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Residual effects of soil sterilants

William V. Sigler Jr.

To the Graduate Council:

I am submitting herewith a thesis written by William V. Sigler Jr. entitled "Residual effects of soil sterilants." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Lawrence N. Skold, Major Professor

We have read this thesis and recommend its acceptance:

H. C. Smith, M. E. Springer, Henry Andrews

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

November 25, 1960

To the Graduate Council:

I am submitting herewith a thesis written by William V. Sigler, Jr. entitled "Residual Effects of Soil Sterilants." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Lawrence N Skold
Major Professor

We have read this thesis and recommend its acceptance:

H.C. Smith

M.E. Springer

Henry Andrew

Accepted for the Council:

H. E. Spivey
Acting Dean of the Graduate School

RESIDUAL EFFECTS OF SOIL STERILANTS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree of

Master of Science

by

William V. Sigler, Jr.

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INTRODUCTION

Weeds and brush growing on land used for industrial purposes cause inconvenience, create a safety hazard, and may be injurious to health. If these could be controlled for several years by making one application of a herbicide, millions of dollars of labor and machinery expense could be saved annually. In addition, there would be much help in reducing allergies and other ailments that affect the health and safety of our population.

Herbicides for controlling vegetation are finding wide use by railroads on roadway and ballast. Some railroads have spent as much as $200.00 per acre for herbicides in switchyards each year. Other areas of extensive use include utility substations, petroleum tank farms, industrial plant areas, storage areas, terminals, lumber yards, parking areas, roadsides, highway guard-rails, fence lines, pipe lines, airport runways, and other non-crop areas.

Although many materials are on the market, little research has been conducted to determine the residual effects of sterilants. Much of the observational work to date has been on coarse textured soils and in areas of low rainfall. This study was initiated to determine the effectiveness of vegetation control by different herbicidal materials used at selected rates and times of application on soils of contrasting physical properties under the climatic conditions found in East Tennessee.

CHAPTER II

REVIEW OF LITERATURE

Definitions

Crafts and Harvey (8) describe terms commonly used when dealing with soil sterilants: "Soil sterilization" denotes treating the soil with chemicals to make it unsuitable for plant growth. "Residual effect" indicates the length of time a chemical will persist in the soil and create the desired results. "Temporary soil sterilant" designates effect for less than one year, "permanent soil sterilant" for more than one year.

History

Chemicals have been used for centuries to control weeds (23). Salt, ashes, and various industrial by-products have been applied to roadsides, fence rows, pathways, and areas of fields infested with noxious weeds to rid them of vegetation. Little scientific progress was made until the latter part of the nineteenth century. Jones and Orton (13) in 1899 compared the use of crude carbolic acid to arsenite of soda, a mixture of white arsenic and sal soda. He reasoned that the former, though a very powerful and quick acting herbicide did not endure as long as the latter.

Ashlander (2) in 1928 reported the use of sodium chlorate, $NaClO_3$; potassium chlorate, $KClO_3$; sodium thiocyanate, NaCNS; sodium cyanide, NaCN and sodium arsenite, $NaHAsO_3$. He stated that the effectiveness of chlorates on perennials was due to rapid penetration through the soil and slow decomposition, especially at low temperatures. Crafts (6) compared several soil sterilants on a cost basis and found trivalent arsenic to be the most feasible chemical for soil sterilization. Extension of its use has since been impaired because of the great potential loss due to mammalian toxicity.

Since 1937, with the discovery of phenoxyacetic acid, researchers have been trying to find out the effects of herbicides on the soil in addition to their deleterious effects on weeds. Much research on residual effect has concerned the substituted phenoxyacetic acid materials and carbamates used for pre- and post-emergence control of weeks in crops. This information has been summarized by Roberts (24). These materials, when applied at the proper rate, kill germinating weed seeds but do not damage some crop plants.

The question raised was whether these herbicides build up a residue in the soil. Reid (21) reported no long-time damage to soil from use of organic herbicides. Hernandez and Warren (11) found that factors affecting microbial activity determined to a large degree the length of time 2,4-dichlorophenoxyacetic acid persisted in the soil. An increase in soil temperature shortened the period of inactivation; an increase in moisture in an air dry soil had the same effect. In sterilized moist soil 2,4-D was still toxic at the end of 12 weeks of storage in the greenhouse; however, in unsterilized soil, 2,4-D was inactivated at the end of 4 weeks.

Many herbicides ordinarily used at pre- and post-emergence rates for controlling weeds in crops are used today for industrial purposes at higher rates against annual and perennial broadleaf weeds and grasses on nonagricultural land.

The 1957 season completed a total of 18 years of research by the Railroads on the control of vegetation. This work represented more than 5,000 individual tests of herbicides, combinations of herbicides, and of rates and dates of application under a wide variety of soil, ballast, climatic and vegetational conditions.

Parris (20) reported no single chemical available that would economically control all plant species found under the many varied conditions throughout the United States. However, he indicated the possibility of reducing costs by following a properly planned long-term weed control program.

In Iowa, seasonal control was obtained by the use of a number of materials, but certain chemical combinations provided the most effective results. Parris (20) favored the use of soil sterilant materials followed in succeeding years with herbicidal oils, and stated that the use of certain soil sterilant chemicals on small areas of particular persistent perennials resulted in a substantial saving. In Florida, a mixture of a systemic grass herbicide and a relatively insoluable soil sterilant controlled most native vegetation for at least one growing season. Montana results showed better control from fall than from spring application of soil sterilant chemicals. With the control of perennial grasses, Canada thistle (*Circium arvense*), became a serious problem. Soil sterilant type materials appeared expensive and good for only one season on Bermudagrass (Cynodon dactylon), in North Carolina.

All of these were empirical studies. Certain treatments were applied to plots and a tabulation of species not controlled was made (22).

Factors Affecting Residual Control

Researchers agree that several factors affect the persistence and movement of herbicides in the soil (8, 11, 23, 24). These factors according to Robbins et al. (23) and explained by Crafts and Harvey (8) and Roberts (24) determine the usefulness of a particular chemical:

1. Inherent toxicity. This is the nature and arrangement of atoms and molecules in some chemicals that make them toxic to plants. Application rate and formulation are important.
2. Absorption. Some chemicals adhere to the surface of soil colloids more than others. Thus, in clay soils they may be so tightly held by the soil particles that they are not available to the plant roots even though they are present in the soil in relatively large amounts. Organic matter also has an influence.
3. Decomposition. Chemicals break down in soils at different rates. Factors affecting bacterial action are of utmost importance.
4. Leaching. Chemicals used as soil sterilants differ in solubility and in the ease with which they move. Soil texture and structure affect the rate of vertical and

lateral movement of water through it.

5. Soil composition. Fertility, salt content, and acidity or alkalinity of soils all affect the toxicity and persistence of a soil sterilant.

6. Species tolerance. Weed species vary widely in their inherent tolerance of chemicals.

Hill et al. (12) continue the list:

7. Physical removal of the chemical by windblow or chemical decomposition by exposure to ultra-violet light in arid areas such as are found in parts of the western United States when the chemical is applied and remains on the soil surface.

Several research workers believe that no one of the afore mentioned factors determines the usefulness of a soil sterilant for vegetation control (8, 17, 25). Rather the interplay of the several factors determine whether a given chemical will kill shallow or deep rooted weeds, whether it be temporary or relatively permanent and to a large degree how much will be required to give satisfactory results. To give successful control of perennial vegetation a herbicide must be distributed in the soil where the roots are located and at the time these roots are active. It must be present in a lethal concentration for a period long enough to permit enough absorption by the roots for killing.

Past Research on Materials Used

Borate

Crafts and Raynor (9) reported that since borates are non-poisonous and fire deterrent, they have advantages over arsenic or sodium chlorate. Furthermore low solubility and high toxicity at low concentrations to some plants reduce probability of reinfestation by seedlings. Crafts and Cleary (7) agreed; however, Crafts and Raynor (9) stated that borates are not retained against the leaching power of moving water to the same extent as arsenic. Stone and Stahler (28) indicated that a unit of boron trioxide is equivalent to a like unit of sodium chlorate as a plant toxicant. Crafts and Raynor (9) would confine the use of borates to coarse soils and gravelly areas where rainfall exceeds 10 inches annually to insure the leaching of the material into the root zone.

Monuron

According to Loustalot et al. (15) experiments in Puerto Rico have shown 3-(p-chlorophenyl)-1,1-dimethyl urea to be potent, non-selective and capable of controlling most weeds when applied at relatively low rates. Weise (31) reported that when monuron was applied at the rate of 60 pounds per acre to soil in Texas vegetation was controlled for 3 to 5 years.

Other researchers have found varying results. At soil sterilization rates, Danielson in Florida (10), stated that 50 pounds per acre of monuron was dissipated sufficiently in 24 months to allow early vegetative growth of snap beans and sweet corn in a sandy clay loam. Andrews and Richards (1) found that 38.4 pounds of monuron was needed to give 70% control of woody species by the end of the second year in Tennessee.

Upchurch and Pierce (29) in a greenhouse experiment found monuron was leached readily from Lakeland soil when present in soil sterilant quantities. They found that 12 inches of simulated rainfall, applied in 8 increments at 1/2-hour intervals, leached 89% of a 40-pound per acre application below 2 inches and 51% below 24 inches.

Differences in findings after a similar experiment were reported by Loustalot et al. (14), who indicated that monuron at 80 pounds per acre failed to leach beyond the 15-inch soil depth.

Other factors causing decomposition of monuron were reported by Loustalot et al (15) and Upchurch and Pierce (30). Upchurch and Pierce (30) reported that greater soil temperatures, above 5° to 45° C, caused less leaching. An increase of organic matter from 0.87 to 1.44% caused an increase from 35 to 95% in the amount of monuron retained against leaching. Loustalot et al. (15) reported that factors generally favoring soil microbial action seemed also to favor disappearance of monuron from the soil. Monuron persisted longer at 10° C than at room temperature. Monuron persisted longer in air dry soil than in soil with a medium or saturated moisture level. Sandy soil retained the toxicity longer than did soils with a higher clay content. Toxicity persisted longer at the higher rate of application.

Simazine

Scudder (26) experimented with 2-chloro-4,6-bis(ethylamino)-S-triazine persistence in two central Florida soils. Thirty-two pounds per acre incorporated into the soil lasted 1 year on peat, stunting squash the second spring. All vegetables including the sensitive turnips and lettuce grew on the plots 1 1/2 years following the initial application.

Sodium Chlorate

Weise (31) reported that an application of this material at the rate of 800 pounds per acre sterilized soil for 3 to 5 years in Texas. Crafts (5) stated that deep rooted perennials could be killed either by rapid absorption and translocation of chlorates within the plant from foliage application or by absorption from the soil by the roots, and that both actions operating simultaneously were more effective than either alone. Wilson et al. (33) agreed with this statement. Ashlander (2) reported that chlorate effectiveness was due to rapid penetration into the soil and slow decomposition, especially at low temperatures. Crafts (5) reported that proper vertical leaching and distribution of chlorate within the soil was essential to success with the soil treatment method, but that leaching sterilized areas with 36 inches of irrigation water returned the area to crop use within one season. Mucher (16) mentioned this method of controlling perennial weeds as too expensive to be employed on large areas.

T C A

This material has been studied more for weed control in crop production than as a soil sterilant (3, 4, 18). Absorption by underground parts was established by Barrons and Hummer (3) as being the primary avenue of entry by trichloroacetic acid for wheat and soybeans. The material had a greater effect on grasses low in carbohydrate reserve than grasses higher in stored carbohydrates. A wide variation in the tolerance of crop plants was found. Blouch and Fults (4) found that TCA gave selective control of annual grasses without crop injury on Fort Collins loam, and non-selective phytotoxicity at the same rate on Valentine loamy fine sand and Terry silty clay loam. The latter soils were low in organic matter and fertility whereas the former soil was high in organic matter, nitrate and phosphate.

Owens (18) reported that without tillage, sodium TCA at the rate of 100 pounds of formulation per acre and up was effective in eradicating centipede grass in Northwest Florida. The herbicide at 50 pounds and 75 pounds per acre without tillage reduced the stand of centipede grass by 50 to 75%, but the remaining sprouts engulfed the entire area. Decomposition of the material allowed the area to be seeded to bahia grass (*Paspalum notatum*), 1 1/2 months after treatment.

Combinations or Mixtures

Parris and Rodgers (19) observed 50 herbicidal treatments for controlling weeds on railroad right-of-way in Florida. A mixture of TCA and sodium chlorate at the rate of 40 to 80 pounds per acre, repeated at 60-day intervals, provided the most effective control in all growth stages. Generally, better response was obtained when the treatments were applied during the dormant season and early plant growth stage with little difference observed between the January and March application. A combination of TCA-sodium chlorate-monuron at rates

40-80-20, 80-80-10 and 80-160-10 effectively controlled weeds throughout the season in all dates of application.

Crafts and Cleary (7) found that a borax-chlorate combination for soil sterilization had several advantages. In addition to being practically non-poisonous the borax reduced the fire hazard to a low level and probability of reinfestation by seedlings. Antagonistic reactions between the two materials were reported to have been reduced to a minimum by using the lowest effective dosage of chlorate and adding enough borax to complete the destruction of the vegetation.

Stone and Rake (27) stated that cumulative effects concerning combinations of materials would be considered by some investigators as demonstrating synergistic action. He would consider the additional increment in herbicidal effectiveness of the complex as resulting from the biostatic activity of the borate addition to the complex.

CHAPTER III

MATERIALS, METHODS AND EQUIPMENT

Field Procedure

This study was designed to study the effectiveness of vegetation control by five selected soil sterilants used at selected rates, applied in the fall and spring, on soils of contrasting physical properties.

These materials were applied to three different soil types: Etowah silty clay, Tellico loam and Neubert fine sandy loam, in order to determine differences in vegetation control by residual effect of the herbicides as influenced by soils of different texture, bulk density, and available water storage capacity. Each soil was within a 3-mile radius of the Tennessee Agricultural Experiment Station at Knoxville. None of the areas selected had been cultivated for at least 5 years, and all were heavily infested with annual and perennial grasses and broadleaf species.

The dominating vegetation on Etowah silty clay was broomsedge (Andropogon virginicus), and crownbeard (Verbesina sp.). Broomsedge, Bermudagrass (Cynodon dactylon), sericea lespedeza (Lespedeza cuneata), and common blackberry (Rhus alleghenienis) were dominant on Tellico loam. Kentucky bluegrass (Poa pratensis), goldenrod (Solidago sp.), sericea lespedeza, and tall red-top (Triodia flava) were dominant on the Neubert fine sandy loam.

Prior to the application of herbicides a botanical survey was made of each area to identify and record the species present. The selected areas were mowed and the weeds raked and removed in September of 1957 to facilitate application of the chemicals.

Five soil sterilants were applied, at three different rates, as shown in table 1. Chemicals were chosen to represent: 1. a commerical mixture; 2. a substituted urea; 3. a triazine; 4. sodium chlorate; and, 5. sodium TCA. The middle rate of each herbicide used was the approximate rate recommended by the manufacturer. The lower rate was 1/3 to 1/2 less and the higher rate was 1/3 to 1/2 more.

A randomized block design with split plots replicated three times was used on each soil type. Plots were 10 feet by 10 feet in size and were split into sub-plots 5 feet by 10 feet for fall and spring applications. An 18-inch border was left between plots. Alleys 5 feet wide separated each range of treatments permitting an evaluation of lateral movement.

Materials applied were first mixed with 3 gallons of water so as to form a slurry. To insure uniformity in distribution of the herbicide 1/3 of the total amount was applied to the plot area in each of 3 successive applications. The fall application was made November 5, 1957, and the spring application March 15, 1958. The following May, July, August, and October plots were rated visually according to the degree of vegetation control. A scale of 0 to 10, using 0 for no control, and 10 for complete kill, as described by Willard (32) was used.

In June, 1958, a second botanical survey was made to identify and record the species that were not controlled by the several treatments.

Table 1.--Herbicides and rates of application.

Herbicide	Rate in lbs. active ingredient per acre
"Chlorea" a/	2320
	3480
	4640
Monuron	50
	75
	100
Simazine b/	10
	20
	40
"Atlacide" c/	800
	1600
	2400
Sodium TCA d/	75
	125
	175
Untreated Check	----

a/CBMM (Chlorea); sodium chlorate (40%), sodium metaborate (57%), and monuron (1.25%), 3-(p-chlorophenyl)-1,1-dimethylurea.

b/50% wettable powder.

c/Sodium chlorate 58%.

d/90%.

Both colored and black and white photographs were made to provide a permanent record of the degree of control.

Laboratory Bioassay

A laboratory bioassay was conducted in order to determine the residual effect of the herbicides. In May, following the application of chemicals, soil samples were collected from each of the plots which had been treated with the heaviest rate of each chemical in the fall and from untreated adjacent areas. Five cores about 7/8 inches in diameter were taken from each plot with a soil sampling tube to depths of 0 to 2, 4 to 6, 8 to 10, 12 to 14, and 28 to 30 inches. The core sections of a given depth of three replications of each treatment on each soil type were composited in the field and placed in quart ice cream cartons.

Samples were removed to the greenhouse within 3 hours and thoroughly mixed. Enough soil was transferred from each sample to nearly fill a 1/2-pint ice cream cup. Indicator crops, a grass and a legume, were sown in each cup, their germination and growth providing a measure of residual effect of the herbicide in the soil.

Because of their large seed size and vigorous germination, Ogden soybeans (*Glycine max*) and Martin milo (*Sorghum vulgare*) were selected as sensitive legume and grass indicators. Ten seeds of each were planted in each cup and covered with 2 tablespoons of soil from the original sample. A filter paper cover prevented disturbance of the soil by watering. Sufficient distilled water was added from a polyethylene water jar to keep the soil near field capacity. A hole in the bottom of the cup was an aid to aeration. The cups were placed in a growth chamber having an average day temperature of 74° F., relative humidity of 52%, and a day length of 16 hours, light being provided by incandescent and cool white fluorescent lights. The night temperature did not deviate appreciably from the day temperature because of automatically controlled electric heaters. Samples were watered each day and at the end of 10 days a stand count was made. At the end of 5 weeks, ratings and photographs were made of the total growth.

CHAPTER IV

RESULTS

Field Results

A botanical survey was made in the fall of 1957 to identify and record the species present on each of the three soil types to be treated; a report is presented in Appendix A. The assistance and counsel of Mr. J. K. Underwood, Associate Agronomist, University of Tennessee, is gratefully acknowledged for identifying many species.

Environmental factors are known to influence the persistence of herbicides in soils. Therefore, rainfall and temperature data from the Tennessee Agricultural Experiment Station Greenhouse which was located approximately centrally among the treated areas are given in Appendixes B and C, respectively.

Soil sterilization herbicides were applied to the fall treated plots on November 5, 1957, and spring treatments were made March 15, 1958.

Figure 1 shows the average number of species on each plot when the tabulation of species not controlled was made. Generally the herbicides in decreasing order of effectiveness of vegetation control during the time studied were "Chlorea", monuron, simazine, "Atlacide", and TCA, respectively. Within 10 days after treatment all rates of all herbicides had killed the vegetation of each plot. "Chlorea" gave immediate control of annual and perennial broadleaf plants and grasses. Monuron did not give as rapid kill as did "Chlorea" but its delayed action was as effective. Monuron failed; however, to control Bermudagrass. Simazine gave control of

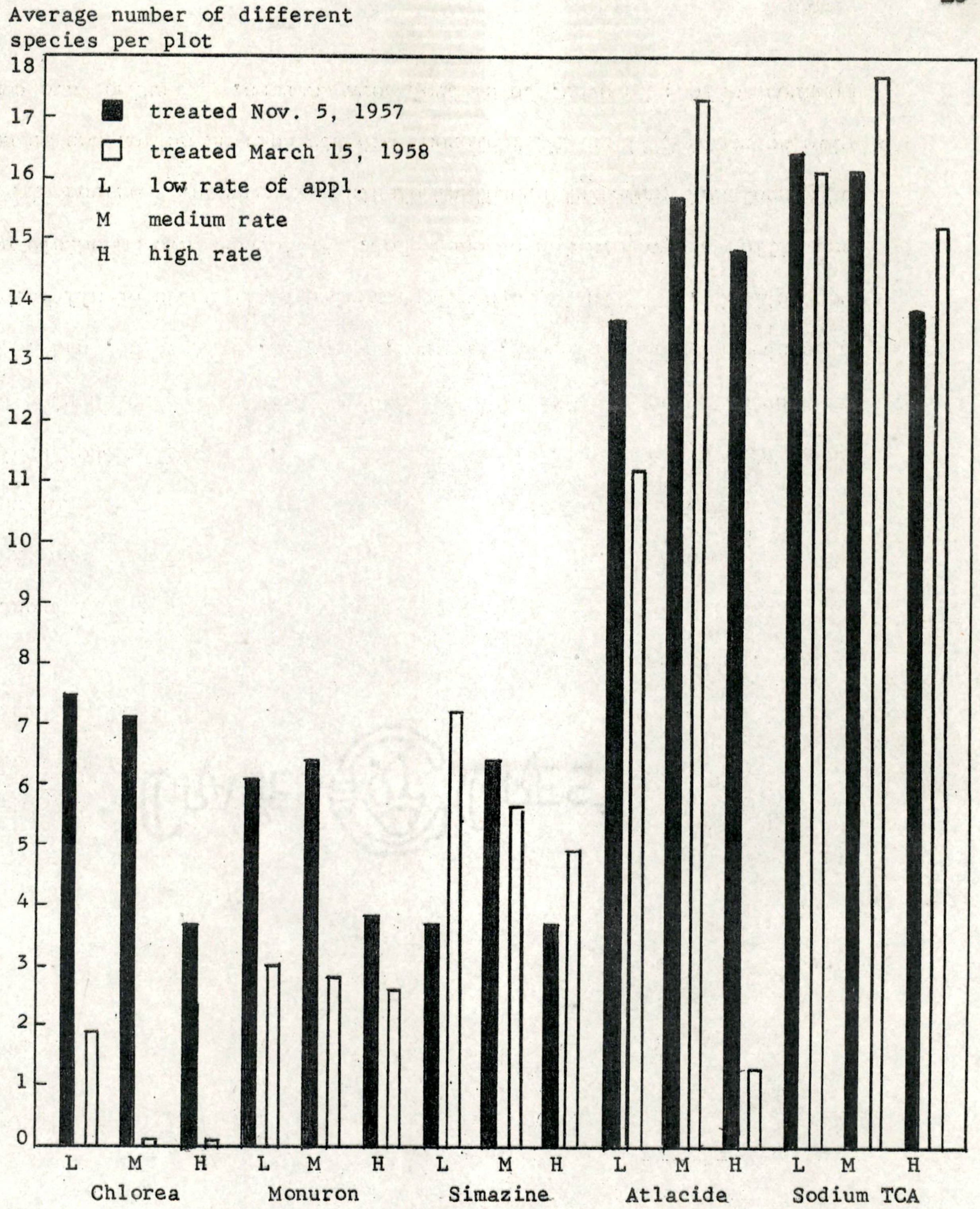


Figure 1--Average number of species per plot not controlled June 20, 1958, after treatment with specific rates of certain herbicides fall and spring 1957 and 1958, respectively. Figures represent an average of 3 replications and 3 soil types.

annual weeds and grasses but did not control perennials, such as Johnson-grass, Bermudagrass and sericea. "Atlacide" controlled broadleaf plants better than grasses, while TCA controlled grasses better than broadleaf plants.

Control ratings were made in May, July, August, and October 1958. The July ratings for fall and spring applications are shown in figures 2 and 3, respectively, on Etowah silty clay, 4 and 5 on Tellico loam, and 6 and 7 on Neubert fine sandy loam. These ratings indicate the degree of control of broadleaf plants and of grasses by each treatment on each soil type. These data show that several of the herbicides failed to control both grasses and broadleaf annuals and perennials.

The differences in residual toxicity among the three soil types were less pronounced than differences among the herbicides used. The only major influence of soil type and time of application in vegetation control is shown in figure 6. On Neubert fine sandy loam, the coarsest textured soil of the three treated herbicides dissipated and gave less general control than on any other treatments when applied in the fall. Parris (20) showed better control in a more arid area, Montana, from fall than from spring application of soil sterilant type chemicals.

In October, photographs were taken of the plots treated with the high rate, and control ratings made. These are shown in figures 8 through 22. It is apparent from these photographs that the chemicals had lost their effectiveness within 1 year from the time they were applied. Vegetation had partially covered the treated areas in all cases, and completely in some. The "Chlorea" treated plots showed less encroachment of vegetation than did the others.

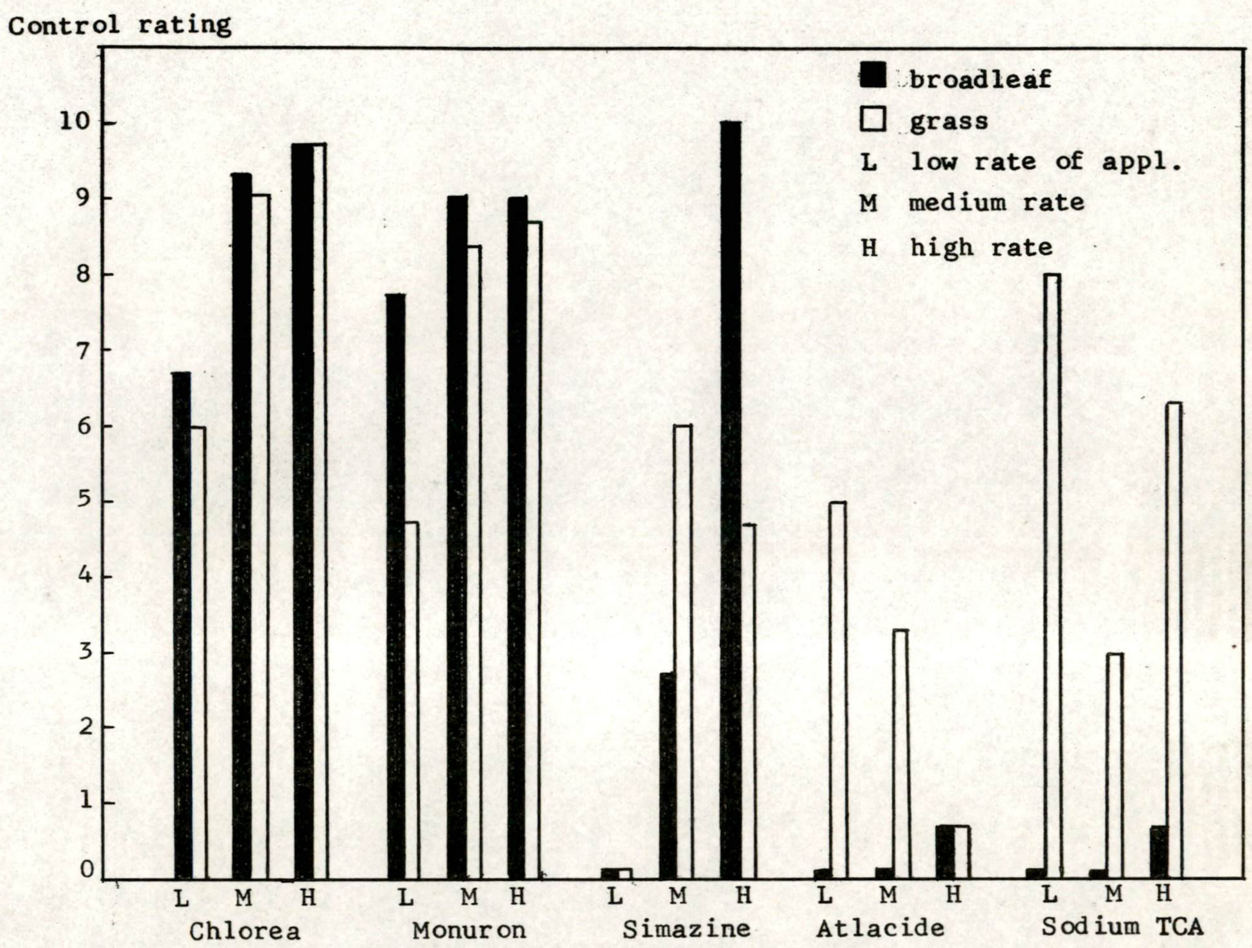


Figure 2--Control rating (July 5, 1958) of plots treated with certain soil sterilization herbicides.
Zero indicates no control; 10, complete control of vegetation.
Herbicides applied November 5, 1957.
Etowah silty clay, Knoxville, Tennessee.

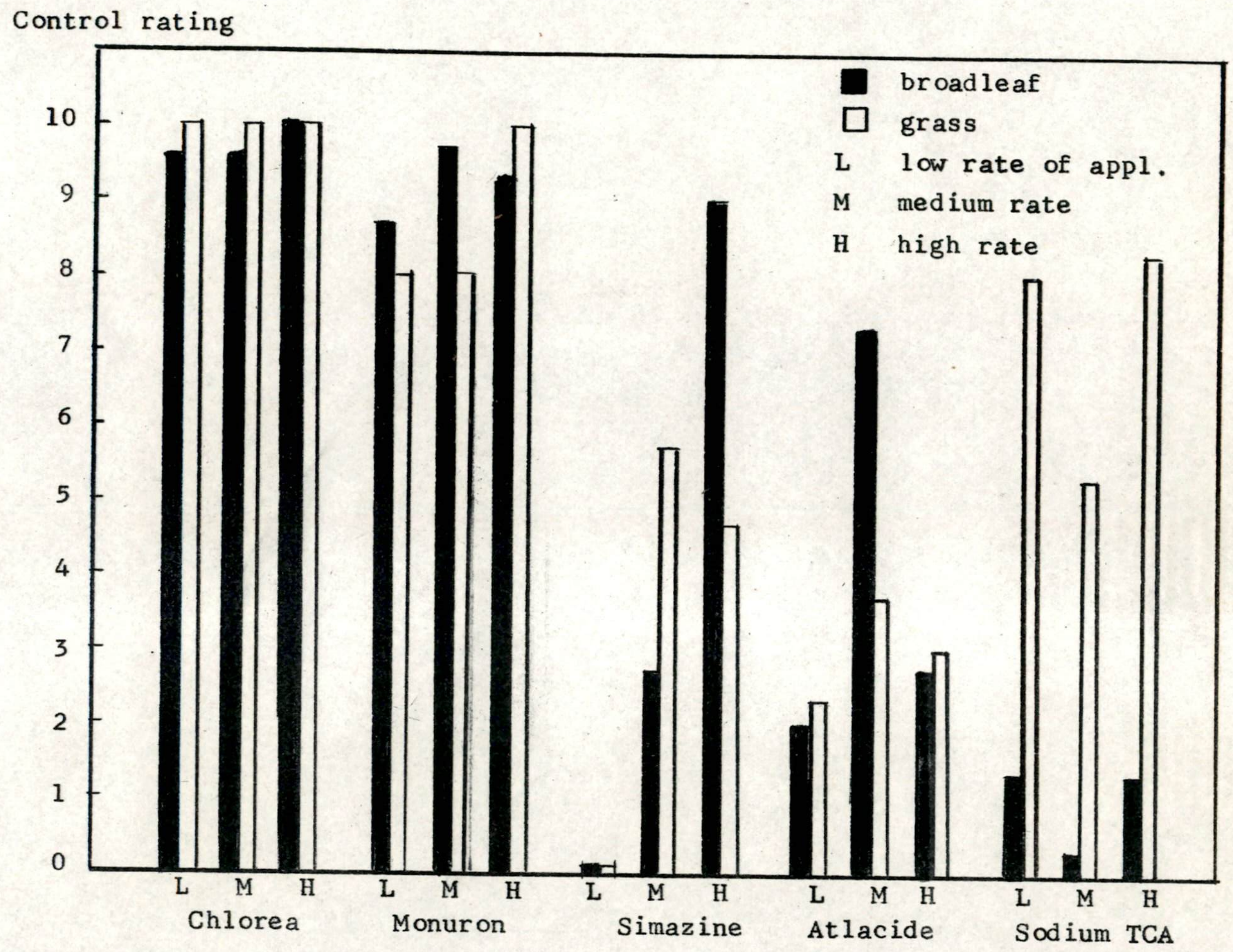


Figure 3--Control rating (July 5, 1958) of certain soil sterilization herbicides. Zero indicated no control; 10, complete control of vegetation. Herbicides applied March 15, 1958. Etowah silty clay, Knoxville, Tennessee.

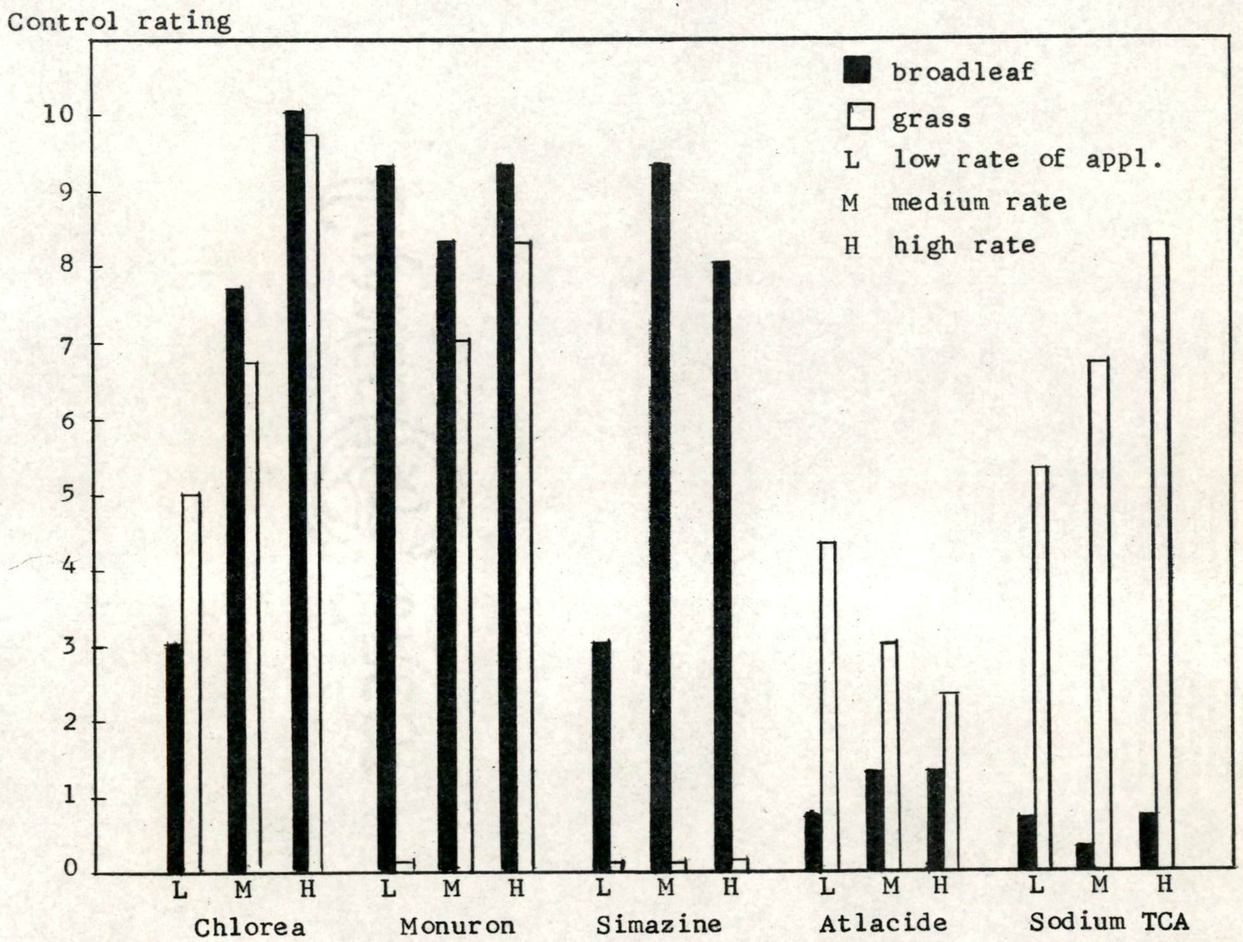


Figure 4--Control rating (July 5, 1958) of certain soil sterilization herbicides. Zero indicates no control; 10, complete control of vegetation. Herbicides applied November 5, 1957. Tellico loam, Knoxville, Tennessee.

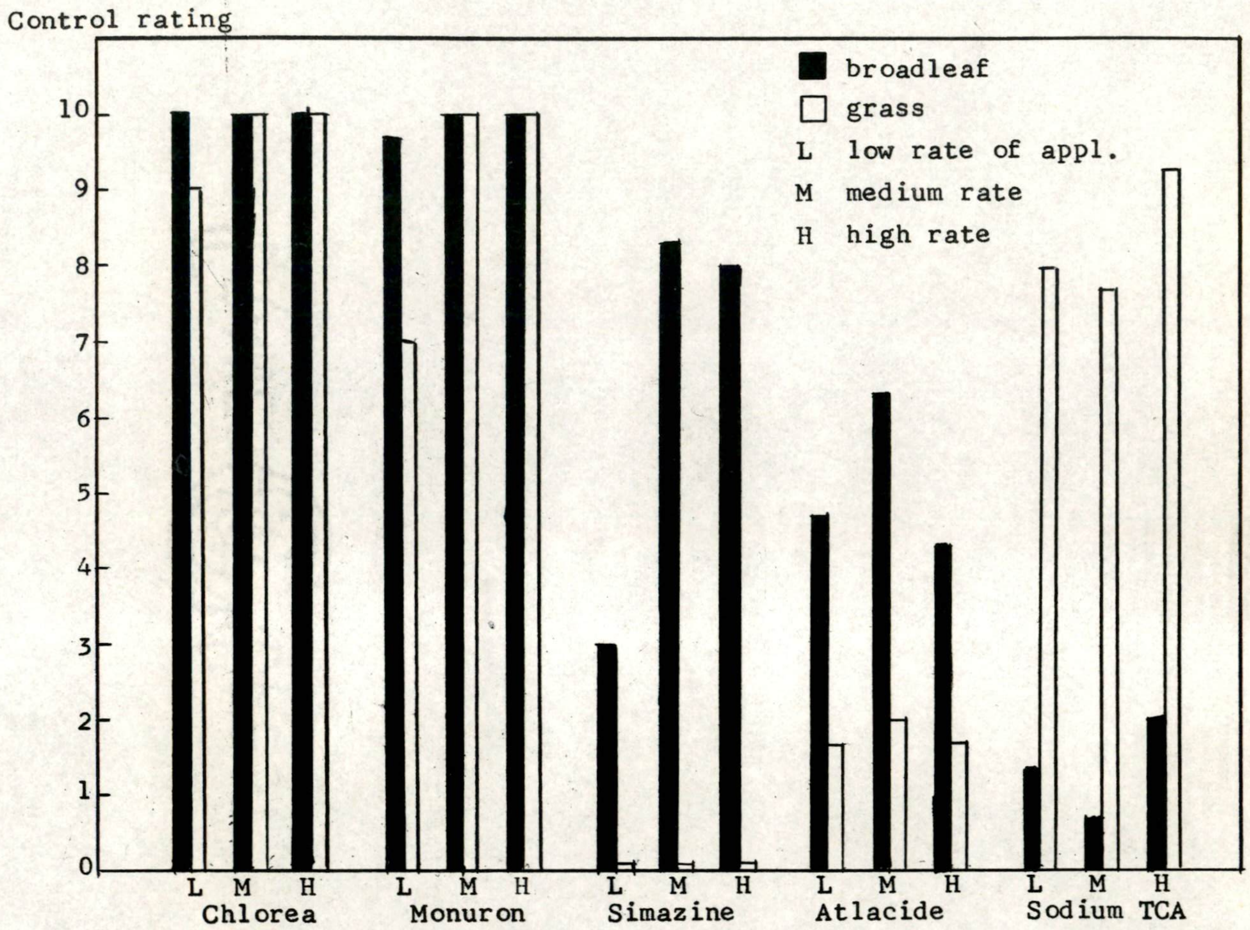


Figure 5--Control rating (July 5, 1958) of certain soil sterilization herbicides. Zero indicates no control; 10, complete control of vegetation. Herbicides applied March 15, 1958. Tellico loam, Knoxville, Tennessee.

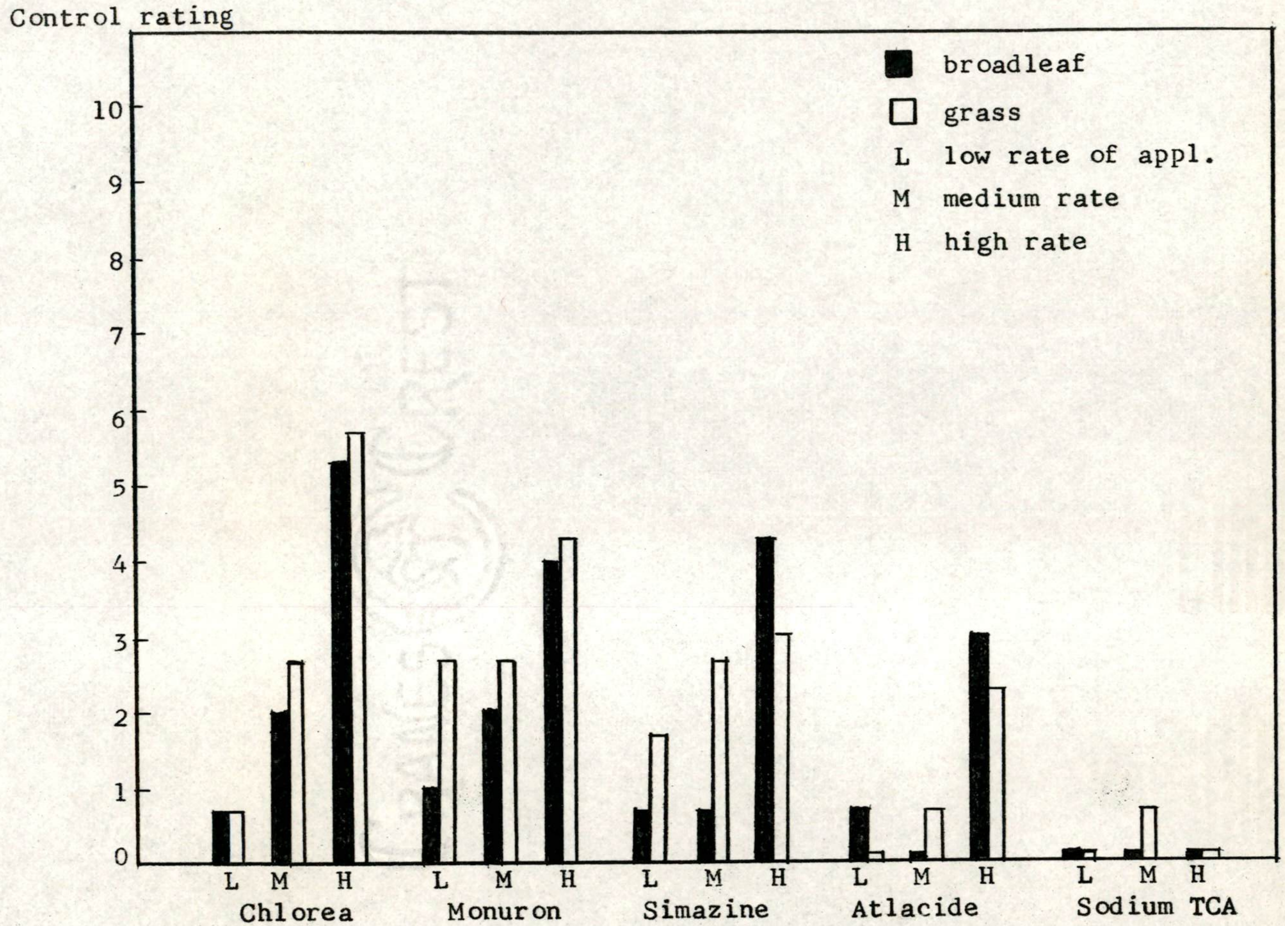


Figure 6--Control rating (July 5, 1958) of certain soil sterilization herbicides. Zero indicates no control; 10, complete control of vegetation. Herbicides applied November 5, 1957. Neubert fine sandy loam, Knoxville, Tennessee.

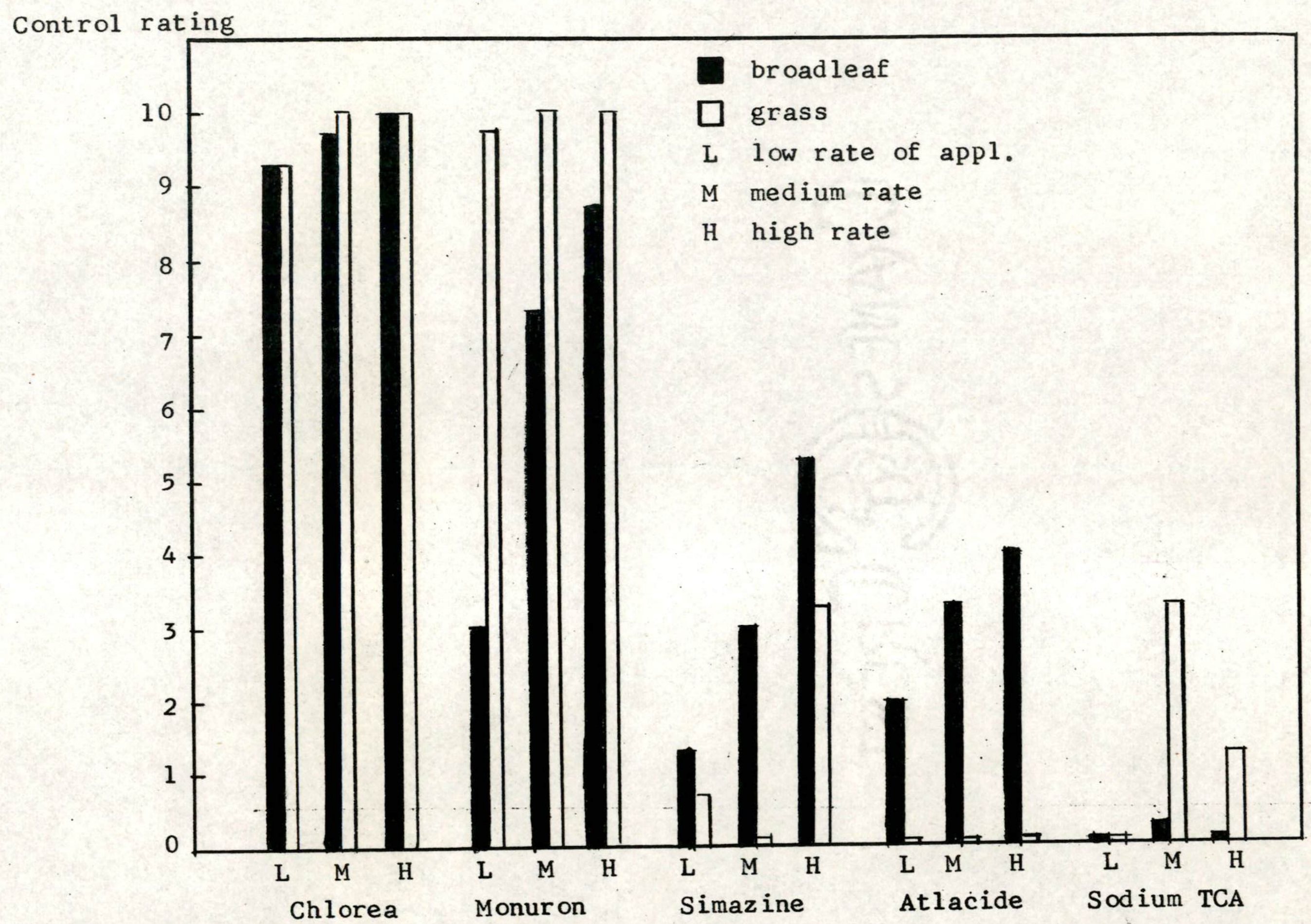
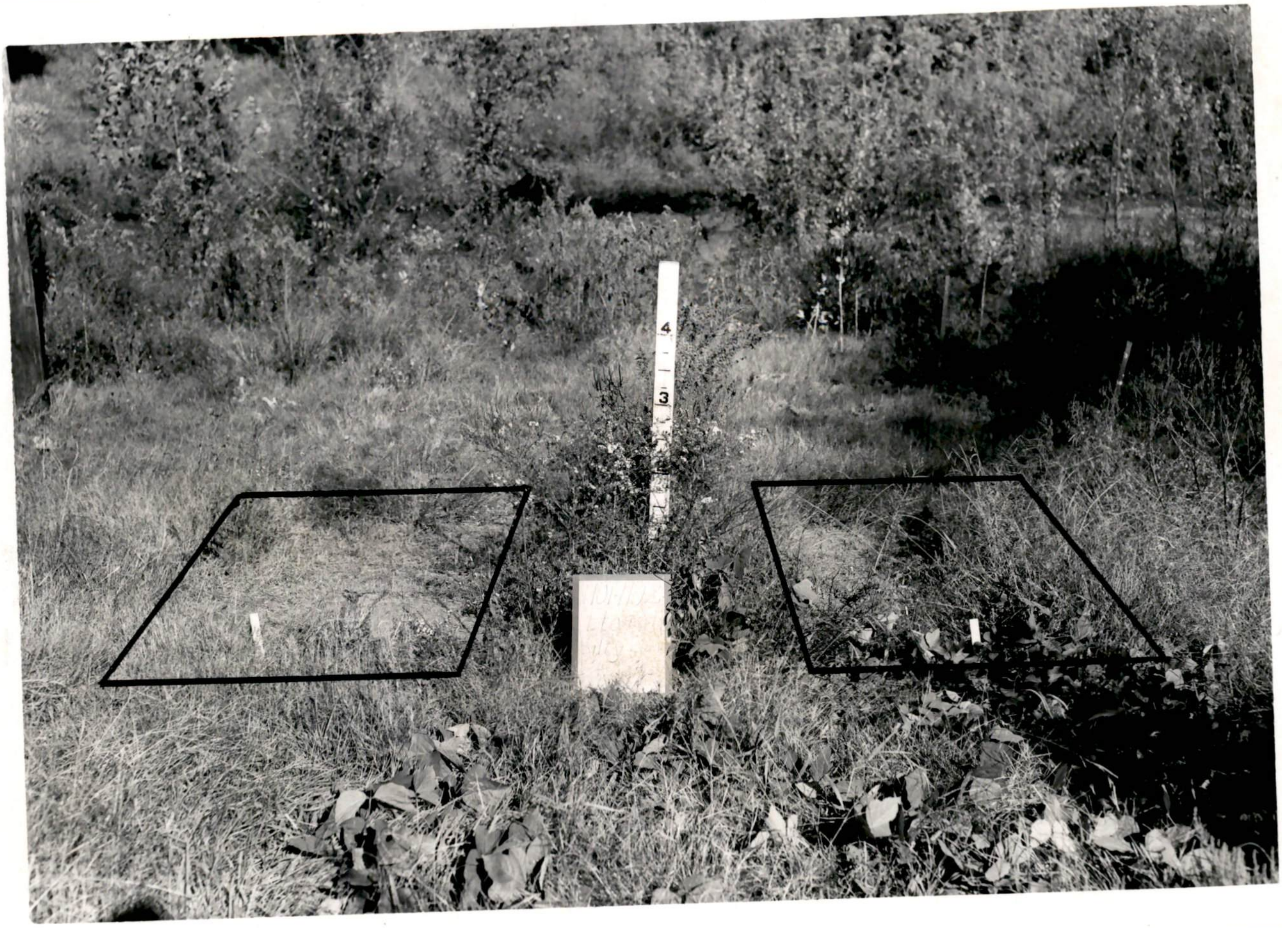


Figure 7--Control rating (July 5, 1958) of certain soil sterilization herbicides.
Zero indicates no control; 10, complete control of vegetation.
Herbicides applied March 15, 1958.
Neubert fine sandy loam, Knoxville, Tennessee.

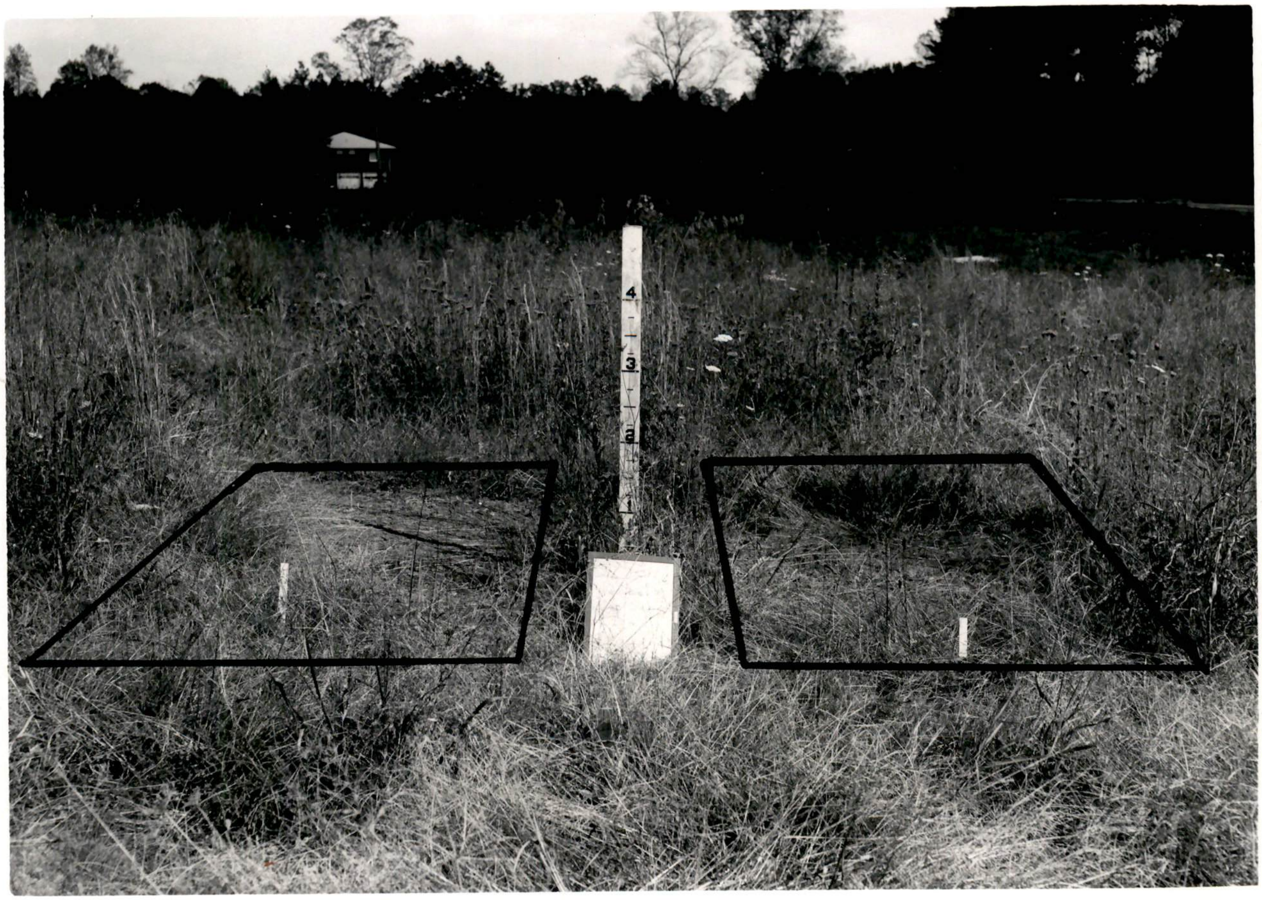


Fall treated   Spring treated

Figure 8--Photograph (October 28, 1958) of Etowah silty clay soil treated with the high rate of "Chlorea".

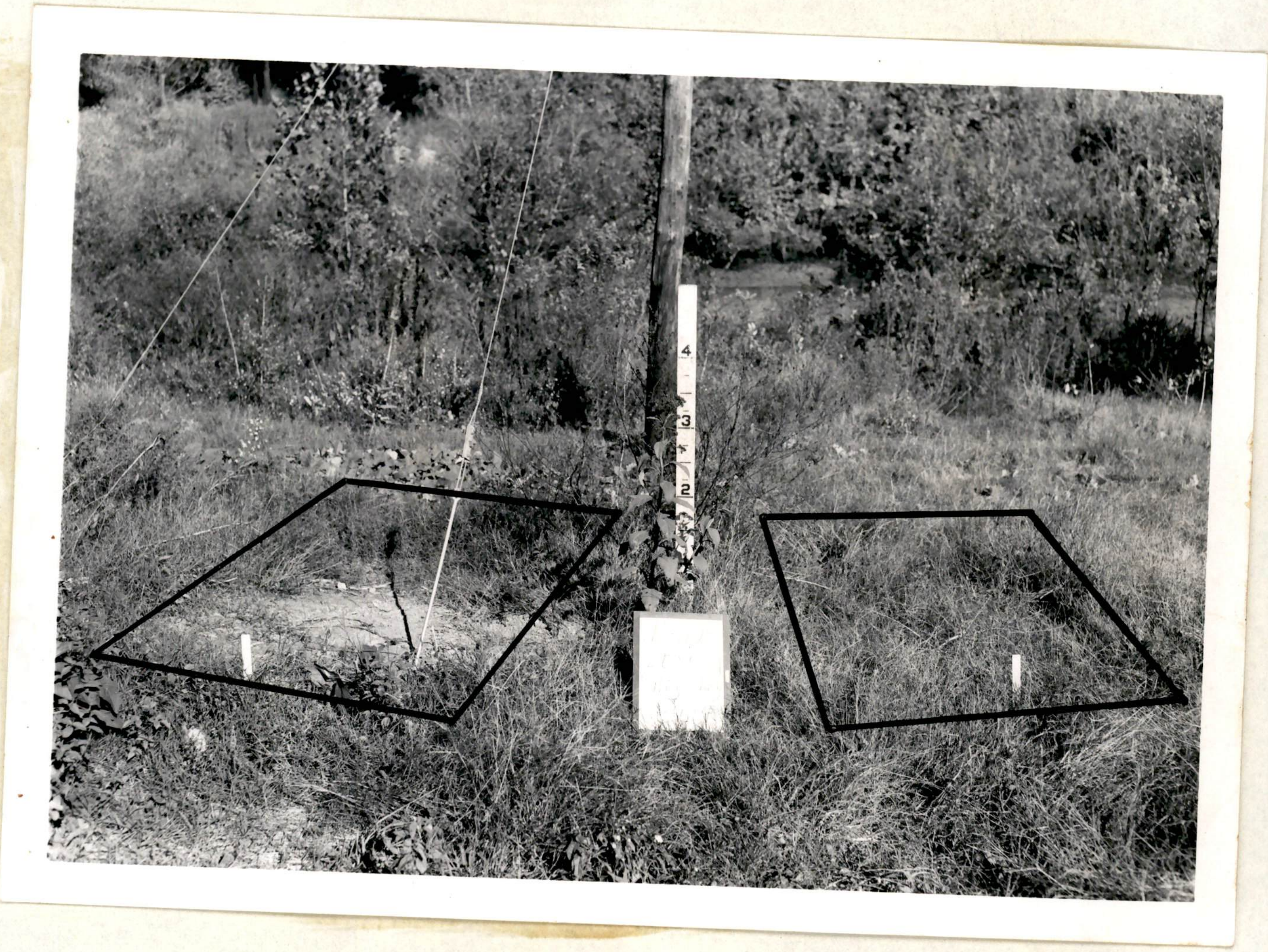
Fall treated Spring treated

Figure 9--Photograph (October 28, 1958) of Tellico loam treated with the high rate of "Chlorea".



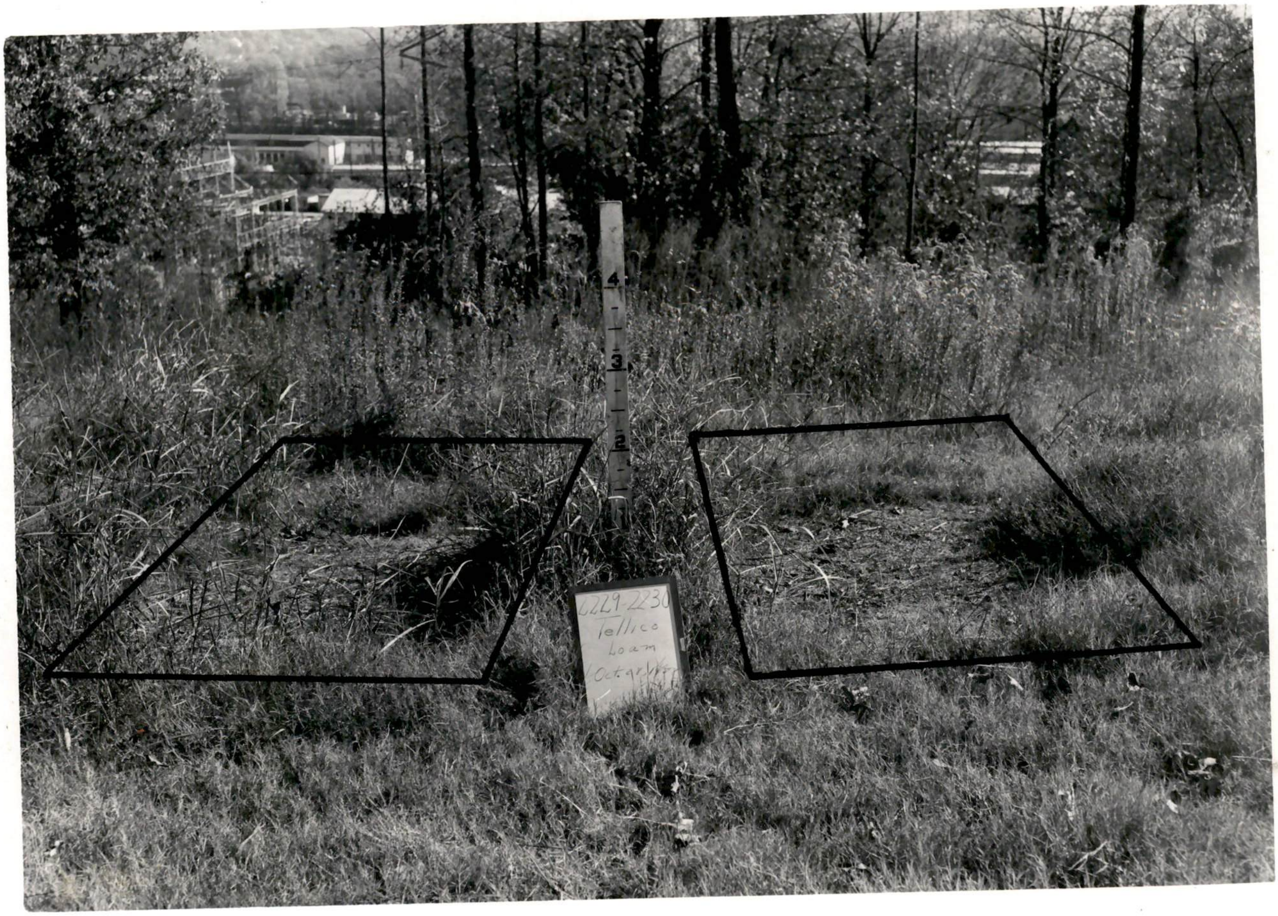
Spring treated   Fall treated

Figure 10--Photograph (October 28, 1958) of Neubert fine sandy loam soil treated with the high rate of "Chlorea".



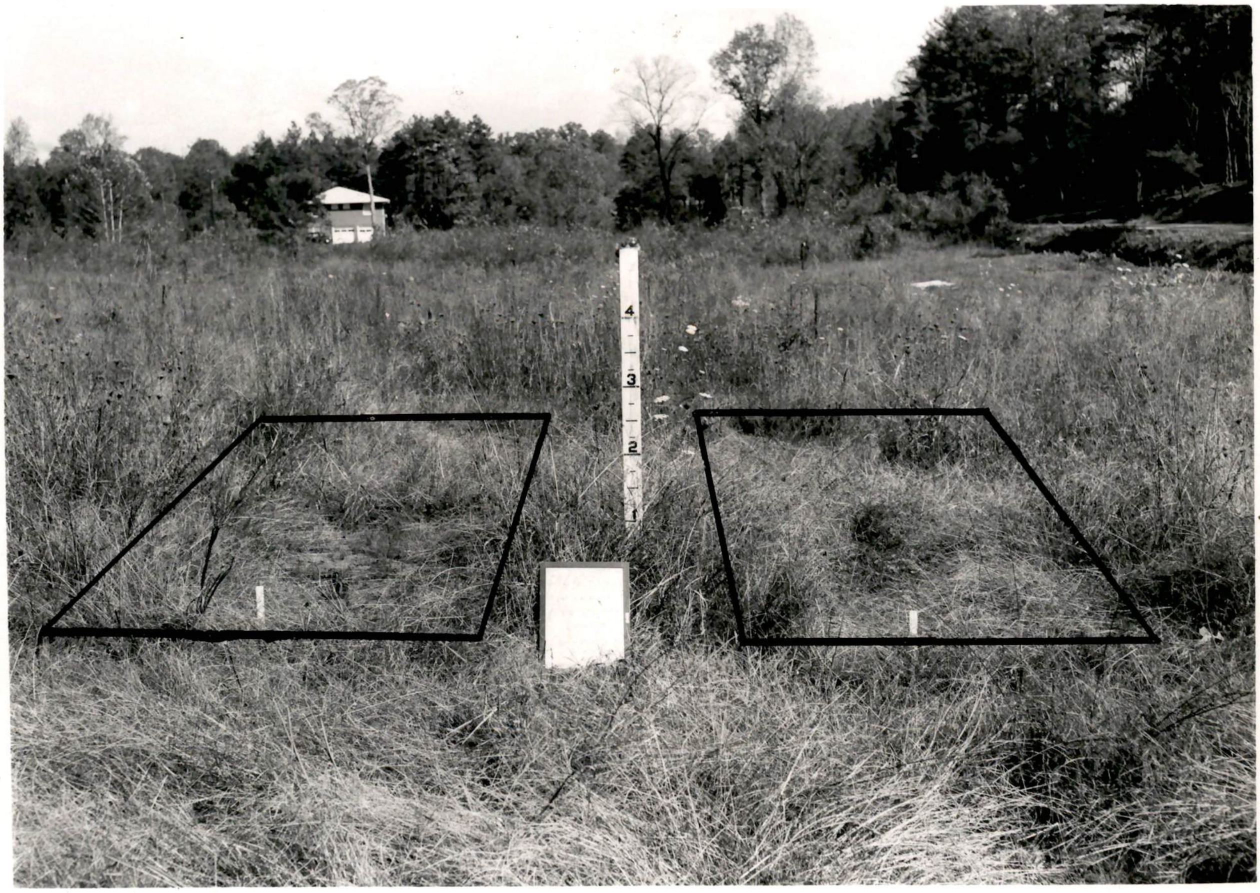
Spring treated   Fall treated

Figure 11--Photograph (October 28, 1958) of Etowah silty clay soil treated with the high rate of monuron.



Spring treated　　　　　　　　　　Fall treated

Figure 12--Photograph (October 28, 1958) of Tellico loam soil treated with the high rate of monuron.

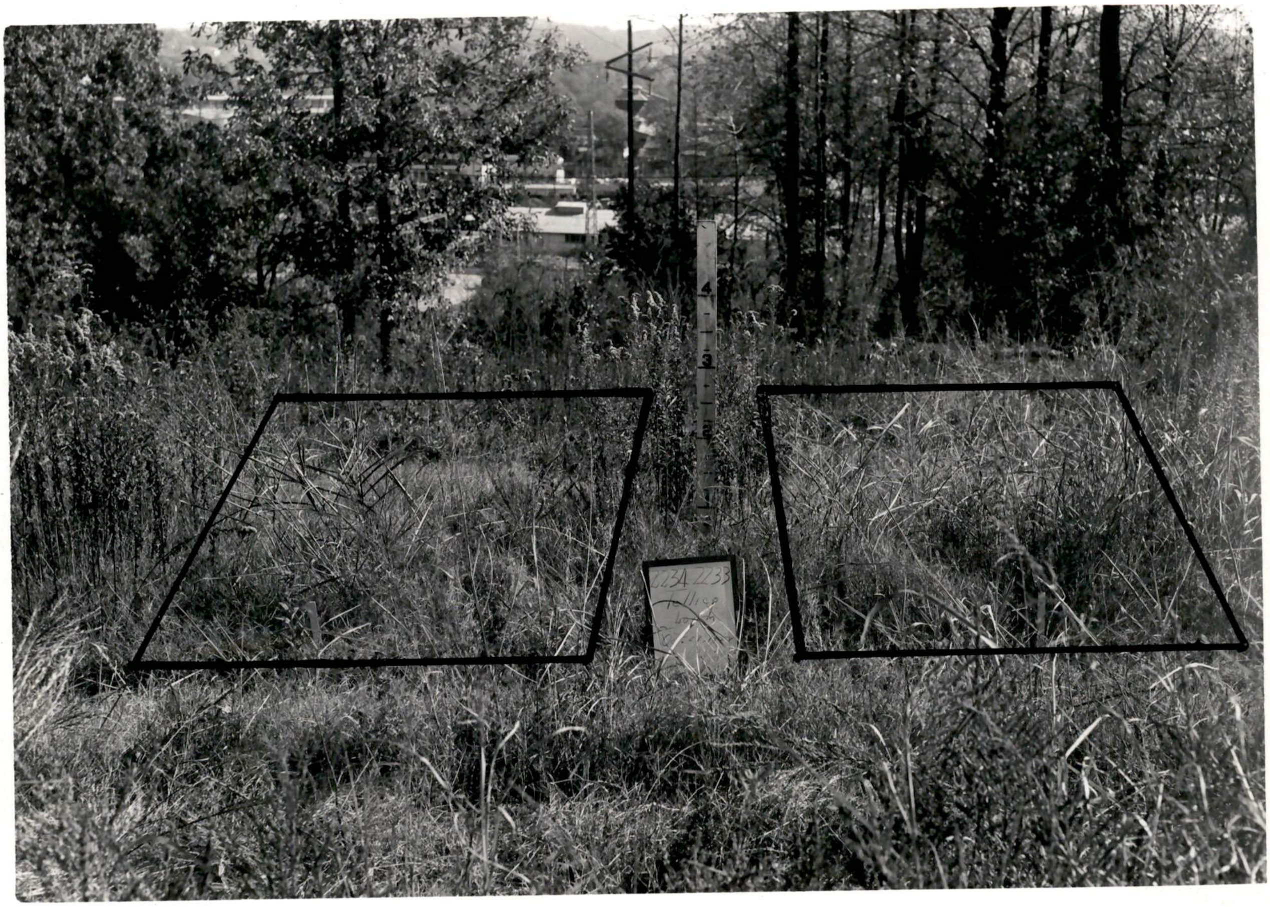


Spring treated　　　　　　　　　　Fall treated

Figure 13—Photograph (October 28, 1958) of Neubert fine sandy loam soil treated with the high rate of monuron.

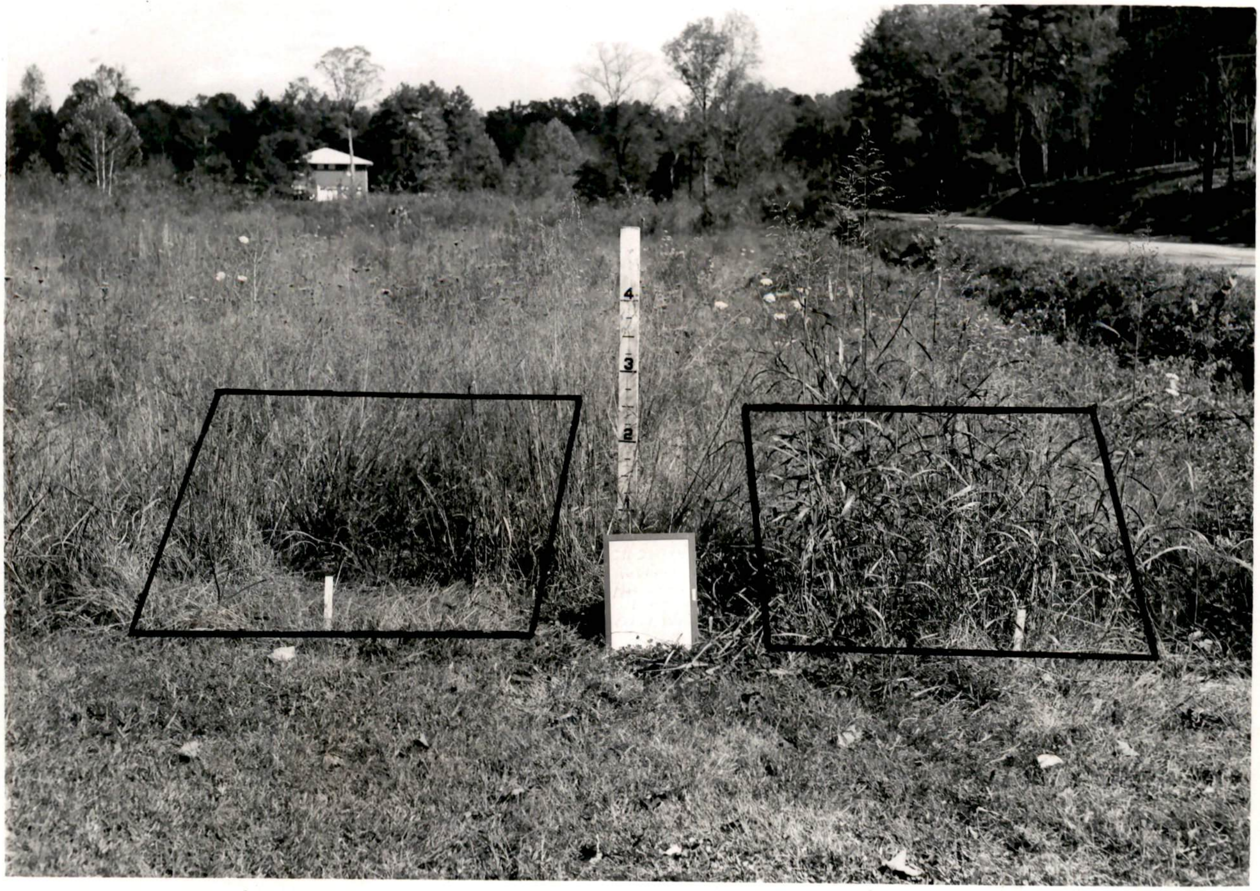
Spring treated Fall treated

Figure 14--Photograph (October 28, 1958) of Etowah silty clay soil treated with the high rate of simazine.



Fall treated Spring treated

Figure 15--Photograph (October 28, 1958) of Tellico loam soil treated with the high rate of simazine.

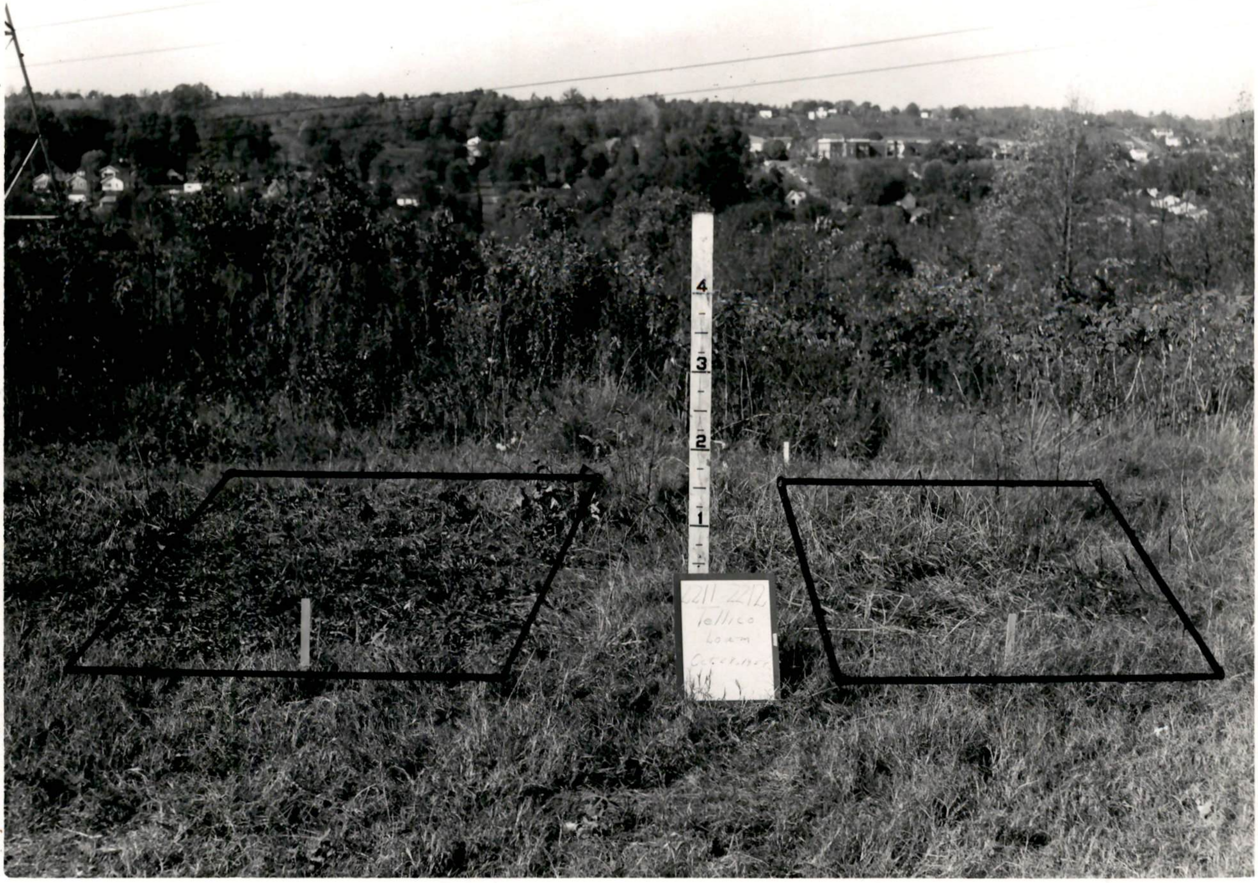


Fall treated Spring treated

Figure 16--Photograph (October 28, 1958) of Neubert fine sandy loam soil treated with the high rate of simazine.

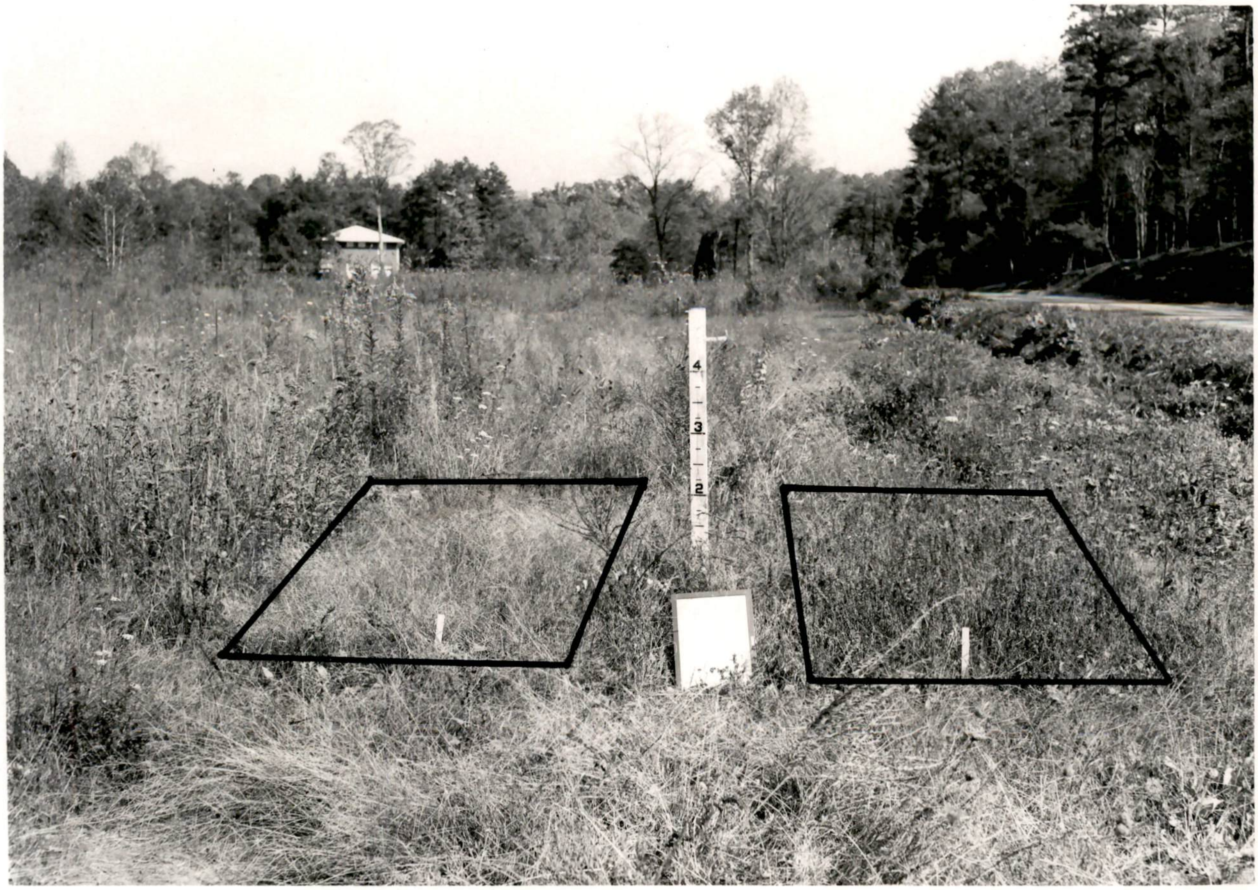
Fall treated Spring treated

Figure 17--Photograph (October 28, 1958) of Etowah silty clay soil treated with the high rate of "Atlacide".



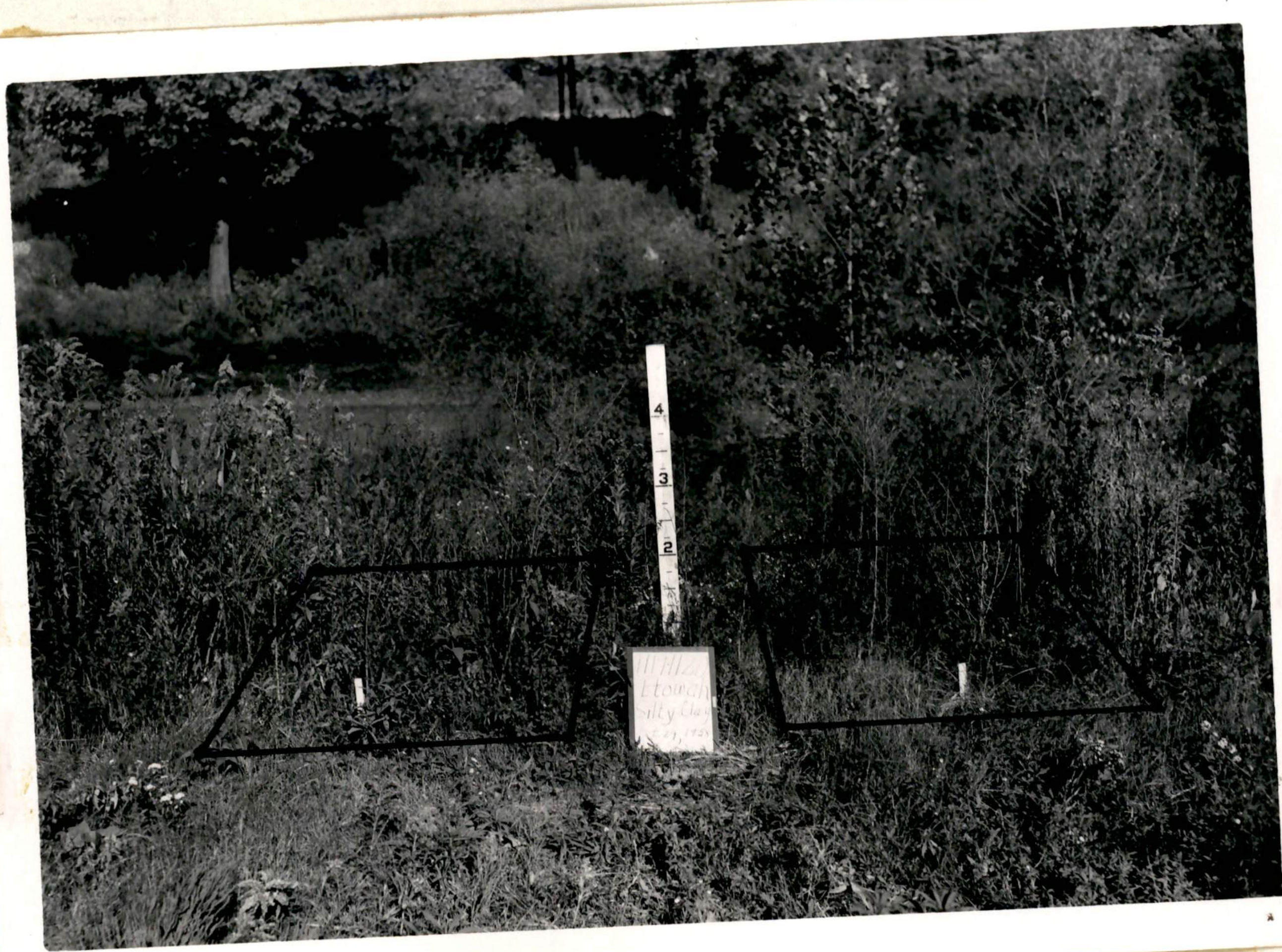
Fall treated Spring treated

Figure 18--Photograph (October 28, 1958) of Tellico loam soil treated with the high rate of "Atlacide".



Spring treated   Fall treated

Figure 19--Photograph (October 28, 1958) of Neubert fine sandy loam soil treated with the high rate of "Atlacide".

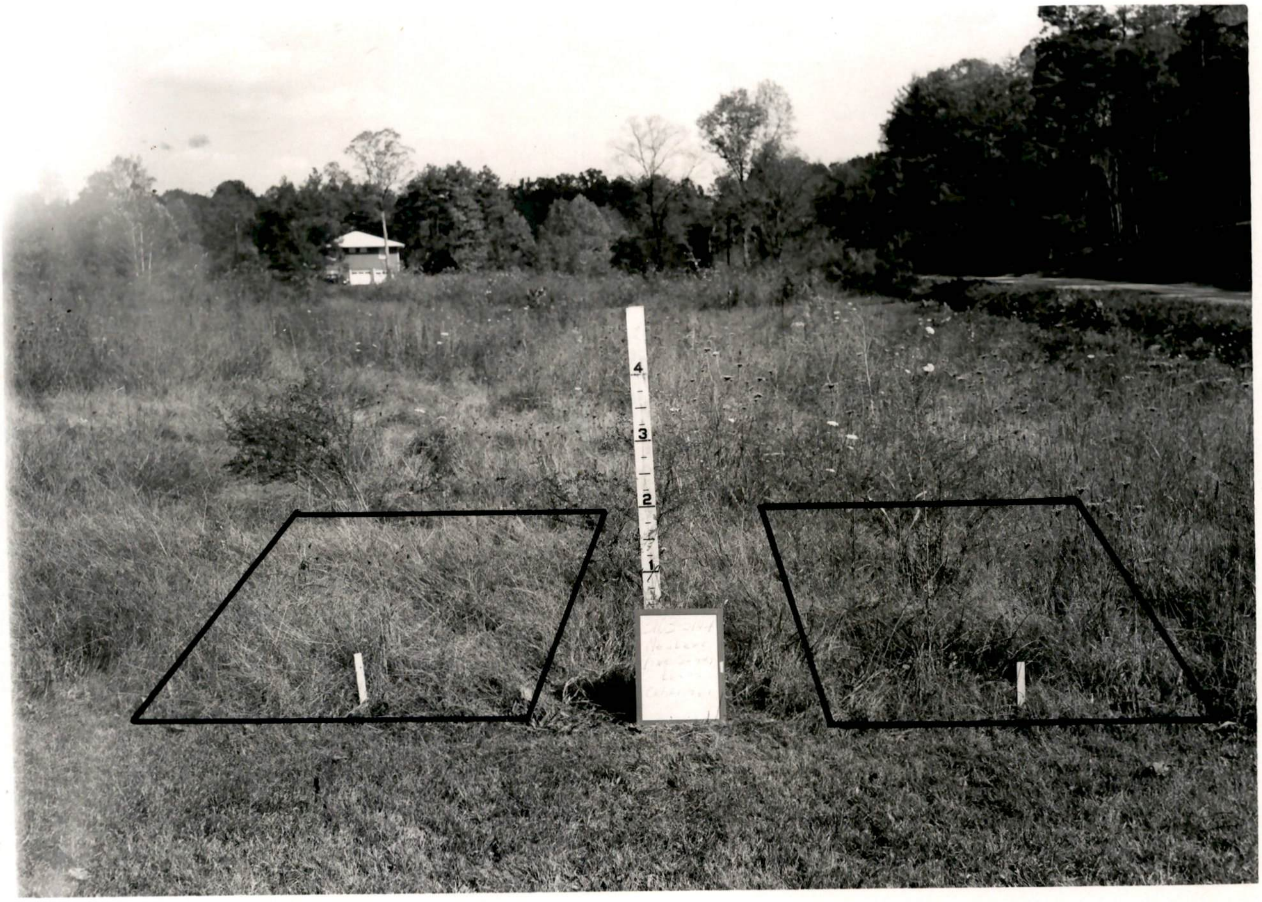


Spring treated Fall treated

Figure 20--Photograph (October 28, 1958) of Etowah silty clay soil treated with the high rate of Sodium TCA.

Fall treated Spring treated

Figure 21--Photograph (October 28, 1958) of Tellico loam soil treated with the high rate of Sodium TCA.



Spring treated Fall treated

Figure 22--Photograph (October 28, 1958) of Neubert fine sandy loam soil treated with the high rate of Sodium TCA.

As far as total vegetation control by soil sterilants and persistence of the herbicides, none rated high. Even the high rate, which was one-third more than the rate recommended by the manufacturer, failed to control all vegetation for as much as 1 year.

In June, 1958, a second survey was made of each plot, and a tabulation was made of the species not controlled by each treatment. The results are found in Appendix D. Some species of weeds and grasses were not killed by certain chemicals regardless of rate used. In other cases higher rates of certain herbicides gave better control than lower amounts of the same or other materials.

Herbicides that are slowly soluble are most often slowly leached, especially if applied at a heavy rate. Their remaining on the soil surface for a long period of time allows for at least partial removal by the lateral movement of surface water. Figure 23 shows the lateral movement of monuron from a plot treated at the heavy rate. This picture shows the most lateral movement of any of the materials used in this study.

Greenhouse Results

A laboratory bioassay was conducted in order to determine the persistence of the herbicides at different soil depths. In May, following the application of chemicals, soil samples were taken from plots treated the previous fall at the high rate and from untreated adjacent areas. Plants were grown in pots filled with these soil samples, as described in the previous chapter. A photograph of indicator plants

Figure 23--Photograph (October 28, 1958) of plots treated with monuron at the high rate. Area to right of marker is outside the plot area. Control resulted from lateral movement of the herbicide. Etowah silty clay, 5% slope. Plot was treated March 15, 1958.

growing in treated and untreated soil is shown in figure 24. The plants showed apparent normal growth. There was no measurable residual toxicity revealed by this technique.

Figure 24--Photograph of Ogden soybeans and Martin milo as legume and grass indicators of persistence or leaching (July 15, 1958). Separate samples from 5 depths represent individual plots which had been treated with 5 different herbicides at the high rate. Plants in all treatments appeared normal. Plots were treated November 5, 1957; samples were taken May 20, and seeded May 25, 1958.

CHAPTER V

DISCUSSION OF RESULTS

More important than the degree of control of either broadleaf plants or grasses is whether a soil sterilant will give effective control of all vegetation long enough to be profitable. The longer a herbicide controls vegetation, the more valuable it becomes. If soil sterilants are to be profitable, residual control for a number of years is desirable. This would save the annual cost of labor and equipment.

In arid areas such as are found in parts of western United States, soil sterilant herbicides do not become inactivated for several years. Wiese (31) reported that either monuron applied at 60 pounds per acre or sodium chlorate applied at 800 pounds per acre would persist for 3 to 5 years in Texas.

It seems evident that certain factors as suggested by several research workers (8, 11, 23) are responsible for the rate of decomposition of herbicides in the soil. Perhaps microbial activity as influenced by temperature and moisture plays the more important part in decomposition. Other factors such as soil fertility, soil type, soil organic matter content, and soil pH as reviewed by Roberts (24) could affect the rate of inactivation. Or it may be that differences in materials allow for physical removal of part of the chemical by windblow or inactivation by ultra-violet light as suggested by Hill et al. (12). Perhaps some of these factors have greater influence on decomposition of herbicides, or maybe there is an interaction of the several factors which determine whether a given chemical will kill shallow or deep rooted weeds, whether it will be temporary or relatively permanent and the rate required to give satisfactory results.

In this experiment, monuron was applied at the high rate of 100 pounds per acre and sodium chlorate at the high rate of 2400 pounds per acre. Neither controlled broadleaf and grass annuals and perennials for as long as 1 year. It was expected that other herbicides used at the high rate in this experiment would have persisted and prevented recurrence of growth, but all vegetation was not controlled.

Generally, time of application showed little effect as pertains to residual control since all materials lasted less than 1 year. Under the adverse climatic conditions found in East Tennessee, time of application could be important for seasonal control or for a specific purpose if used on a temporary soil sterilization basis. Parris (20) found better control from fall applications than from spring applications in Montana. In that arid area it seems reasonable.

The only difference in toxicity as affected by soil type in this experiment was observed on Neubert fine sandy loam, the coarsest textured soil of the three tested. The fall treated plots showed less control of vegetation than any of the other treatments. Several research workers (8, 23, 24) agree that herbicides are inactivated more rapidly in a coarser textured soil. There was not a wide difference in the textural grades of the soils studied which may account for the small difference noted.

"Chlorea" gave immediate control of annual and perennial grasses and broadleaf plants in this experiment. Monuron did not kill vegetation as rapidly as did "Chlorea", but its delayed action was as effective, except that it failed to control Bermudagrass. Simazine gave control of annual weeds and grasses but did not control perennials such as Johnsongrass, Bermudagrass, and sericea. "Atlacide" controlled broadleaf plants better than grasses and TCA controlled grasses better than broadleaf plants.

Weed species vary in their inherent tolerance of chemicals (8). Other research workers (23, 24) have reported that inherent toxicity, application rate, and formulation are important factors affecting residual toxicity.

Parris (20) reported no single herbicide available that would economically control all plant species found under the varied conditions throughout the United States. He favored the use of soil sterilant type material followed in succeeding years with contact killing herbicidal oils. On small areas infested with certain persistent perennials the use of certain soil sterilant chemicals resulted in a substantial saving. Certain combinations of soil sterilants provided the most effective results but were expensive.

From the results of this experiment it does not seem feasible to use a single soil sterilant for the control of all vegetation under the soil and climatic conditions prevailing in this area.

CHAPTER VI

SUMMARY AND CONCLUSIONS

To determine the possibilities for long-time vegetation control 5 selected soil sterilants were applied, at 3 different rates, on November 5, 1957, and March 15, 1958, to 3 soils of contrasting physical properties. Before treatments, a botanical survey was made to identify and record the species present on each of the three soil types to be treated. Control ratings were made in May, July, August, and October 1958. In June, 1958, a survey was made of each plot, and a tabulation made of the species not controlled by each treatment. In October, 1958, photographs were taken of the plots treated with the high rate.

Within 10 days after treatment all rates of all herbicides had apparently killed the vegetation of each plot. None of the soil sterilant treatments rated high in total control of vegetation by residual toxicity. Even the high rate, which was 1/3 more than the rate recommended by the manufacturer, did not control all vegetation for as much as 1 year. The general order of control was "Chlorea", monuron, simazine, "Atlacide", and TCA.

"Chlorea" gave immediate control of annual and perennial grasses and broadleaf plants. Monuron did not kill as rapidly as did "Chlorea" but its delayed action was as effective except that it failed to control Bermudagrass. Simazine gave control of annual weeds and grasses but did not control perennials, such as Johnsongrass, Bermudagrass and sericea. "Atlacide" controlled broadleaf plants better than grasses, while TCA controlled grasses better than broadleaf plants.

Generally, time of application of herbicides at soil sterilant rates showed little effect as pertains to residual control since all materials lasted less than 1 year. The only difference in toxicity as influenced by soil type was observed on Neubert fine sandy loam, the coarsest textured soil of the 3 tested. The fall treated plots on this soil showed less control of vegetation than any of the other treatments.

A laboratory bioassay, 7 1/2 months after treatment, failed to show any residual toxicity in the soil at any of 5 depths down to 30 inches. The indicator plants grew normally in samples of soil taken in May from plots treated the previous fall at the heavy rates of each herbicide and from adjacent areas. Either the herbicides had been decomposed, had leached deeper than the depths tested at the time soil samples were taken; or, the compositing and mixing of the soil samples destroyed the toxicity of the herbicides.

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LITERATURE CITED

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APPENDIXES

APPENDIX A

A tabulation of species found growing on the 3 soil types
before herbicides were applied
Knoxville, Tennessee
September 9, 1957

Scientific name	Common name	Etowah silty clay	Tellico loam	Neubert fine sandy loam
Acalypha rhomboidea	three-seeded mercury	*[a]	*	*
Achillea millefolium	common yarrow			*
Albizzia julibrissin	silk-tree	*	*	
Allium vineale	wild garlic	*	*	*
Amaranthus hybridus	green amaranth	*		
Ambrosia bidentata	lanceleaf ragweed	*	*	*
Ambrosia trifida	giant ragweed	*		
Ampelamum albidus	climbing milkweed	*		
Andropogon virginicus	broomsedge	*	*	*
Apocynum cannabinum	Indian hemp	*		
Arctium minus	common burdock	*	*	
Asparagus officinalis	garden asparagus		*	
Asclepias purpurascens	purple milkweed			*
Asclepias syriaca	common milkweed	*		
Aster ericoides	aster			*
Aster spp.	aster	*	*	
Bidens frondosa	devils beggarticks		*	
Brachyelytrum erectum	brachyelytrum	*	*	
Bromus catharticus	rescuegrass	*		
Campsis radicans	trumpet-creeper			*
Carex pensylanica	sedge			*
Cassia fasciculata	partridgepea		*	
Cassia nictitans	wild sensitive plant			*
Cassica tora	sicklepod			*
Celtis occidentalis	hackberry	*	*	
Cercis canadensis	redbud	*		*
Chenopodium album	common lambsquarters	*	*	
Chenopodium ambrosicides	Mexican tea	*	*	
Chrysanthemum leucanthemum	oxeye daisy		*	*
Cirsium altissimum	tall thistle		*	*
Cirsium discolor	common thistle	*	*	*

[a]See footnote at end of table.

APPENDIX A (continued)

Scientific name	Common name	Etowah silty clay	Tellico loam	Neubert fine sandy loam
Convolvulus arvensis	field bindweed			*
Convolvulus sepium	hedge bindweed	*		*
Crepis sp.	hawksbeard		*	
Cynodon dactylon	Bermudagrass	*	*	
Cyperus retrofractus	galingale		*	
Cyperus sp.	galingale	*	*	
Cyperus strigosus	galingale			*
Datura Stramonium	jimsonweed	*		
Daucus Carota	wild carrot		*	*
Desmodium canadense	Canada tick trefoil	*	*	*
Digitaria ischaemum	smooth crabgrass			*
Digitaria sanguinalis	large crabgrass		*	*
Dioscorea batatas	Chinese yam	*		
Diospyros virginiana	persimmon	*	*	*
Duchesnea indica	Indian strawberry	*		
Elephantopus carolinianus	elephant's-foot	*	*	
Eleusine indica	goosegrass		*	
Erechtites hieracifolia	hawkweed		*	
Erigeron canadensis	horseweed		*	*
Erigeron sp.	fleabane		*	
Eupatorium altissimum	thoroughwort		*	
Euphorbia corollata	flowering spurge			*
Euphorbia maculata	spotted spurge		*	*
Fragaria sp.	strawberry		*	*
Gladiolus hortulanus	garden gladiolus		*	
Gleditsia triacanthos	honey-shuck	*		
Gnaphalium purpureum	purple cudweed		*	*
Hypericum prolificum	St. John's-wort			*
Ipomoea hederacea	morningglory			*
Ipomoea lacunosa	ivyleaf morningglory	*		
Ipomoea purpurea	common morningglory	*		
Juncus tenuis	slender rush		*	
Lactuca canadensis	tall lettuce		*	
Lactuca sp.	wild lettuce			*
Lespedeza cuneata	sericea	*	*	*
Ligustrum ovalifolium	California privet	*	*	
Liriodendron tulipifera	tulip-tree		*	
Lonicera japonica	Japanese honeysuckle	*	*	*

APPENDIX A (continued)

Scientific name	Common name	Etowah silty clay	Tellico loam	Neubert fine sandy loam
Maclura pomifera	osage orange	*		
Menispermum canadense	moonseed			*
Morus alba	white mulberry	*		
Muhlenbergia schreberi	nimblewill			*
Oxalis repens	sheep sorrel			*
Oxalis stricta	yellow woodsorrel		*	
Panicum anceps	panic-grass		*	*
Panicum meridionale	panic-grass		*	
Paspalum dilatatum	dallisgrass		*	
Paspalum pubescens	paspalum	*		
Paspalum pubiflorum	paspalum	*		
Passiflora incarnata	maypop passionflower	*		
Passiflora lutea	yellow passionflower	*		
Perilla frutescens	perilla	*		
Phlox paniculata	perennial phlox	*		
Physalis longifolia	longleaf groundcherry	*		
Phytolacca americana	pokeweed	*	*	*
Plantago lanceolata	buckhorn plantain	*	*	*
Plantago major	broadleaf plantain			*
Platanus occidentalis	sycamore			*
Poa pratensis	Kentucky bluegrass	*		*
Polygonum aviculare	prostrate knotweed		*	
Polygonum hydropiperoides	mild smartweed	*		
Polygonum pensylvanicum	Pennsylvania smartweed	*	*	
Polymnia uvedalia	bearsfoot	*		
Prunus persica	peach	*	*	
Prunus serotina	black cherry	*	*	
Pueraria lobata	kudzu	*		
Pyrus malus	apple		*	
Quercus alba	white oak		*	
Quercus falcata	Spanish oak		*	
Ranunculus abortivus	kidneyleaf buttercup			*
Ranunculus parviflorus	smallflowered buttercup	*		
Rhus glabra	smooth sumac		*	
Rhus radicans	poison ivy	*	*	*
Rosa sp.	rose			*
Rubus hispidus	dewberry		*	*
Rubus sp.	blackberry	*	*	*
Rudbeckia hirta	black-eyed susan			*
Rumex obtusifolius	broadleaf dock			*

APPENDIX A (continued)

Scientific name	Common name	Etowah silty clay	Tellico loam	Neubert fine sandy loam
Salvia lyrata	lyre-leaved salvia			*
Sambucus canadensis	ederberry	*		
Sassafras albidum	white sassafras		*	*
Senecio smallii	Small's ragwort		*	*
Silene sp.	catchfly		*	
Smilax rotundifolia	common greenbrier		*	*
Solanum carolinense	Carolina horsenettle	*	*	*
Solidago altissima	goldenrod	*	*	*
Sorghum halapense	Johnsongrass	*		*
Spiraea	spiraea			*
Taraxacum officinale	dandelion	*		*
Trifolium pratensis	red clover	*		*
Trifolium repens	white clover	*		
Triodia flava	tall red-top	*	*	*
Ulmus alata	winged elm			*
Ulmus areicana	American elm	*	*	
Urtica dioica	stinging nettle	*		
Verbena urticifolia	white vervain			*
Verbesina occidentalis	yellow wingstem	*	*	*
Verbesina virginica	tickweed	*		
Vernonia altissima	tall ironweed	*		*
Vicia sp.	vetch		*	
Viola papilionacea	violet	*		
Vitis aestivalis	summer grape			*
Vitis labruscana	foxgrape		*	

[a]Asterisk indicates species present on soil type.

APPENDIX B

Inches of daily and monthly precipitation, University of Tennessee Agricultural Experiment Station, Knoxville, November, 1957 through October, 1958

Day	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1				.28			.35	.98				
2								.02		.25		
3		.24								.09		.08
4												
5							.22					
6				.61		.46	.66		.97			
7		1.47		.35	.55		1.44		.89		.54	
8	.61	.86					.07		.11			
9		.12			.39				.13	.15		
10						.42	.41					
11							.03			.13		
12							.01		.40			
13			.80		.58				.76			
14	.65											
15			.05			.49						
16	2.30								.29			
17	.50				.75		.61				.34	
18	2.45											
19	.54	.27										
20		1.55	.16				.94	.17	1.48			
21			.06			1.01			.12	.59	1.64	
22	.80					.52		.33		.13		
23									.60			
24			.40		.35					.55		
25	.87	.96	.22			1.44						
26				.75	.21			.78	.20			
27				.51		.72						
28		.17				.03			.17			
29	.05											
30					.93						.76	
31		.22							.09			
Total	8.77	5.86	1.69	2.50	3.76	5.09	4.74	2.28	6.21	1.89	3.28	.08

APPENDIX C

Daily maximum and minimum temperatures, degrees F., at the Tennessee Agricultural Experiment Station, Knoxville, November, 1957 through October, 1958

	November		December		January		February		March		April	
Day	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1	40	74	28	48	32	34	30	34	42	60	44	68
2	42	73	36	60	14	40	20	24	42	65	40	72
3	57	62	36	52	16	46	16	34	40	58	56	76
4	54	56	32	36	21	38	16	40	32	57	56	70
5	54	62	25	55	22	44	36	38	33	66	52	76
6	32	62	36	60	22	38	40	51	48	58	56	75
7	32	63	56	56	30	38	42	44	48	54	52	50
8	54	64	46	56	18	26	24	34	48	56	34	64
9	38	58	38	40	14	42	16	30	50	56	44	66
10	30	58	26	48	22	54	16	32	40	51	56	65
11	22	54	20	24	28	58	20	40	40	60	52	50
12	40	62	6	26	30	52	20	36	38	58	40	68
13	50	64	18	44	36	46	18	34	48	56	38	68
14	56	65	38	51	46	46	20	46	40	54	44	70
15	48	68	50	63	43	44	34	35	34	52	54	56
16	56	68	54	58	38	44	14	20	33	54	54	78
17	60	71	53	58	30	37	4	18	36	48	50	78
18	60	73	52	66	34	40	6	22	44	46	50	82
19	50	54	54	53	26	42	10	32	40	54	56	80
20	40	54	58	65	32	52	24	44	36	44	60	80
21	42	53	42	60	44	62	20	52	30	42	64	71
22	38	40	34	62	32	40	40	47	30	52	56	58
23	40	48	34	58	30	53	28	61	43	48	40	82
24	50	50	41	56	40	54	32	67	46	50	62	83
25	42	60	48	58	36	42	36	65	50	58	60	66
26	38	66	56	56	32	43	52	60	52	58	56	64
27	36	66	30	54	35	36	48	65	50	58	58	76
28	46	64	42	44	36	36	52	65	50	52	60	75
29	54	66	34	50	26	38			36	60	64	68
30	40	42	27	54	30	51			50	58	50	72
31			32	42	42	56			56	60		

APPENDIX C (continued)

Day	May		June		July		August		September		October	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1	62	68	66	88	66	90	76	84	70	88	54	58
2	64	78	68	86	66	94	72	84	60	88	52	60
3	66	82	62	88	68	95	72	84	64	91	54	60
4	66	81	70	86	70	90	70	90	68	90	56	72
5	66	82	72	86	70	86	70	90	68	92	54	80
6	62	56	70	85	70	88	68	92	68	92	56	82
7	40	48	62	90	72	88	70	90	64	90	54	78
8	44	66	66	84	72	76	72	88	62	86	50	78
9	52	58	70	86	70	84	72	86	56	84	55	76
10	56	75	68	90	70	86	70	90	58	86	62	76
11	61	80	68	86	72	86	72	90	70	83	44	72
12	60	82	65	89	74	80	72	90	66	74	42	72
13	56	80	68	94	70	86	74	88	66	84	44	78
14	50	84	72	94	70	86	74	88	60	90	50	82
15	60	85	73	92	72	88	74	90	64	86	58	86
16	60	86	68	84	76	86	72	89	74	88	56	80
17	62	88	62	84	70	86	70	88	72	86	58	80
18	64	80	62	88	72	90	64	86	60	80	56	84
19	63	70	62	86	74	92	64	90	54	80	55	80
20	64	78	72	90	72	90	68	91	64	84	50	78
21	56	84	66	88	70	85	72	88	64	74	46	78
22	53	83	68	80	72	84	72	88	68	86	56	73
23	60	88	56	82	74	85	74	84	64	92	54	74
24	64	90	62	85	70	78	72	80	64	88	46	74
25	66	82	62	90	66	86	68	84	66	88	46	64
26	64	86	72	80	72	92	62	86	68	88	48	56
27	62	84	60	80	72	90	64	84	70	80	46	55
28	64	86	60	84	78	90	62	86	54	77	42	66
29	56	80	60	88	76	92	64	88	54	78	36	70
30	56	86	64	90	70	94	66	90	56	70	40	70
31	66	88			71	86	70	90			40	74

APPENDIX D

A tabulation in June, 1958, of species not controlled on plots treated with selected herbicides, Knoxville, Tennessee.

Botanical name	Common name	Time of treatment and material									
		Fall					Spring				
		Chl.a/	Mon.	Sim.	Atl.	TCA	Chl.	Mon.	Sim.	Atl.	TCA
Acalyph rhomboidea	three-seeded mercury		Lb/		H	H				H	H
Acer negundo	box-elder									M	
Achillea millefoium	common yarrow		M	L		L					L
Albizzia julibrissin	silk-tree	H	H	M	M	H	H	H	H	H	H
Allium vineale	wild garlic	M	M	M	H	L	L	M	H	H	H
Ambrosia bidentata	lanceleaf ragweed	M		L	H	H				H	H
Ambrosia sp.	ragweed			M							
Ambrosia trifida	great ragweed		M		H						H
Ampelamus albidus	climbing milkweed	L	H	H			H	H	H		
Ampelopsis cordata	ampelopsis						L			H	
Andropogon sp.	beardgrass					H					L
Andropogon virginicus	broomsedge		L	L		H			M	H	
Apocynum cannabinum	Indian hemp		M	M				M	M		
Arctium minus	common burdock				H					H	
Arctium sp.	burdock			L		H			L		H
Aristida sp.	triple-awned grass									M	
Asclepias syriaca	common milkweed	L	H	H	M	H	L	H	H	H	H
Asparagus officinalis	garden asparagus									H	H
Aster sp.	aster			L	H	H				M	H
Bidens frondosa	devils beggarticks				M						M
Brachyelytrum erectum	brachyelytrum									M	
Bromus japonicus	Japanese brome			H	H	H				M	M
Campsis radicans	trumpet-creeper	H	H	H	H	H	L	H	H	H	H
Carex cephalophora	sedge				H				L		
Carex granularis	sedge					L					
Carex leavenworthii	sedge								L		
Carex retroflexa	sedge	L		L	H						

a/ b/See footnotes at end of table.

APPENDIX D (continued)

Botanical name	Common name	Time of treatment and material									
		Fall					Spring				
		Chl.	Mon.	Sim.	Atl.	TCA	Chl.	Mon.	Sim.	Atl.	TCA
Carex sp.	sedge	H	M	M	H	H			M	H	H
Cassia tora	sicklepod				M		L		H	M	H
Celtis occidentalis	hackberry		M	M	L				L	H	M
Cerastium viscosum	mouse-ear chickweed				L	H					H
Chenopodium album	common lambsquarters			M	H	H				M	H
Chenopodium ambrosioides	Mexican tea				H	H					H
Chrysanthemum leucanthemum	oxeye daisy				M	H				H	H
Circaea sp.	enchanter's nightshade				L	L					
Cirsium altissimum	tall thistle					L					H
Cirsium discolor	common thistle					L					M
Cirsium sp.	thistle					H					M
Convolvulus sepium	hedge bindweed		H		M	H		M		M	H
Crepis pulchra	hawksbeard				M						H
Cuscuta sp.	dodder	H		M	H	M			M		L
Cynodon dactylon	bermudagrass	H	H	H	L	H	M	H	H	H	L
Cyperus esculentus	yellow nutsedge			M	M					H	
Cyperus ovularis	sedge					L					
Cyperus sp.	sedge				H	M				H	
Datura stramonium	jimsonweed				H					H	M
Daucus carota	wild carrot	H	L	L	H	H			M	H	H
Desmodium canadense	Canada tick trefoil		H	H	M	H		H	H	H	H
Desmodium rotundifolium	tick trefoil		L								
Digitaria ischaemum	small crabgrass								M	M	H
Digitaria sanguinalis	large crabgrass	H	H	M	H	H		H	H	H	H
Digitaria sp.	crabgrass	H	M	L	H				L	H	H
Dioscorea batatas	Chinese yam										M
Diospyros virginiana	persimmon			M						M	
Duchesnea indica	Indian strawberry				L	H			M		H

APPENDIX D (continued)

Botanical name	Common name	Time of treatment and material									
		Fall					Spring				
		Chl.	Mon.	Sim.	Atl.	TCA	Chl.	Mon.	Sim.	Atl.	TCA
Eleusine indica	goosegrass									H	M
Erigeron sp.	fleabane	M			H	H		M		H	H
Eupatorium rotundifolium	composite	L			H					M	M
Eupatorium sp.	thoroughwort									H	L
Euphorbia corallata	flowering spurge										L
Euphorbia dentata	spurge	H	H		H	M	H				
Euphorbia maculata	spotted spurge	H	M	L	M	H	M			H	H
Fragaria sp.	strawberry		M	L		H					M
Galinsoga parviflora	smallflower galinsoga				M						
Geranium carolinianum	Carolina geranium				H	H				H	M
Geum canadense	rose					L					
Geum virginicum	spurge										L
Gnaphalium purpureum	purple cudweed				L	M					H
Hordeum pusillum	little barley				M						
Houstonia sp.	madder					L					
Ipomoea pandurata	bigroot morningglory					L				H	H
Ipomoea purpurea	common morningglory				M	H					
Juncus biflorus	rush				M					H	
Juncus tenuis	slender rush			M	H	H			L	H	
Lactuca scariola	prickly lettuce	M			H	H				L	H
Lactuca sp.	lettuce					H					H
Lepidium virginicum	Virginia pepperweed				H	H				H	H
Lespedeza cuneata	sericea	H	H	H	H	M	M	M	H	H	M
Lespedeza stipulacea	Korean clover				M	H					
Lespedeza striata	Japanses clover										H
Liriodendron tulipifera	tulip-tree	M		H						L	H
Lithospermum officinalis	gromwell										L

APPENDIX D (continued)

Botanical name	Common name	Fall Chl.	Fall Mon.	Fall Sim.	Fall Atl.	Fall TCA	Spring Chl.	Spring Mon.	Spring Sim.	Spring Atl.	Spring TCA
		Time of treatment and material									
		Fall					Spring				
Lobelia siphilitica	great lobelia	M				M				H	H
Lonicera japonica	Japanses honeysuckle			H	L	H		L		L	M
Lychnis alba	white cockle				H	H					H
Melilotus sp.	sweet clover				M	M					
Menispermum canadense	moonseed		H	H				H			M
Mollugo verticillata	carpetweed									H	
Monarda fistulosa	wild bergamot					M					
Morus rubra	red mulberry								H	L	
Tillandsia	moss					M					M
Muhlenbergia schreberi	nimblewill	L		M		H			L	H	M
Oenothera biennis	common eveningprimrose				M	H					H
Oxalis sp.	wood-sorrel			L	H	H				H	H
Panicum anceps	panic-grass		H	H		H	L	M	H		
Panicum dichotomum	panicum			L							
Panicum lanuginosum	panic-grass			L	H	H			L		
Panicum sp.	panic-grass	L			M	L				M	H
Paspalum sp.	watergrass	H	M	H	H	L	H		M	M	H
Passiflora incarnata	maypop passionflower								H	H	
Penstemon sp.	beard-tongue					H					
Perilla frutescens	nightshade				M						
Phaseolus polystachios	kidney-bean	M								L	
Phleum pratense	timothy			L		L					M
Physalis sp.	ground-cherry	M	M	M	H	H		L		H	H
Phytolacca americana	pokeweed				H	H				M	H
Plantago aristata	bracted plantain				H						
Plantago lanceolata	buckhorn plantain	M	M		H	M	M			H	H
Plantago major	broadleaf plantain	H	M		H	M			L	H	H

APPENDIX D (continued)

Botanical name	Common name	Time of treatment and material									
		Fall					Spring				
		Chl.	Mon.	Sim.	Atl.	TCA	Chl.	Mon.	Sim.	Atl.	TCA
Plantago sp.	plantain	H	H		H	M				H	L
Plantago virginica	pale-seed-plantain					M					L
Poa pratensis	Kentucky bluegrass			L	H	M				H	H
Polygonum aviculare	prostrate knotweed				M						
Polygonum sp.	knotweed				H					H	
Prunus serotina	black cherry				M	H			H		H
Pyrrhopapus carolinianus	false dandelion					M					M
Pyrus malus	apple			H							
Quercus sp.	oak			M					M		
Ranunculus abortivus	smallflower buttercup					H			H		L
Ranunculus parviflorus	kidneyleaf buttercup					M					
Rhus copallina	dwarf sumac								M		
Rhus glabra	smooth sumac		M	H	M	H		L			H
Rhus radicans	poison ivy							L	M		
Rosa sp.	rose					H					
Rubus allegheniensis	sow-teat blackberry		H	M	H	H		H	H		H
Rubus hispidus	dewberry			L					M		M
Rudbeckia hirta	black-eyed susan					L					
Rumex obtusifolius	broadleaf dock			M	M	M	L		H	H	H
Sassafras albidum	white sassafras	M								M	
Senecio smallii	Small's ragwort	L				H					H
Setaria sp.	bristly foxtail	L								M	
Setaria viridis	green foxtail	M			L					L	L
Sida spinosa	prickly sida				H	H				H	H
Silene antirrhina	sleepy catchfly										L
Sisyrinchium albidum	blue-eyed grass				M						
Sisymbrium officinale	hedge mustard				M	M					

APPENDIX D (continued)

Botanical name	Common name	Time of treatment and material									
		Fall					Spring				
		Chl.	Mon.	Sim.	Atl.	TCA	Chl.	Mon.	Sim.	Atl.	TCA
Smilax rotundifolia	common greenbrier		M		H	H		H	M	L	L
Solanum carolinense	Carolina horsenettle	H	M	M	M	H	H	H	M	H	H
Solanum nigrum	black nightshade									L	
Solanum sp.	nightshade			M		M					
Solidago sp.	goldenrod		M	H	H	H		L	M	H	H
Sorghum halepense	Johnsongrass	H	M	H	H	H		H	H	H	M
Specularia perfoliata	venus lookingglass	L			H	H					H
Stellaria media	common chickweed				H	H					M
Taraxacum officinale	dandelion	L	M	M	M	H			H	H	H
Trifolium campestre	large hop clover			L	H	H				H	H
Trifolium dubium	clover										L
Trifolium pratense	red clover				H	H				H	
Trifolium repens	white clover			L	H	H				H	M
Triodia flava	tall red-top	H	M	H	M	M			H	H	H
Ulmus alata	winged elm				H	L			H	L	
Ulmus americana	American elm	L		M		H			L	H	H
Ulmus sp.	elm							H			
Verbascum blattaria	moth mullein									L	M
Verbascum thapsus	common mullein	M				M					M
Verbena scabra	verrain				H	M					
Verbesina sp.	crownbeard			M	H	H		H		H	H
Vernonia altissima	ironweed		H	L		M			M	H	H
Veronica arvensis	corn speedwell	M	L		H	M					H
Veronica peregrina	purslane speedwell	H	L		H	H					H
Vicia grandiflora	vetch				H	H			L		
Vicia sativa	common vetch				M						
Viola papilionacea	violet			L							M
Vitis sp.	grape				H						

APPENDIX D (continued)

a/Chl. (Chlorea), Mon. (Monuron), Sim. (Simazine), Atl. (Atlacide), and TCA (Sodium TCA).

b/Letters "L", "M", and "H" refer to low, medium and high rates of application. Where "L" is shown the species was found only at the low rate of application, where "M" is shown the species was found at the medium and low rates, and where "H" is shown, the species was found at all rates. Where no letter is listed the species was not present on that treatment and was either controlled by all rates or had not been present on that plot.