steady rate, two people performed the test procedure. While one person recorded the readings, the other operated the penetrometer. The operator was responsible for pushing the instrument into the ground and reporting the readings. A flat soil surface was created before each measurement was obtained. This was accomplished by brushing away any litter or debris. Doing this assured that there were no obstructions to interfere with the accuracy of the readings. Holding the instrument in a vertical position, it was uniformly pushed into the ground, and readings were observed and recorded.

Two measurements per subsample were recorded. The first measurement was the depth at which 300 p.s.i. was first reached, and was designated the "non-compacted zone". The second measurement was the depth at which 300 p.s.i. was maintained without exceeding that pressure, this was designated the "total depth". This final reading was recorded when penetration was no longer possible, to a maximum depth of twenty-seven inches (probe length). Depth was recorded to the nearest inch. Survival of all trees in the entire spacing study was also recorded.

DATA ANALYSIS

Absurv statistical package (Anderson Bell, Corp.) was used to run statistical analyses on all data. Percent survival and average height were calculated on data from both growing seasons.

A "zone of compaction" was calculated by subtracting non-compacted zone values from the total depth values. Chi-square tests were performed on the data. The analyses compared height versus non-compacted zone and height versus the compacted zone. All three variables, (i.e., height, compacted zone, non-compacted zone), were regrouped two times. Comparisons were made amongst the variables (non-regrouped, and regrouped two times), with a chi-square analysis being performed on all possible comparisons.

Correlations were performed relating height and the non-compacted zone, and height and the compacted zone.

Linear regression analyses were also performed on the data. Both the non-compacted zone and the zone of compaction were regressed on total stem height.

RESULTS AND DISCUSSION

The portion of the study which was not vandalized (that portion located on lot two) had 56.28 percent survival with an average height of 1.17 meters, a minimum height of 0.12 meters, and a maximum height of 2.99 meters (refer to Table 9).

Results from chi-square analyses were not significant, suggesting that compaction was not a significant factor in influencing tree growth on this site. The data for all three variables were grouped to form new variables. The new variables were height regrouped, non-compacted zone regrouped, and compacted zone regrouped. These regrouped variables were again condensed and labelled as new variables. The original and regrouped non-compacted zone and compacted zone variables were compared in all possible combinations to the original and regrouped height variables. Comparisons made between all variables still failed to yield significant results, and are not able to explain the growth differences observed in the field. Results from all chi-square analyses can be found in Table 3.

Correlation analyses showed there to be no relationship between the non-compacted zone and height (correlation value of -0.00236), nor between the compacted zone and height (correlation value of 0.27099).

Linear regression analyses for both the non-compacted zone versus height and the compacted zone versus height indicated that there was not a significant linear relationship. The results suggest that the soil characteristic measured does not explain the performance of black locust on this site. Results from both analyses are presented in Tables 4 and 5.

Table 3. Results of chi-square analyses, making various comparisons between the height and the non-compacted zone and compacted zone. The variables have been regrouped up to two times, and further analyses made.

Test Comparison	df	Chi-sq.	Prob
Compacted zone vs. height	225	215.21	0.668
Non-compacted zone vs. height	180	194.86	0.212
Compacted zone regrouped vs. height	72	86.62	0.115
Non-compacted zone regrouped vs. height	135	126.24	0.693
Compacted zone regrouped vs. height regrouped	75	89.42	0.122
Non-compacted zone regrouped vs. height regrouped	40	39.82	0.478
Compacted zone twice regrouped vs. height regrouped	20	18.71	0.541
Non-compacted zone twice regrouped vs. height regrouped	10	9.53	0.482
Compacted zone regrouped vs. height twice regrouped	34	40.08	0.218
Non-compacted zone regrouped vs. height twice regrouped	18	23.33	0.178
Compacted zone twice regrouped vs. height twice regrouped	4	6.22	0.183
Non-compacted zone twice regrouped vs. height twice regrouped	2	2.72	0.063

Table 4. Results of a linear regression analysis relating the non-compacted zone and total height for black locust sampled from lot two during the 1992 growing season.

Source	df	S.S.	F value *
Regression	1	4.7022	6.4646 ns
Residuals	27	19.639	
Total	28	24.341	

$R^2 = 0.1632$

* ns - not significant

Table 5. Results of a linear regression analysis relating the zone of compaction and total height for black locust sampled from lot two during the 1992 growing season.

Source	df	S.S.	F value *
Regression	1	0.5643	0.6408 ns
Residuals	27	23.776	
Total	28	24.341	

$R^2 = 0.0129$

* ns - not significant

Graphs of the data for the non-compacted zone and the compacted zone are presented in Figures 9 and 10. When a regression line was fitted to these graphs, it seemed to be skewed by the presence of some outlying data points. Further investigation of these points revealed that all but two data points occurred in a part of the field that was questionable. These particular trees were located in an area which supported little vegetation. This area was rectangular measuring fourteen meters long by five meters wide. It was speculated that there may be something obscure, other than compaction (e.g., past dumping of toxic substances, leaking sewage tiles. etc.), occurring in that area which could possibly be influencing tree growth. These points were eliminated from the data sets, regression analyses relating the same variables were performed, and graphs of the regressions plotted.

The second set of regression analyses indicated a non-significant relationship between the non-compacted zone versus height and the compacted zone versus height. The eliminated data points did not have a significant influence on the regression. Results from the second set of regression analyses are presented in Tables 6 and 7, and the graphs are shown in Figures 11 and 12.

The data used for the above analyses included twenty-nine sampled trees; three subsamples per tree. Collection of more data points may have yielded more reliable results. It is important to reiterate that more than half of the data were lost to vandalism. Had this not occurred, there would have been seventy samples, which may have yielded different results.

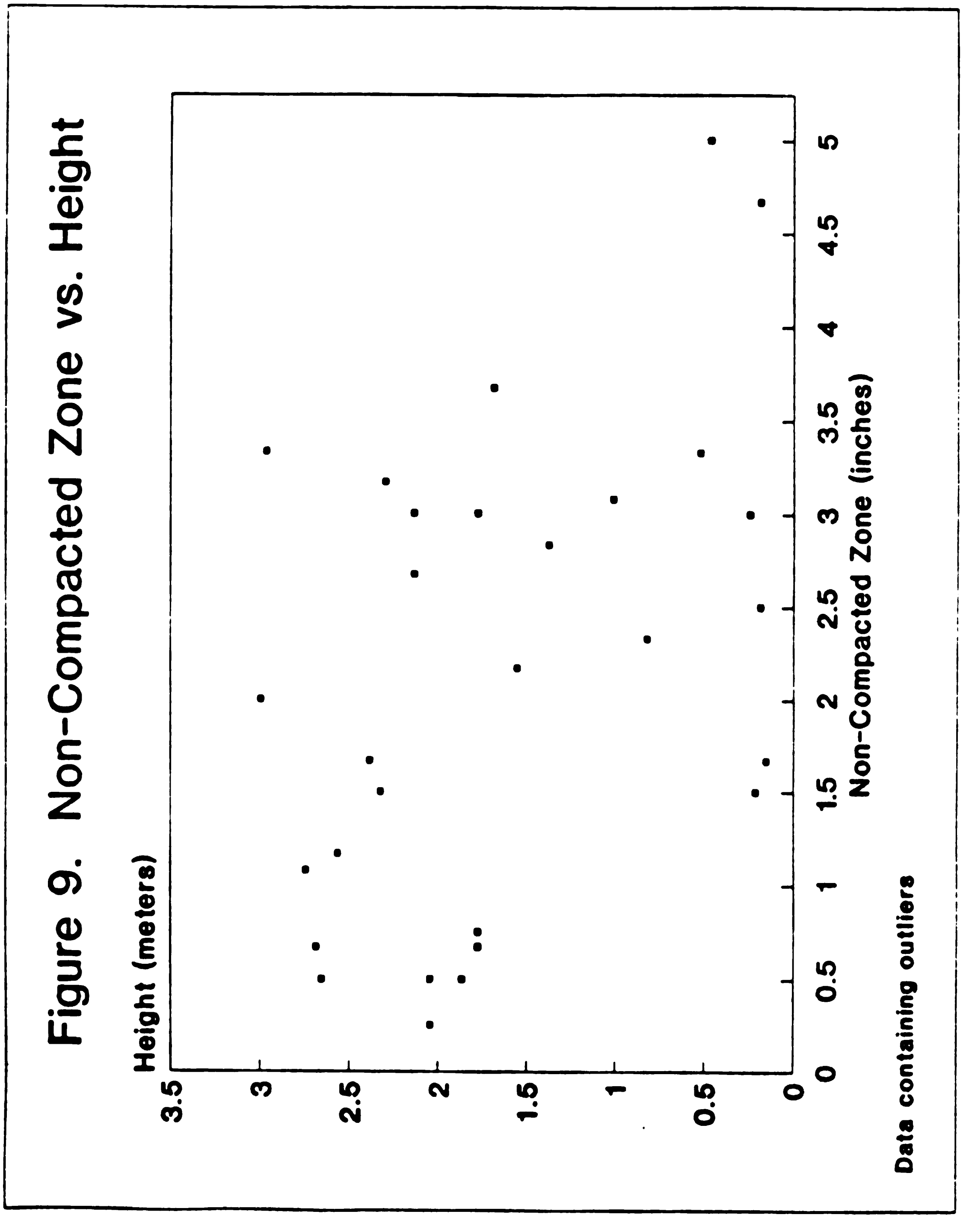

Figure 9. Regression of non-compacted zone (x) on height of black locust (y) sampled from lot two of the research site.

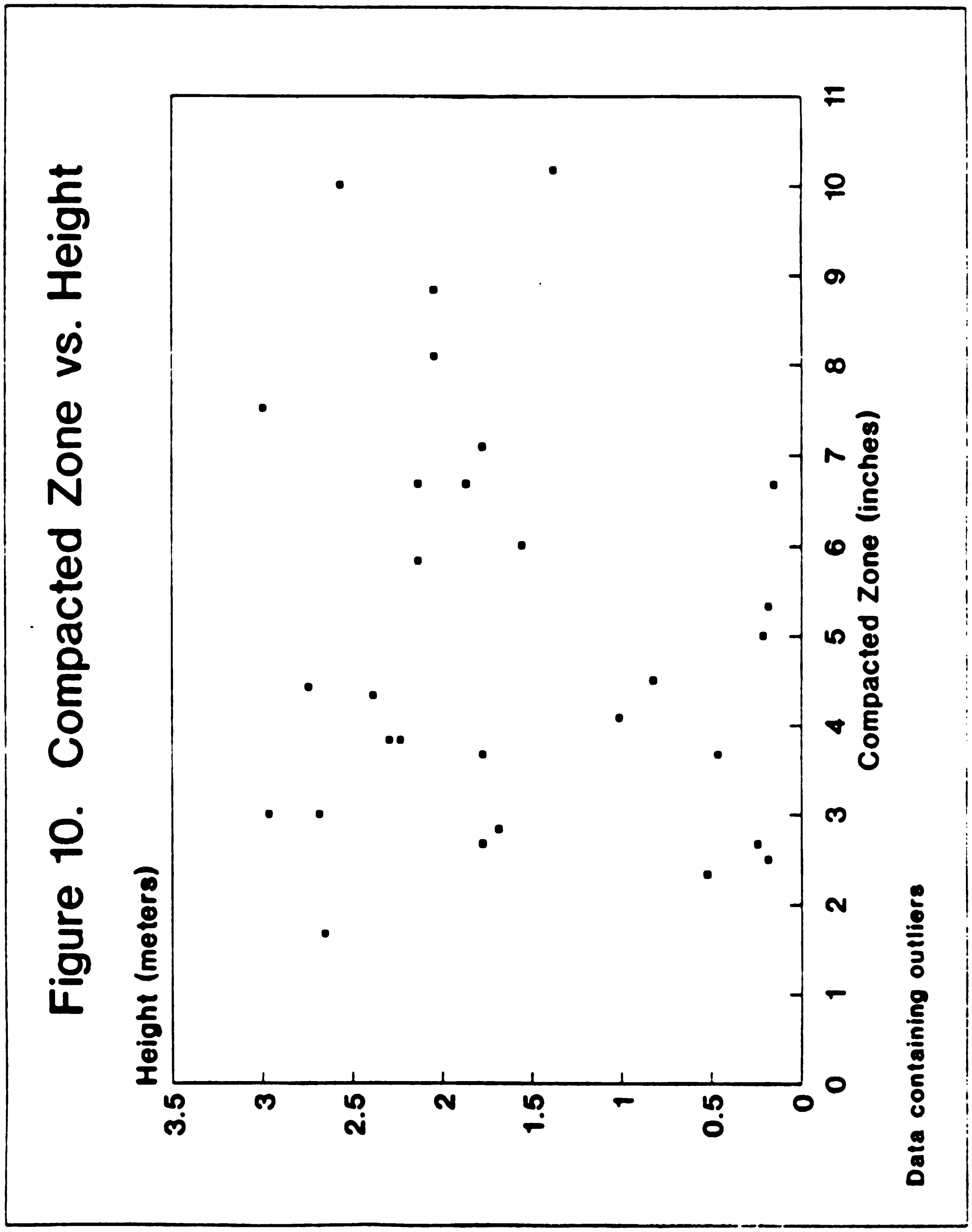

Figure 10. Regression of compacted zone (x) on height of black locust (y) sampled from lot two of the research site.

Table 6. Results of a linear regression analysis relating the non-compacted zone and total height from black locust trees sampled from lot two during the 1992 growing season. Data used for this analysis do not contain the outliers.

Source	df	S.S.	F value *
Regression	1	0.2568	0.3621 ns
Residuals	22	15.605	
Total	23	15.862	

$R^2 = 0.0285$

* ns - not significant

Table 7. Results of a linear regression analysis relating the zone of compaction and total height for black locust trees sampled from lot two during the 1992 growing season. The data used for this analysis do not contain the outliers.

Source	df	S.S.	F value
Regression	1	0.0037	0.0052
Residuals	22	15.858	
Total	23	15.862	

$R^2 = 0.0452$

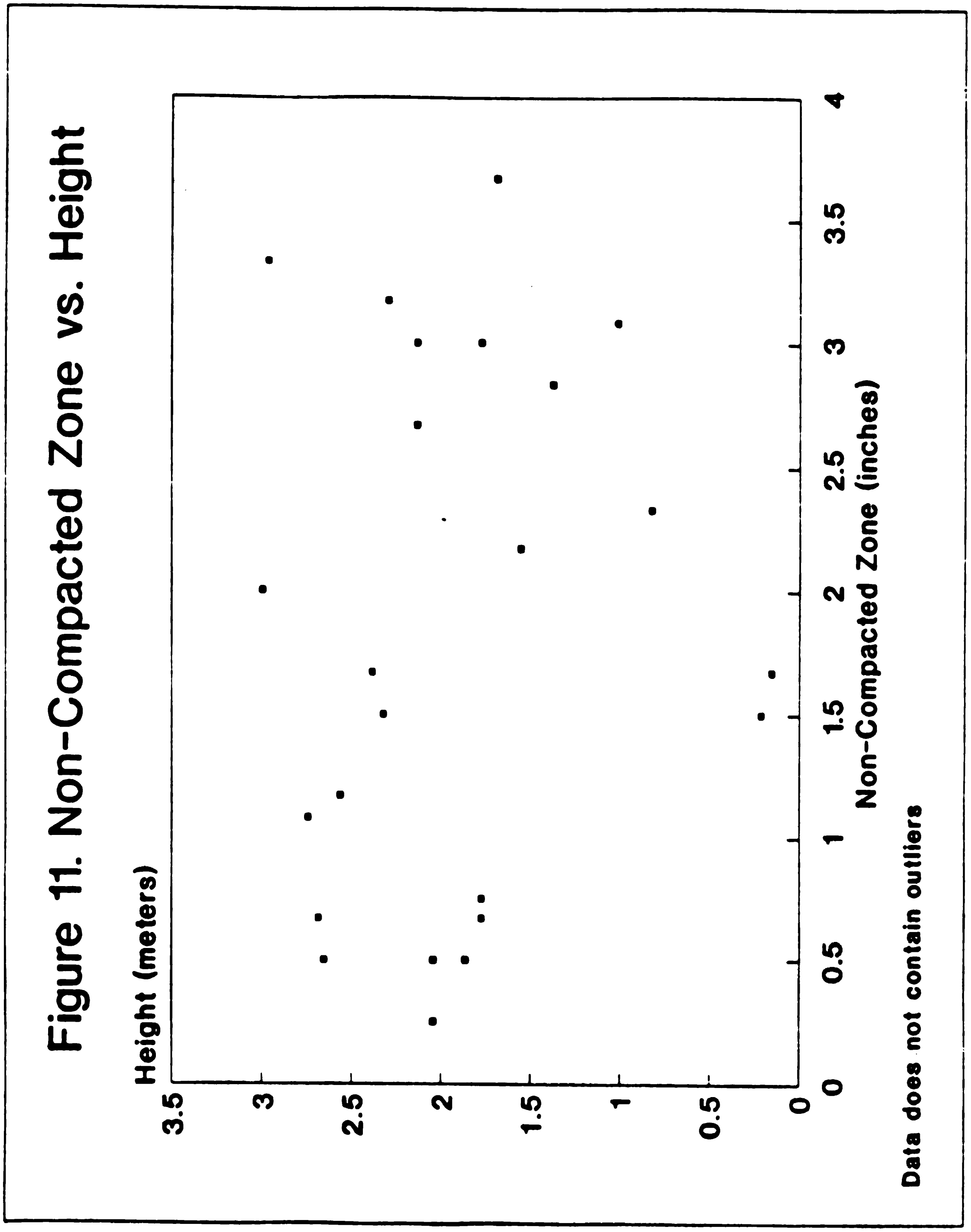

Figure 11. Regression of non-compacted zone (x) on height of black locust (y) sampled from lot two of the research site. Data does not contain outliers.

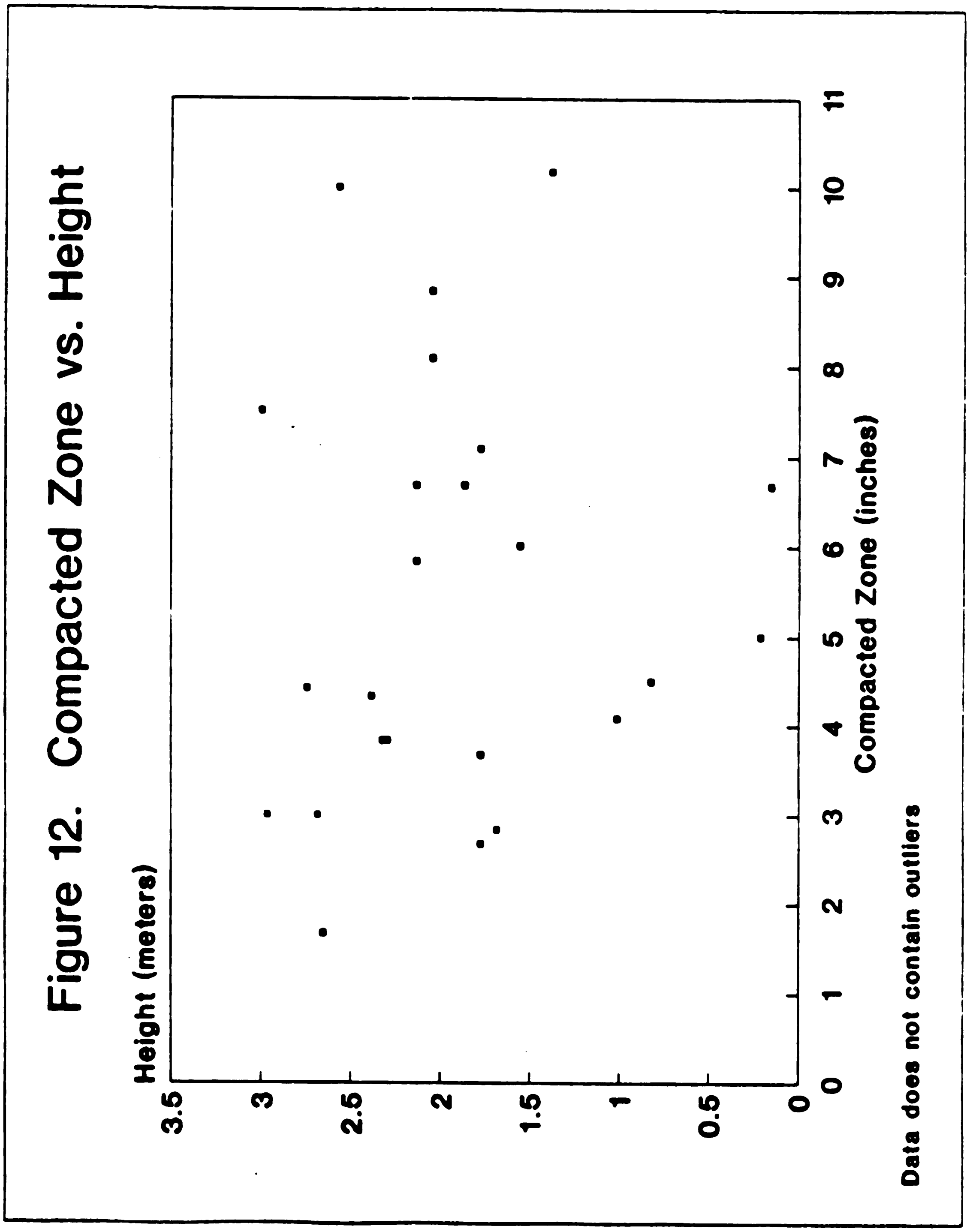

Figure 12. Regression of compacted zone (x) on height of black locust (y) sampled from lot two of the research site. Data does not contain outliers.

In an urban site, there are many factors influencing tree growth. This study did not indicate that compaction had a significant effect on tree growth. It would not be reasonable to completely rule out compaction as having an influence. The level of compaction which was found here was just a portion of the range of values for the degree of compaction. For example, if one portion of the site did not show a large degree of compaction while the other portion did, regression analyses may have yielded more significant results. Because a great portion of the site was compacted, obtaining significant results for a range of soils with varying degrees of compaction was difficult.

The data revealed broad variation in the total depth measurement around each tree. Variations in the non-compacted zone readings ranged from a quarter of an inch to six inches around the same tree. For the total depth measurement, there were variations in depth up to fifteen inches at one tree. This much variation in compaction within one tree microsite seems unusual, considering that the maximum diameter was never more than three feet. This extreme variation may be explained by the degree of variability at this site, or it could be an indication of improper use of the penetrometer.

Another contributing factor to the variation found around some trees and the non-significant relationship between height and compaction could be that penetrometer readings were not accurate. The most reliable readings are obtained when the penetrometer is inserted into the soil at a slow, steady rate. The presence of foreign material makes this difficult to accomplish, and may have resulted in inaccurate readings which were not able to reflect if there was a significant interaction between height and compaction.

Although the city blocks used for this research are considered to be "open urban land" (they presently have no buildings on them), they still showed vertical and spatial variability from past human activities and they consist of miscellaneous fill and preexisting artifacts (foundations). The presence of anthropeic materials could have affected tree survival and growth. There was a substantial amount of foreign matter on the site used for this research, visible on the surface and when digging or planting. Planting with either the dibble bar or shovels was difficult. Planting in 1991 was done according to the design for the spacing study. In order to maintain the integrity of this study at the time of planting, treatment spacings were adhered to. Therefore, if an immovable object was encountered when planting, the planter had no choice but to inch away from the planting spot until a workable location was found. Many times it was not possible to find a suitable location without severely skewing the spacings (and hence the row effect), therefore the tree was planted as deep as possible at the intended location; even if that meant planting on top of a large piece of anthropeic matter. It is possible that improper planting lead to mortality or poor growth; but in many cases, finding a spot free from anthropeic material was unavoidable and the tree had to be planted at a shallow depth.

Soil conditions were probably the most influential factors affecting tree performance, as opposed to atmospheric conditions (pollution, heat island, precipitation). Performance of these trees on the site in Detroit, can most likely be attributed to a combination of factors found in an urban environment, emphasizing the soil. There are many confounding factors that need to be studied (like contaminants, soil fertility, anthropeic materials, poor species-to-site selection), but this was beyond the realm of this project. Because the site was so variable, it would take a major research effort to determine the factors directly influencing growth.

During data collection in 1991, it was noticed that many of the dead trees, had chewed roots. Because the symptoms indicated insect damage, several samples of dead trees were taken to the Pest Diagnostic Center in the Entomology Department at the campus of Michigan State University. It was diagnosed that white grubs had recently chewed and killed the roots of the trees sampled. Because white grubs were frequently encountered during planting, their activity could be a likely explanation for some mortality. It is also possible that their populations were present in isolated locations, resulting in the patchy tree growth patterns that were observed at the end of the first and during the second growing seasons.

Another factor that may have influenced growth was that these trees were mowed twice during the first growing season. It is possible that survival and growth would have been greater had this not occurred. However, these trees seemed to grow in spite of both mowings, hence the mowings may not have been a significant confounding factor. In fact, observations made after both mowings indicated that those trees that had been mowed, grew more vigorously than those that were not mowed. Survival and growth results from the 1991 growing season are presented in Table 8.

The average amount of new growth (based on 1991 data) for mowed lot two (7.50 centimeters) is 1.85 centimeters less than that for unmown lot four (9.35 centimeters). It is important to stress that the lot two trees had been mowed, for the second time, in early August. They had about two months (sixty-nine days) to produce new growth before the first frost on October 11, 1991. Determining the growth potential (by dividing the number of days that each set of trees had to grow (lot two - 69; lot four - 155 days) into the average amount of new growth per lot), indicates that the trees which were mowed two times (lot two) grew nearly twice as much (1.82 times) as those that were never mowed.

This outcome may be due to a better root-to-shoot ratio being established in the trees that were mowed. It was speculated that the lot two trees would have the reserves to put on more growth before winter, but not enough to make it through the winter and into spring. However, these trees were able to survive the winter and were able to increase their total height by almost six times (5.9 times) during the second growing season. Because all trees on lot four were vandalized, it was not possible to determine the amount of

Table 8. Survival and growth results for lots two and four for the 1991 growing season; according to the original (spacing study) experimental design.

LOT 2

Trt.	Percent* Survival	Avg.* Height	Hgt.* Range	New* Growth	N.G.* Range
1	74.67	20.07	12.5-77.8	7.65	0.1-65.9
2	75.00	20.74	12.5-71.1	7.59	0.1-56.7
3	62.50	16.87	12.5-50.0	6.80	0.1-40.5
Total	72.88	19.77		7.50	

LOT 4

Trt.	Survival	Height	Range	Growth	Range
1	70.99	32.20	13.8-72.0	9.04	0.1-38.1
2	65.40	37.09	15.5-102.0	9.17	0.1-73.9
3	77.30	42.00	14.1-97.2	10.78	0.1-56.0
Total	70.30	34.76		9.35	

* Units are in centimeters

growth that those trees gained during the second growing season. Survival and growth results for the 1992 growing season for lot two are presented in Table 9.

It is possible that some mortality could be attributed to a high weed and grass population during the first growing season. Although the lots were treated with a post-emergent herbicide prior to planting, fertilizer applications may have encouraged weed growth. "Black locust usually is more successful than other trees in becoming established" in heavy ground cover (Ashby, et al., 1985). It is possible that competition from weeds did not contribute to the majority of first year mortality that was calculated (28.41 % average). The trees were able to grow well, if in a suitable place. At this point it is not possible to determine long term survival or vigor.

In summary, the stated hypothesis that areas displaying poor tree survival and growth have a greater degree of soil compaction than those areas displaying better tree survival and growth was rejected.

In the event that Detroit would have the resources to conduct city-wide planting operations of black locust, they would need some recommendations. Given the amount of information obtained from this research, it would be difficult to say for certain what the success of such an effort might be. Continuous site monitoring needs to be carried out for several years. This would provide information on long term survival and growth of black locust on this particular site. If the trees are able to thrive on this site with only two

Table 9. Survival and growth results for lot two for the 1992 growing season; according to the original (spacing study) experimental design.

Trt.	Percent Survival	Total Height*	Range*
1	58.70	123.0	12.0-287.0
2	58.30	115.0	15.0-299.0
3	44.00	102.0	12.0-192.0
Total	56.28	117.0	

* Units are in centimeters

years of maintenance (i.e., site preparation, weed control, planting, etc.), then it would be possible to suggest that the city needs only two years of major maintenance investment. In this case, Detroit could begin, with little resources, to establish some urban forests of black locust.

Follow-up studies should focus on soil physical, biological, and chemical conditions. Extensive soil analyses would provide information on nutrient and micro-nutrient availability and deficiencies, contaminants and their toxicity, microfauna populations, and other physical, biological, and chemical properties of the soil. Establishing a grid system over the site and collecting soil samples for extensive analyses may provide more detailed information regarding present soil conditions and the extent of its variation. Penetrometer readings in conjunction with bulk density readings may offer more information on the degree of compaction.

Future research could also be conducted on the trees already established at the research site. A natural phenomenon with older black locust stands is deterioration, loss of trees, and canopy breakup. Future studies could focus on underplanting the site with different species and determining their success. Examining the condition of the soil and its influence on the new plantings would provide information on any soil amelioration that hopefully would have resulted from planting black locust on these sites.

Examining root performance may also provide more information on soil conditions. A detailed study on plant roots (morphology, growth patterns, nutrient content), though tedious, can reveal a myriad information, if there are analytical data from both foliar and other tissues with which to correlate. A species comparison trial would provide information on the most suitable species for these urban sites. If locust exhibits adequate survival, it could serve as a nurse crop for less "site"-tolerant species. In terms of aesthetic appeal, wildlife value, and property value, the establishment of a mixed stand would be more beneficial than a monoculture. A stand of mixed species could provide several food sources for wildlife, resulting in variable wildlife species. Mixed stands can be more appealing aesthetically, which could potentially increase property values. Mixed stands are also usually healthier because they are less susceptible to devastating attacks by pests. The species comparison trial could also consider any soil or atmospheric variations that exist within this urban area. It would also provide data on species mortality and this would provide increased confidence in selecting plant material for vacant lots in the city. If such data were applied across the city, soil analyses should be conducted per site to ensure that chosen species are site-suitable.

CHAPTER V

DIRECT SEEDING STUDY

INTRODUCTION

Revegetating a large city such as Detroit can be time consuming and expensive. Without sufficient funds, it can be difficult to embark on a revegetation project. Direct seeding of woody species is an alternative revegetation method. It is economically feasible because it requires less labor than planting. If planned properly, direct-seeded trees may quickly revegetate derelict lands, such as those found within Detroit's urban areas. Another benefit of direct seeding is rapid coverage of a large area. It seems worthwhile to consider direct seeding as a method of revegetation because Detroit has so much vacant land. This will provide rapid revegetation and offer the myriad benefits that are associated with trees in an urban area. The functions of trees in an urban area range from architectural and aesthetic uses to climatological (cooling, windbreaks, etc.) and engineering uses (erosion control, sound control, etc.) (Miller, 1988).

The objective of this study was to evaluate the success of direct seeded black locust in Detroit. This experiment attempted to test the hypothesis that direct seeding of black locust on an urban site will be successful.

LITERATURE REVIEW

The use of direct seeding versus planting nursery stock for woody establishment on disturbed land, is controversial. Either method is certainly situation-dependent. Results depend on site selection, species selection, seed source and treatment, planting time, and other cultural methods (Wakeley, 1954).

Direct seeding has both successes and failures. Direct seeding is usually favored to avoid the high costs of stock, shipping, and planting. Direct seeding eliminates dependence on a nursery and results in more time available for field work. The trees also have a better chance for more normal root development (Wakeley, 1954).

The high costs associated with the use of nursery stock for revegetating large areas of land can be prohibitive. The initial cost of the stock, labor and maintenance, especially for the first year, can make planting uneconomical. Because planted seedlings have so little time to adapt and to recover from the stress of outplanting, they become more susceptible to climatic stresses (Hipkins and Coartney, 1987).

In contrast, direct seeding offers a lower initial cost, lower maintenance costs and lower labor costs relative to using nursery stock. Newly emerged seedlings have an advantage over planted seedlings because they do not utilize their starch reserves to overcome the strains of lifting, planting, and adapting to a new environment (Hipkins and Coartney, 1987).

The disadvantages of direct seeding are: 1) rodent damage and 2)germination problems. Seeds and young seedlings (new shoots) commonly fall prey to rodents because new seedlings are smaller and tender. Rodent damage can be extensive. Seeds that do germinate can be affected by insects and disease. Weather can also be a problem. Despite careful planning and disease and rodent prevention, the weather is uncontrollable and not easily predicted. Low temperatures and more importantly, dry periods can prevent germination. Even if there is germination, extensive drought can kill almost everything (Wakeley, 1954).

MATERIALS AND METHODS

This part of the study was initiated in mid-April 1991 and terminated in June 1992.

Site Description

A detailed description of the study site can be found in Chapter Four.

Seed Preparation

In early June 1991 about 900 black locust seeds were treated for sowing. The seeds were scarified by soaking them in a ninety-three percent solution of sulfuric acid for one hour, while stirring occasionally. Scarification, prior to planting, increases the percentage of early germination (Ashby, et al., 1985). Scarified seeds were then rinsed well with water and stored in a seed cooler at thirty-five degrees fahrenheit and fifty percent relative humidity until sowing time, three days later.

Site Preparation

1991 - A ten meter by ten meter area was marked off and was broadcast sprayed with the post-emergent herbicide glyphosate at a rate of three pounds a.i.a. A diagram showing the plot layout can be found in Figure 13.

Soil Sampling

1991 - Soils were sampled in the same manner as described in the compaction study. Refer to the soil sampling section in Chapter Four.

Weed Control

The use of certain herbicides on different soil types has been found to prevent or decrease germination in direct seeded black locust (Geyer, Melichar and Long, 1987). The use of any potentially harmful herbicide was avoided in this study.

1991 - Weed control was established by broadcast spraying the experimental plot with the pre-emergent herbicide glyphosate at a rate of three pounds a.i.a. per acre.

1992 - The site was spot sprayed to the point of drip with a 1.5 percent solution of glyphosate.

Seeding

1991 - Seeds were sown at a one meter by one meter spacing. Because of compaction, it was not feasible to mechanically cultivate the entire site. Using a hoe, a small area was cultivated where the seeds were to be sown. A planting hole, about a quarter of an inch deep, was formed. Five to seven seeds were planted in each hole, and were covered with a thin layer of soil. The seeds were then watered until about a ten inch diameter area was saturated. Orange, wooden stakes

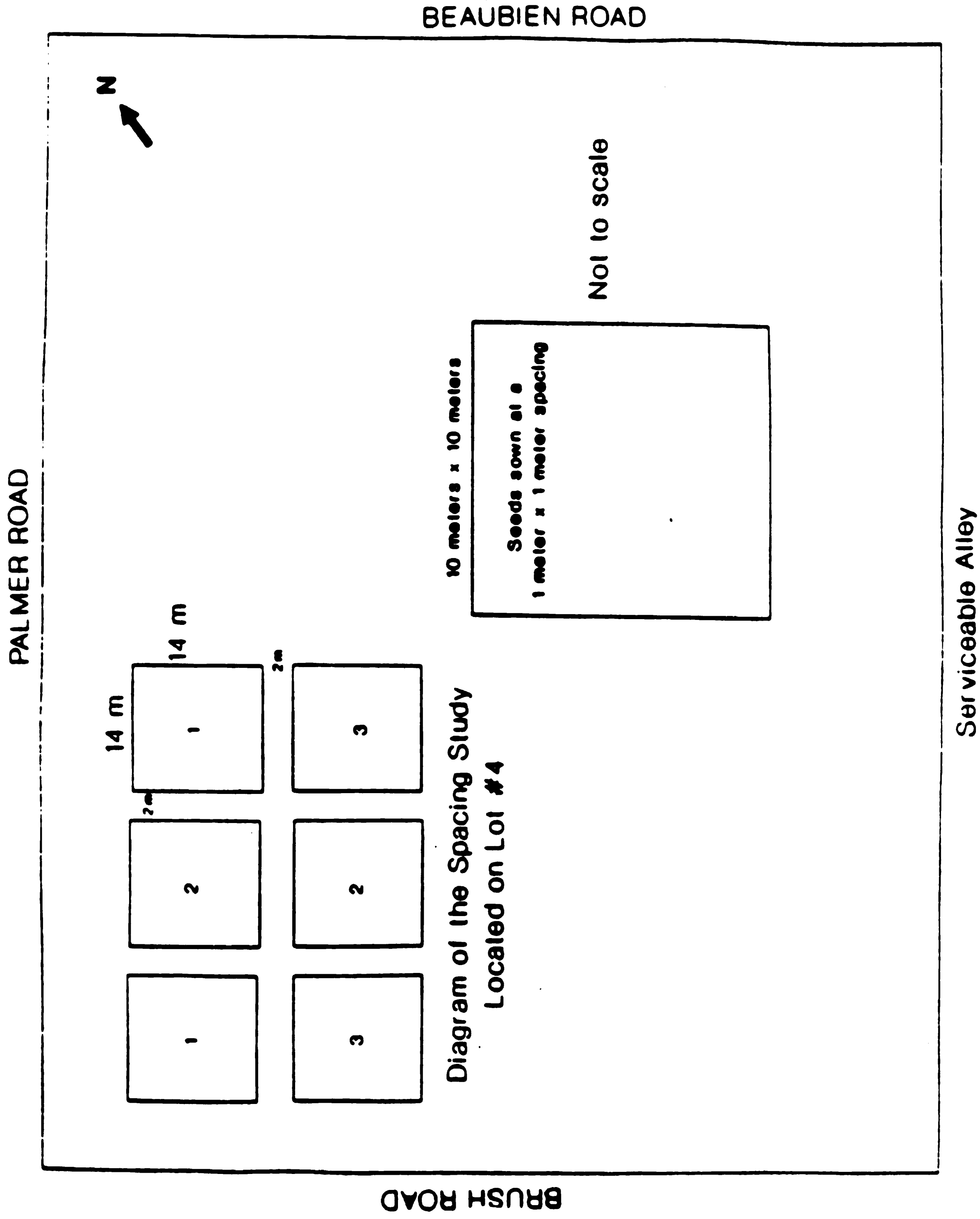

Figure 13. Diagram of the Direct Seeding Study*
Located on Lot #4
***(Not drawn to scale)**

marked seed location. During times of low precipitation, the seeds were watered if funds and time allowed; four times across the growing season.

Data Collection

1991 - Observations on germination were made throughout the growing season. Because the seeds failed to germinate, germination could not be recorded.

RESULTS AND DISCUSSION

No germinated seeds were observed during the experiment across both growing seasons. Possible reasons for failure of the seeds to germinate are varied.

Depending on the site, it may be necessary to take steps to protect the seeds from animals. The seeds used in this study were not treated to prevent rodents and birds from consuming them, because there did not appear to be a lot of wildlife in the study area to be concerned with excessive rodent damage.

Hipkins and Coartney (1987) suggest that compacted soils offer a poor growing medium for seeds. Failure of the seeds to germinate may have been caused by the lack of seed-soil contact and poor aeration of the compacted soils (Hipkins and Coartney, 1987). This certainly could have contributed to germination failure in this study. Perhaps species to site selection was not suitable. Hipkins and Coartney (1987) also note that seeds which are not pre-treated by scarification, are able to remain viable for the next year if they fail to germinate during the first. Whereas pre-treated seeds, as used in this study, are normally lost to germination in the future if they fail to germinate the first year,. This is because the seed coat has been destroyed, exposing the embryo to dehydration.

The most likely reason for germination failure of this study was the lack of soil moisture, or drought conditions. The problem of low soil moisture content was exacerbated by the extremely high temperatures and low precipitation levels that occurred during the season. It is suggested that applying mulch to areas which have been seeded will aid in reducing soil water loss and help to discourage animal pilferage (Wakeley, 1954). Because the site had established vegetation, the use of herbicides created a cellulose mulch cover when the pre- existing vegetation fell to the ground after being treated. This low mulching rate might have provided a sufficient mulch layer which could have promoted soil moisture retention (Hipkins and Coartney, 1987).

Because of the directive to cease research operations (in May, 1991) until further notice, planting efforts were suspended for approximately four weeks. Once back on schedule, the seeds were sown at the end of June, a very late time to begin a seeding study. This, combined with low levels of precipitation, created a situation that was likely to be unsuccessful. Added to this, because of budgetary constraints, it was not possible to water the site as it would have required. It is probable that the extremely dry soil conditions at the time of sowing, and the inability to water with regularity were two probable reasons for germination failure.

It is likely that the low viability of the seeds used for this study was an additional factor for the lack of germination. The seeds provided for this study were tested for germination in 1990. They were scarified by the same methods used in this study, and placed in a germination chamber. The test revealed only twenty-one percent germination in 1990.

In summary, sowing should have been conducted in early spring, when the soil moisture content would have been higher. Only high quality, viable seeds, as determined through germination test, should have been used. This does not lead to the conclusion that this would have been the way to prevent failure. Even if seeds of higher viability had been sown during the spring, other factors may still have contributed to low germination.

A future study could be to examine if direct seeded black locust had better survival and growth than bare root plantings on a site with so much anthropeic matter. It is assumed that seeded trees would have the advantage, once established, because they would have better root development. The roots of seeded trees have the opportunity to grow into areas that are free from obstructions, while bare root trees, with their roots already formed and growing in a set form, will have a more difficult time getting established and surviving on such a site. Future research could incorporate a study on the effects of watering schedules with mulching treatments on the germination rate and survival of the seedlings. This could be conducted in conjunction with comparisons made between different species.

It is highly recommended to conduct pre-sowing germination tests on species used in any study. Observing germination and survival of seeds sown at different times throughout the growing season may also provide useful information. Studying scarified versus non-scarified seeds and their germination during the season in which they were sowed and subsequent years, would provide information on seed treatment and the appropriate sowing times. Incorporated to any seeding research should be the testing of several different species on an urban site.

Future research could also incorporate studies on the success of hydromulching on urban sites. Again, testing the hydromulching success of different species that may seem suitable to these site would provide more flexibility for direct seeding as a revegetation method for the city. Broadcast seeding is another method similar to hydromulching. Studying the success of broadcast application of a seed mixture on bare land that needs rapid cover (because it is susceptible to erosion) may be worthwhile. A mixture of grass and a herbaceous legume with black locust seeds has effectively been used in reclamation practices (Ashby, et al., 1985).

The objective of the direct seeding study was to evaluate the success of direct seeded black locust on an urban site. The hypothesis was to test whether direct seeded black locust will be successful on an urban site. This hypothesis could not be addressed because percent germination was zero.

CHAPTER VI

FALL PLANTING TIME STUDY

INTRODUCTION

If a city undertakes extensive tree planting on its vacant lots, in order for them to function most efficiently, labor needs to be distributed throughout the year. During the spring and summer the city would be occupied with planting seedlings, maintaining previously planted lots, and the continuous upkeep of vacant lots. Conducting some of the more labor-intensive tasks, such as planting, during the fall, could result in cost reductions and the ability to revegetate more vacant land each year.

Containerized seedlings were used in this study for two reasons: 1) because of the ease of planting when soil moisture is low and 2) containerized stock is more successful a site adaptation than bare root stock (Van Sambeek et al., 1987). A high degree of soil compaction was not conducive for efficient dibble bar use. By the end of the growing season, when soil moisture content is low and the soil less workable, shovels were the only usable planting tools. The subsoiling action of the shovel created a more favorable growing medium for the seedlings by loosening the soil deeper in the profile, offering a better rooting medium. It also helped insure deeper planting, which is desirable to decrease frost heaving.

Container-grown stock can more efficiently adapt to a site and sooner than bare root stock (Van Sambeek et al., 1987). Planting stock that is able to quickly adapt to its site is preferred in this study because of the harshness of the site combined with the fact that the seedlings had very little time to acclimate before they were outplanted.

The objective of this study is to determine the effect that timing of fall planting has on the survival and growth of black locust. The hypothesis of the study is that black locust seedlings planted later in the fall will have better survival and growth than those planted earlier in the fall.

LITERATURE REVIEW

An increase in early growth can be gained by using containerized seedlings. Despite past research findings indicating that fall-planted stock show less survival than spring-planted, the former is not a complete loss. Fall-planted seedlings have been shown to have significant height growth over spring-planted, outperforming those planted during the spring. Because of the increased costs associated with the use of containerized stock, its use is justified in situations where there is a need for rapid height growth or high value seedlings are grown. Planting this stock during the fall, with it's higher height growth and lower survival than spring-planted, is also justified because it creates a larger frame of time for planting and spreads labor across the year (Van Sambeek et al., 1987).

Use of containerized stock also aids in the reduction of outplanting shock (Von Althen and Prince, 1986). Outplanting shock occurs as a result of a decrease in the amount of roots, especially fine roots, that are damaged or broken off during outplanting. Poor root regeneration results in poor growth and survival. Failure of roots to properly regenerate may be due to root loss during lifting, low carbohydrate reserves, desiccation during storage, or poor contact of roots with the soil. Intact root systems allow for stronger root regeneration which insures better survival and growth, even during periods of stress (Van Sambeek et al., 1987).

Based on results from a study done on containerized black walnut (*Juglans nigra* L.), Van Sambeek et al. (1987) speculate that exposure of the root collar after outplanting may have an effect on survival. In their study, they found that forty percent of seedlings that had exposed root collars died, compared to a fourteen percent mortality rate of those with non-exposed root collars (Van Sambeek et al., 1987). These findings indicate the importance of proper planting depths of seedlings.

Frost heaving leads to higher rates of mortality in bare root seedlings versus containerized seedlings. With an intact root system, a containerized seedling has a fibrous root system that acts as an anchor, decreasing the incidence of frost heaving. This can allow for an extension of the normal planting season to include fall planting (Van Sambeek et al., 1987). It may be true that deep planting of bare root seedlings can decrease the incidence of frost heaving (Van Sambeek et al., 1987).

When extending the planting season into the fall, dormant stock must be used, regardless of whether it is containerized or bare root. Actively growing stock is not able to be successfully fall planted (Van Sambeek et al., 1987). Von Althen and Prince (1986) found that most of the mortality of containerized stock occurred within the first planting year, and attributed this loss to improper or lack of hardening off.

MATERIALS AND METHODS

This part of the study was initiated in late August 1991 and terminated in mid-October 1992.

Site Description

A detailed description of the study site can be found in Chapter Four.

Experimental Design

The experiment was established as a randomized complete block design with four blocks. There were four planting treatments replicated four times, for a total of sixteen experimental plots. A plot map for this study is shown in Figure 14. Actively growing, containerized black locust seedlings were received one week prior to the first planting date. Seedlings were planted four times at two week intervals during the fall season. Planting dates were August 27, September 12 and 25, and October 11 of 1991.

Site Preparation

Each of the sixteen delineated plots were six meters by six meters. Two meter buffer zones were left between plots. The entire study area, including buffer zones was 9,000 squared feet.

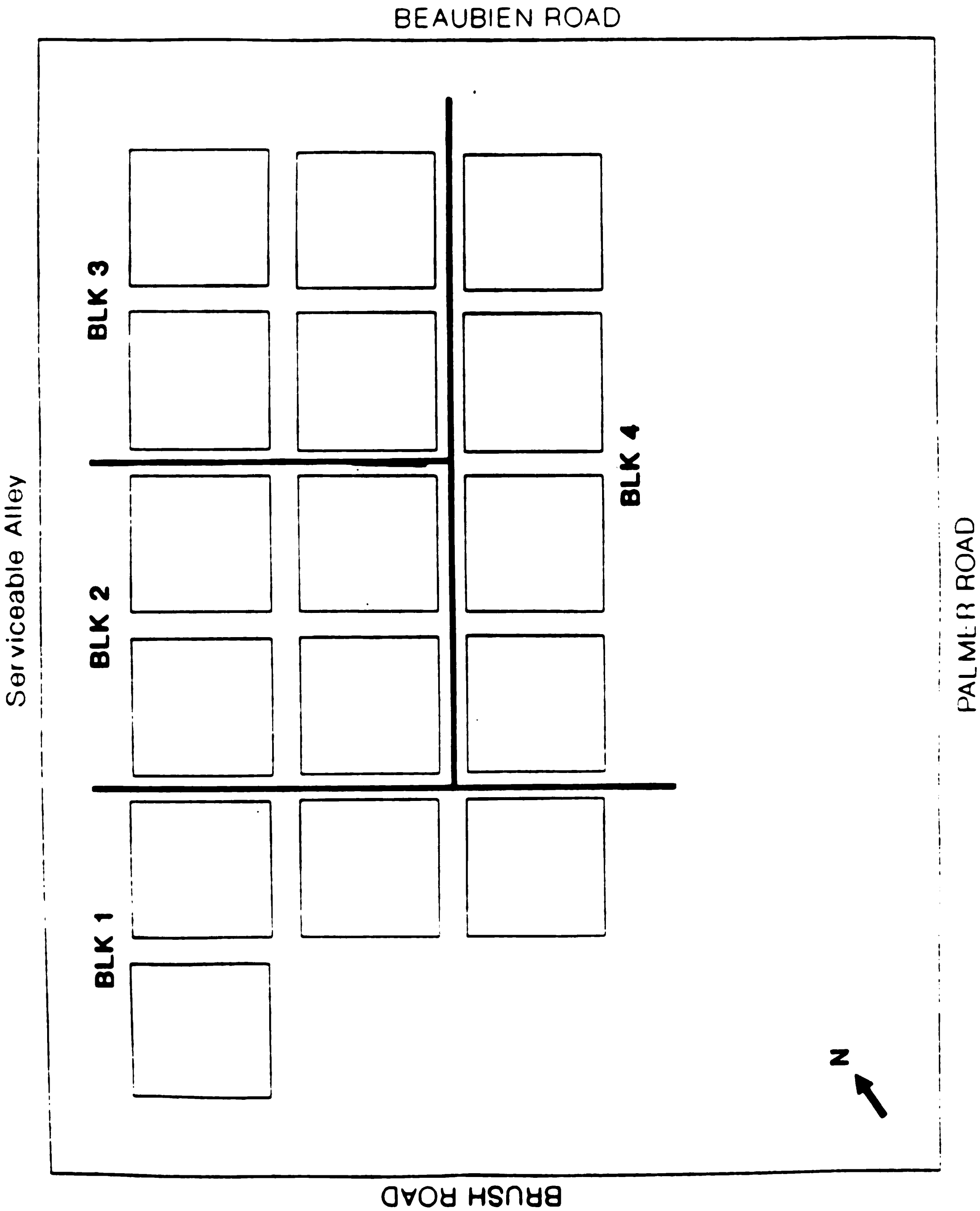

Figure 14. Diagram of the Fall Planting Time Study Located on Lot #3

Soil Sampling

1991 - Soils were sampled in the same manner as described in the compaction study. Refer to the soil sampling section in Chapter Four.

Weed Control

1991 - Weed control was established by broadcast spraying the experimental plots with the post-emergent herbicide glyphosate at a rate of three pounds a.i.a.

1992 - All experimental plots were spot sprayed to the point of drip with a 1.5% solution of glyphosate. Treflan 5G, a pre-emergent herbicide, was also broadcast applied to all plots during a rain in order to increase its effectiveness. It was applied at a rate of two pounds per 1,100 square feet, or four pounds a.i.a.

Planting

1991 - The planting stock was 1-0 containerized black locust seedlings received from a nursery in Indiana. The seedlings were received in August, one week prior to planting. They were acclimatized in a shade house until planting. On each planting date, the appropriate number of seedlings were taken to the site to be planted. The seedlings remained in their containers until they were planted. They were hand planted at about a quarter of an inch above the nursery soil height to minimize frost heaving. Whenever rocks or sidewalk remnants were encountered, they were removed in order to maintain the proper spacing. There were a total of 576 seedlings planted at a one meter by one meter spacing; with sixteen plots of thirty-six seedlings per plot.

Data Collection

Seedling survival was evaluated and total stem height measured in the spring after the seedlings were planted. Stem height of each tree, from soil level to the terminal meristem, was measured in June, 1992. Height was recorded in centimeters. Although the plots were treated with both pre- and post-emergent herbicides in the spring, weed growth was excessive, killing most of the trees as well as making it impossible to determine plot boundaries. Total height was not collected at the end of the growing season. Budgetary constraints made it difficult to frequent the site for observation and to purchase materials for adequate site maintenance.

Data Analysis

A one-way analysis of variance (ANOVA) was performed on the data using Absurv statistical package (Anderson Bell Corp.). Before analysis of variance was done all data were checked for normality, homogeneity of variances and additivity. The assumption of equality of variance between the treatments was tested by Bartlett's F test. Because of the lack of homogeneity between the variances, percentages received an arcsin transformation. Fisher's Protected Least Significant Difference (FPLSD) test was applied to the data to determine how the treatments differed from each other.

RESULTS AND DISCUSSION

Bartlett's F test revealed significant differences at the .01 level. The analysis of variance, using the transformed data, revealed significant differences between the treatments at the .05 level. Planting time did significantly affect overwintering survival. Results of the analysis of variance for the four treatments are given in Table 10.

Planting trees later in the fall season increased overwintering survival. Survival results are presented in Table 11. The FPLSD analysis showed that treatments one and two were significantly different from each other and from treatments three and four at the .025 probability level. Treatments three and four did not significantly differ from each other. Figure 15 indicates a small difference in percent survival (nine percent) between treatments three and four; survival for treatment four was greater than the other treatments. Although the height data that was collected is representative of mid-season growth, average height was calculated and graphed for each treatment. Average height for the treatments are shown in Figure 16. Results of the FPLSD analysis are presented in Table 12.

Even though significant differences in planting times occurred, results of this study are not reliable because the planting stock used in each treatment was not at the same physiological state when outplanted, rendering treatment comparisons invalid. The first frost date for East Lansing was September 21, 1991; in Detroit it was October 10, 1991. Treatments one and two were not exposed to a frost prior to

Table 10. Analysis of variance of arcsin transformed data showing a significant difference between fall planting treatments.

Source	df	S.S.	M.S.	F	Prob>F
Block	3	429.7869	143.2623	4.09	0.0436
Treatment	3	1909.637	636.5457	18.17	0.0004
Error	9	315.3406	35.03785		
Total	15	2654.764			

Table 11. Overwintering success of containerized black locust seedlings planted at two-week intervals and four planting times during the fall season.

	Treatment Survival and Growth				
	1 (8/27)	2 (9/12)	3 (9/25)	4 (10/11)	Avg.
Percent Survival	16.7%	37.5%	53.5%	62.5%	42.5%
Avg. Total Height (cm)	33.32	46.10	52.02	65.43	49.23
Height Gain (cm)	13.00	25.78	31.70	45.11	28.91

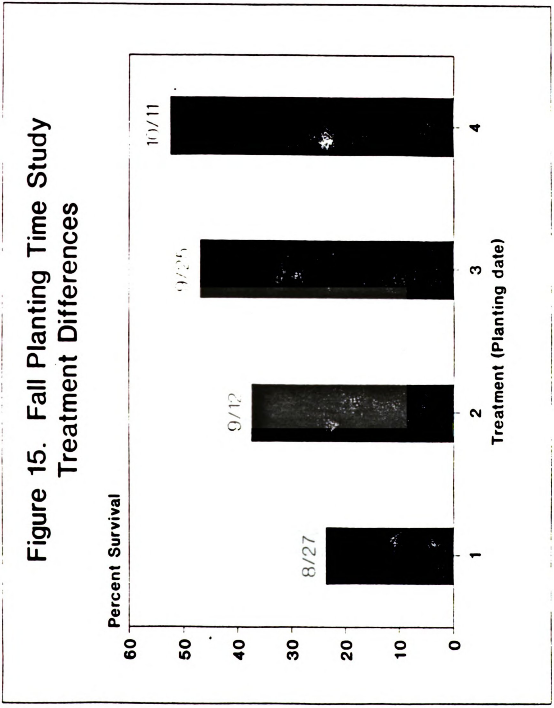

Figure 15. Percent survival of black locust (y) sampled from the four treatments (x) in the fall planting time study in 1992.

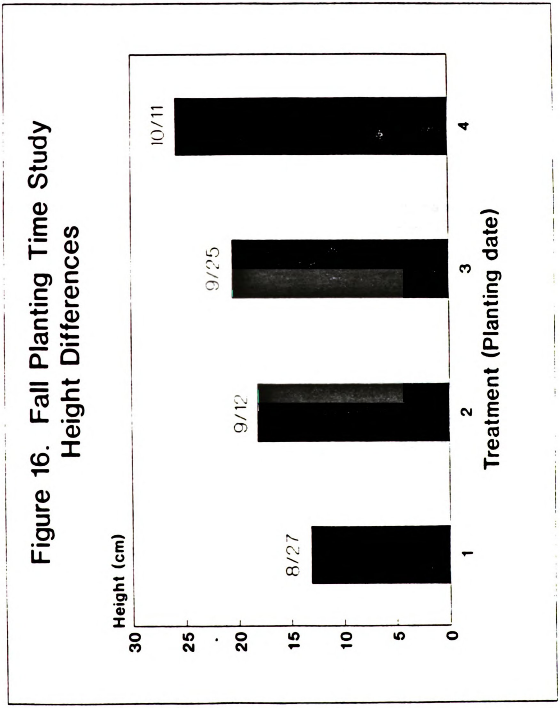

Figure 16. Average height of black locust (y) sampled from the four treatments (x) in the fall planting time study in 1992.

Table 12. Fisher's Protected Least Significant Difference (FPLSD) test of mean values of survival and planting times for containerized black locust seedlings planting during the fall season.

Treatment	Mean (%) Survival	Mean Arcsin Transformation	
1 (8/27)	16.7	23.60	A *
2 (9/12)	37.5	37.40	B
3 (9/27)	53.5	46.93	C
4 (10/11)	62.5	52.40	C
FPLSD = 10.932			

* means with the same letter are not significantly different from each other at the .025 probability level.

outplanting, whereas treatments three and four had frost exposure. "Fall planting must be in perfect physiological synchronization with their intended environment" (Ellington, 1985). All seedlings should have been acclimatized in Detroit where they would have been exposed to the same environmental conditions as the site.

Although treatment comparisons are not reliable, discussion of treatment differences may be valuable. One would expect that survival and height for treatments one and two to be greater than those for treatments three and four. This is because one and two had more time after outplanting to establish a root system and accumulate stem height.

Because three and four were outplanted later in the growing season, they would not be able to establish a vigorous root system nor gain much height before winter. However, treatments three and four showed better survival and growth than one and two (refer to Table 11 and Figures 15 and 16). This is probably because treatments one and two were severely stressed following outplanting, and did not have sufficient energy reserves for proper establishment before winter. There must be adequate soil moisture for the seedling after outplanting to encourage root growth. If adequate soil moisture is not provided, "the whole point of fall planting concept is lost" (Ellington, 1985). Soil moisture was low at the time of planting treatments one and two (August 27 and September 12, respectively). It is probable that a low soil moisture content affected the performance of the trees in these treatments, resulting in their survival and height differences with treatments three and four.

It is possible to attribute some mortality to frost heaving. Although shovels were used to increase planting depth, ensuring a proper planting depth was still difficult. Large slabs of buried concrete were frequently encountered, and the amount and quality of topsoil sparse. Although planting was carried out to the best of ones ability, this was not enough to always ensure an appropriate planting depth because of site conditions. One report indicates frost heaving as being the cause for extensive amounts of initial seedling mortality (Anderson et al., 1983).

Another report indicates that frost heaving was not a problem. But instead, insufficiently hardened off stock for fall planting or improperly planted seedlings were reasons for poor survival (Van Sambeek et al., 1987). Planting stock must be sufficiently hardened off before it is planted during the fall. For hardwoods, this is after exposure to low temperatures, at which point they become dormant after the first few frosts or after the tree has shed its leaves (Stoeckeler and Jones, 1957). Treatments one and two had not been exposed to frost and were not hardened off prior to outplanting. It is strongly speculated that this was a major factor in the low survival found in these two treatments.

The lack of mid-season weed control could also be another explanation for the mortality. Although the plots received a spring herbicide treatment, weed growth that season was excessive. This killed most of the trees, as well as making it impossible to determine plot boundaries and locate the seedlings for measurement.

In their study on containerized black walnut, Von Althen and Prince (1986) found that although fall-planted containerized seedlings had significantly greater mortality than fall-planted bare root stock, those that did survive showed a significant growth advantage. They attribute this to the avoidance of outplanting shock. Research conducted by Van Sambeek, et al. (1987) supports this finding. However, fall-planted containerized stock performed worse than spring-planted containerized stock. Their study indicates that survival of containerized fall-planted stock is much less than that of spring-planted stock, but that early height growth was greater in the fall-planted stock.

The main reasons for conducting planting during the fall are to lengthen the planting season and spread out the work load which would result in cost reductions. Repeating a fall planting study in the future may be worthwhile. The study conducted during this project would need to be revised, giving consideration to the design and results from this study. Another fall planting research option would be to compare a spring planting to a fall planting, using either containerized or bare root planting stock. Because the later planting treatments (three and four) showed increased survival, future fall planting research should emphasize outplanting that commences much later in the fall.

Providing the necessary soil moisture for seedling root growth and establishment seems to be a critical factor (Adams, et al., 1991). For better fall planting results, the stock should be acclimatized to the planting site, an adequate water supply should be provided, and the amount of vegetative competition should be decreased.

Determining the effect that timing of fall planting had on the survival and growth of black locust was the objective of this study. The hypothesis was that trees planted later in the fall season would have increased survival over those that were planted earlier during the fall. Because of the inability to provide sufficient maintenance during the growing season and poor experimental design, the hypothesis could not be validated or disproved.

CHAPTER VII

COMPOST STUDY

This experiment was undertaken but could not be satisfactorily completed due to uncontrollable circumstances. In spring 1992, an experiment to study the effects of the surface application of compost on the growth and survival of black locust was initiated. The objectives of this study were to test the effects of surface application of compost on the survival and height of black locust. The hypothesis was that the surface application of compost would help to maintain weed control, conserve moisture and promote better growth.

There were four treatments which consisted of: 1) a six to eight inch surface application of compost alone, 2) a combination of pre-emergent and post-emergent herbicides with a compost application, 3) a combination of pre-emergent and post-emergent herbicides, and 4) a control of no compost or weed control. A diagram of the plot layout for this experiment is presented in Figure 17. The 1-0 planting stock used for this study was questionable in terms of vigor when provided for planting. It seemed to be of low quality and in poor health. There was tip dieback on most seedlings which comprised about ninety-five percent of total seedling height. The roots also showed some signs of necrosis. Mid-season survival was only fifteen percent (sixty-five of 432 trees). Several weeks later, some of the trees in this study were inadvertently mowed, further decreasing the sample size. Heavy mortality made it impossible to obtain reliable information from this study.

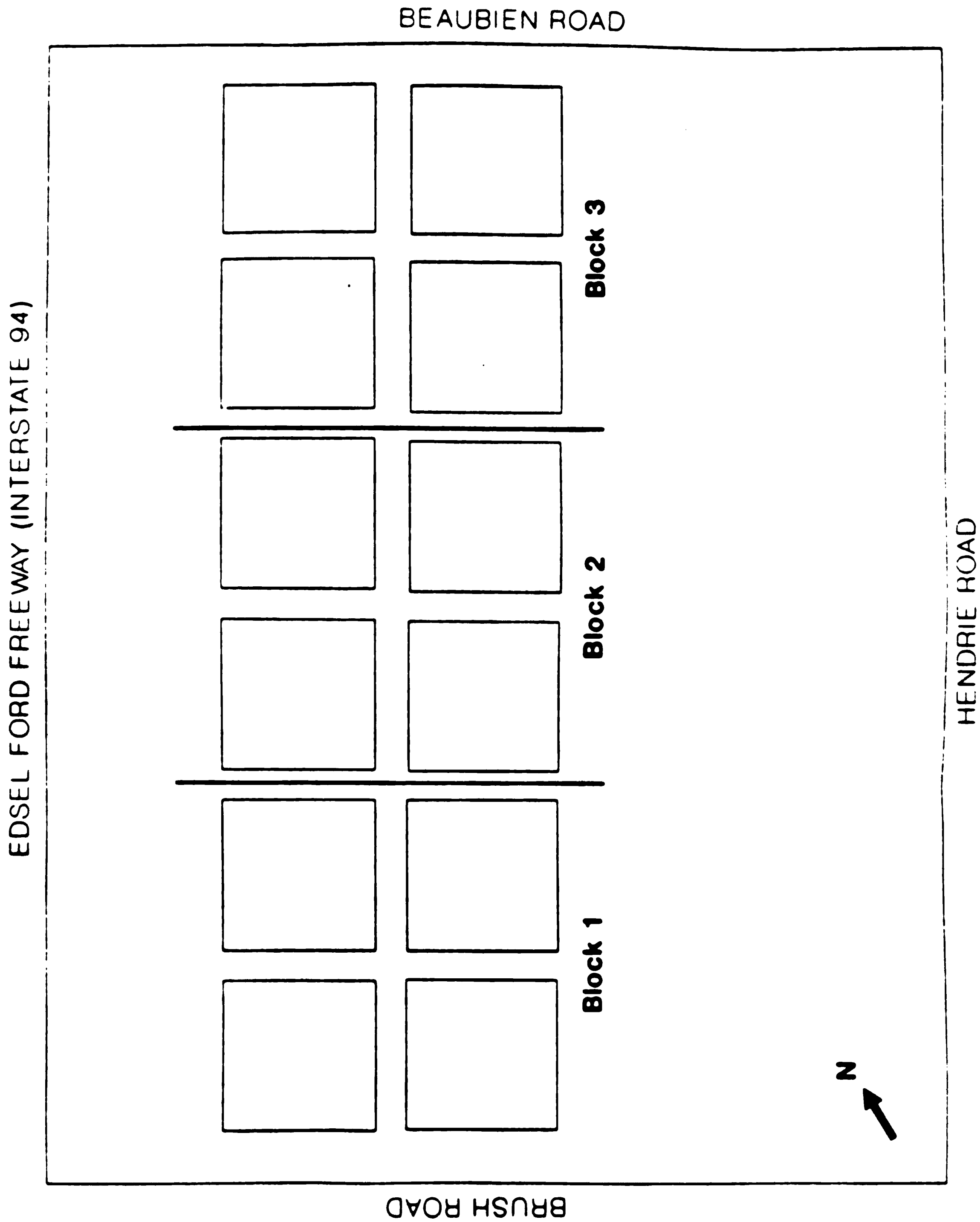

Figure 17. Diagram of the Weed Control Study Located on Lot #1

CHAPTER VIII

SUMMARY AND RECOMMENDATIONS

The purpose of this research project was directed at assessing the performance of, and suitable cultural methods for, black locust on an urban site within Detroit. This chapter summarizes the findings of this project and then draws conclusions. Recommendations are also given for future research.

SUMMARY OF FINDINGS

Several studies were conducted to provide information on the performance of black locust on the site after two growing seasons. The compaction study focused on the effect that soil compaction has on the growth and performance of black locust. The hypothesis that areas that are more compacted will have less tree growth, was not supported by this study.

The direct seeding study evaluated the success of seeded black locust on an urban site. The hypothesis that direct seeded black locust would be successful on this site could not be tested because the seeds did not germinate. The fall planting time study was conducted to determine the best time during the fall season to plant black locust seedlings. The hypothesis was that seedlings planted later during the fall will have better survival than those planted earlier during the fall. The hypothesis could not be tested for two reasons, 1) because of the inability to collect data at the end of the growing season, and 2) because of flawed experimental design.

The compost study was undertaken to determine the effect of a surface application of compost on black locust performance but this study was unable to be completed.

DISCUSSION

Based upon the findings of this research, it is not possible to determine what would be the best cultural methods for black locust on this site. Based on July, 1993 observations made on the remaining trees and their survival and growth data from 1991 and 1992, black locust shows good performance on this site. It is likely that black locust would be a suitable species for revegetation of this site and others that are similar.

Perhaps the most important aspects of conducting research in an urban area or implementing an urban reforestation project, are planning and design. Careful assessment of research project objectives, like funding, making sure they meet the objectives of the potential user, and thorough site assessment are necessary to ensure success.

Because vandalism became an issue for this particular project, giving consideration to a more sociological approach in combination with the biological research is recommended.

Based on the information obtained through this research, it is difficult to give specific recommendations to the city. Thorough on-site investigation is needed in order to effectively determine potential uses for the vacant land in Detroit. At this point, further research is strongly suggested. The research recommendations given throughout this text are ideas formulated on the experience and information gained from this effort, and they were presented for future consideration by both the city and other researchers.

FUTURE RESEARCH RECOMMENDATIONS

* Species comparison trial on various sites throughout the city

* Spring planting versus fall planting using containerized ɒ bare root stock of several species

* Fall planting conducted later in the fall season comparing stock that has been acclimatized at the planting location and outside of planting location; testing different watering regimes after planting

* Direct seeding initiated in early spring, testing different watering regimes or mulch applications on several species

* Examining the response of different species to fertilizer applications based on site soil nutrition

* Detailed soil surveys assessing physical, biological, and chemical properties across a range of urban sites to determine the extent of variability

Future research projects should be assured full support so that they may meet their objectives. It is important that research designs, plans, schedules, and needs be carefully thought out, and accepted and understood by city officials.

If further research is not able to be conducted, then the best suggestion to the city, assuming that they prefer trees on the vacant land, would be to establish city-wide plantings of trees. Depending on the long term survival of black locust on this research site, city-wide planting operations may be economically, aesthetically and environmentally feasible. City-wide plantings of bare root black locust, along with other species known to be tolerant of urban environments such as that encountered in this research, would be a reasonable practice.

GLOSSARY

APPENDIX

Table A.1. Fertilizer recommendations for twelve composite soil samples collected from the study site in 1991 and 1992.

1991

Nutrient	Fertilizer Recommendation (pounds/1000 ft^2/year)
Nitrogen (N)	2.0 - 3.0
Phosphate (P_2O_5)	4.0 - 5.5
Potash (K_2O)	0

1992

Nutrient	Fertilizer Recommendation (pounds/1000 ft^2/year)
Nitrogen (N)	3.0
Phosphate (P_2O_5)	1.0 - 7.0
Potash (K_2O)	0

* Recommendations were made based on trees and shrubs as crops

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