EFFECTS OF COMPETITION CONTROL ON ONE YEAR SURVIVAL AND FIELD GROWTH OF SCOTCH PINE (*Pinus sylvestris*)

By

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ABSTRACT

EFFECTS OF COMPETITION CONTROL ON ONE YEAR SURVIVAL AND FIELD GROWTH OF SCOTCH PINE (*Pinus sylvestris*)

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Effect of competition control on first year survival and field growth of Scotch pine was examined. Mechanically planted seedlings were submitted to five treatments: 1) no weed treatment; 2) elimination of shading (control); 3) weeding with simazine + glyphosate; 4) weeding with glyphosate; 5) mechanical weeding.

Bud conditions and initial diameter were used as an index of seedling quality and compared to survival and growth. Depth of planting was also compared to survival.

Plant water stress was measured in three treatments and compared to competition treatment.

All methods of competition control, except elimination of shading increased survival and growth. High quality seedlings had greater survival and growth. Depth of planting had no effect on survival. Plant water stress was lower where vegetation was removed mechanically.

Dissipation of simazine from soil followed a pseudo-first order reaction. Only 1.5% of the concentration of the parent compound applied remained after 120 days.

To my daughter Barbara

VITA

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MASTER OF SCIENCE

Final examination: April 10, 1979

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CHAPTER I

INTRODUCTION

Forest planting has become a major forest activity in Brazil since 1966. The principal objectives of the plantations are to produce raw material for pulp, paper and fiberboard industries, although lumber production may in some cases be an important goal. *Pinus elliottii*, *P. taeda* and tropical pines such as *P. caribaea* and *P. oocarpa* are the most widely used coniferous species in reforestation programs. The seedlings are planted systematically either by hand or by machine. Direct seeding is not a widespread regeneration method and natural regeneration is yet impractical for these species are not native to Brazil.

To insure the success of any reforestation program it is necessary to know the causes of failure and their relative importance for any given locality under specific conditions. Failures have frequently been associated with the competitive influence of herbaceous vegetation. The forester, therefore, has to decide whether or not competing vegetation should be removed before tree seedlings are planted. This decision has to be based on knowledge of

how the vegetation affects the seedlings for any particular site. The source of this knowledge is either very careful scientific field observation or research such as reported in this study.

Once competition control has been decided upon, several methods are available to accomplish it. The choice between various alternative practices should take into consideration the cost per unit of long-term gain, bearing in mind the management objectives, as well as responsabilities to society.

Herbicides are becoming one of the most important and effective means of vegetation control. Use of herbicides has several advantages over alternative methods such as prescribed burning, scarifcation or cultivation. They are more selective, do not disturb the soil and can provide a long lasting effect.

The fact that herbicides cause no physical disturbance in the soil becomes very important when reforestation is to be done in soils subjected to erosion as is the case in some areas of southern Brazil. In such areas agriculture is impractical and a forest stand would represent the best alternative land use. To assure success in the early years, herbicides can be used to control competing vegetation while the mulch of dead herbs and grasses protect the fragile soil. However, the environmental consequences of herbicides must be very well understood so that they can be used with minimum impact on the environment.

The primary objective of this study was to investigate the effects of competition control on survival and field growth of planted Scotch pine (*Pinus sylvestris* L) in the first growing season. The possible effects of seedling quality as defined by diameter size, and bud conditions as well as depth of planting were also to be examined.

A secondary objective was to determine the persistence of the herbicide simazine in the soil and its possible effects on survival and growth.

This study combines forest ecology and weed science in a field experiment relating to planting of conifer forests. This is relevant to my home country, Brazil, as well as relevant to the regeneration of conifers in the North Central United States.

The study is to be continued in the future years providing more detailed information about the effects of competition control.

CHAPTER II

LITERATURE REVIEW

The primary concern of this review is the response of pines to competition control in the first year after planting and the methods used to achieve this control. Only artificial regeneration will be considered.

Artificial Regeneration and Competition Control

The establishment of a new timber stand requires favorable conditions. These conditions have to be created and maintained and this includes the elimination of existing vegetation that would compete with the seedlings for moisture, space, nutrients and light.

Manipulation of existing vegetation can have substantial influence on the severity of the habitat and can improve survival and growth of the seedlings and the overall quality of the stand (Lane and McComb, 1948; Wilhite, 1961; Newton, 1964a and 1964b; White, 1967 and 1975; An. 1968; Wilde, 1968).

The degree and duration of competition control required will depend on the species to be established and on the environment. Critical aspects to seedling survival

and development include such things as soil moisture retention capacity, composition and habits of competing vegetation and length and severity of the growing season (Newton, 1973).

Two growing seasons without serious moisture stress according to White (1975) and An. (1968) seems to be adequate for the establishment of conifers under relatively severe conditions. Shading and mechanical action of woody vegetation can be important on some sites and release must be sufficient to bring about conifer dominance. This usually happens in the first five years.

Therefore one concludes that a successful conifer regeneration program requires control of herbaceous vegetation and grasses in the first two years. After the seedlings are established they normally outcompete the existing vegetation.

Methods of Competition Control

The suitability of a method to achieve these two years of competition control has to take into consideration the silvical requirements of the pine species and the characteristics of particular sites. Improvement of the environment has to be maximized in relation to detrimental effects. It is also an economics problem. The cost of achieving the desired control by the various methods available has to be considered and also how much can be spent to obtain maximum results based on the productive

capacity of the new stand.

Competition control should not result in erosion or compaction of the soil. If a chemical is used it should not cause injury to the desired trees or animals on or off site.

Mechanical Weed Control

As used in this review mechanical weed control is the same as mechanical site preparation.

Mechanical methods of site preparation may range in intensity from simple buldozing of the vegetation to a combination of treatments such as shearing, raking, piling and burning the residues, followed by disking or bedding. The machinery utilized ranges from standard farm and construction implements to specific equipment for the clearing of difficult sites. Some of the methods not only remove unwanted vegetation but also may prepare the soil for reforestation. This soil disturbance, however, may be aesthetically undesirable, may increase erosion, adversely affect streams and may also be detrimental for wild life habitat (An., 1968; Carter *et al*., 1975).

Cultivation tends to shift the location of weed seeds, bringing them closer to the surface where conditions are more favorable to germination (Anderson, 1977).

Another point to consider is that sometimes large areas of forest land consist of steep rocky sites where mechanical equipment cannot be used efficiently.

After the trees are planted, weed control may be carried out by power driven rotary tillers that operate through the cutting action of revolving knifes. Where labor is available hand tools such as hoes, grub hoes and matocks may be used. Hand pulling is best adapted to the removal of weeds growing near or between trees where it is difficult to reach with a hoe or cultivator.

Various methods all have the objective of removing vegetation or preparing the soil. Specific effects may be obtained by various methods and equipment. The point of interest for this study are the specific effects obtained with mechanical weed control and not the technique used to achieve this control.

The Use of Herbicides

The chemical terminology as set forth by the Weed Science Society of America is listed in Appendix C for the herbicides mentioned in this review.

The utilization of herbicides in forest management has been reviewed by McQuilkin (1960) and Hovind (1967).

The use of chemicals to control unwanted vegetation in forestry made little progress until after World War II. Sodium arsenite and sodium chlorate, some oils and carbon disulfide were used, but the availability of effective and easy to handle chemicals apparently was the limiting factor.

The discovery of the herbicidal properties of the phenoxy compounds and the development of aerial spraying

techniques greatly increased use of herbicides in forestry practice. Since then a great number of new chemicals for use on both herbaceous and woody plants have developed, making herbicides a standard tool for forest management.

McQuilkin (1960) reported the use of 2,4-D with poor results, and then 2,4,5-T by the early 1950's as the most effective against woody plants. According to Hovind (1967) the practicability of establishing conifer plantations without mechanical site preparation was demonstrated in the late 1950's and early 1960's by the use of simazine, dalapon and amino-triazole.

Carvell (1960) tested radapon, trichloroacetic acid (TCA) and Varsol for grass control for conifers planted in old fields. Their effects on herbaceous vegetation and injury to pine were compared. A concentration of 30 g per liter of water (0.25 lb/gal) of radapon was used to treat spots 60 cm in diameter prior to planting. Half were sprayed in late fall, half in early spring. Excellent control of grasses was obtained in both cases during three growing seasons. Additional experiments showed that the same concentration of radapon applied after planting during the growing season caused severe injury to white pine, while fall application did not result in damage to the seedlings. TCA applied at the same concentration (30 g/l of water) controlled only grasses and injured the new foliage of white pine, Scotch and red pine and also Norway spruce. Undiluted Varsol gave good control of grasses

and herbs but since it is a contact poison the roots were not killed and control lasted only one year. Only minor damage to the foliage of pines and spruce was observed.

Furtick (1961) listed the herbicides simazine, atrazine and diuron as the most promising for silvicultural purposes because of the marked insensitivity towards coniferous trees while killing a broad spectrum of annual and some perennial weeds. According to the author these herbicides will control unwanted vegetation for 6 to 12 months depending on species, soil type and rainfall. He also mentions that herbicides dalapon and amitrole can be used successfully only where direct application to the conifers is avoided.

Swingle (1961) reports the use of ammonium sulfamate and amino-triazole (amitrole) as foliage spray herbicides and fenuron pellets for brush control. Also in 1961, Kuntz described the use of herbicides such as simazine, atrazine and other triazines, dalapon, monuron, diuron and amitrole, alone or in combination to treat new tree plantings, with the results varying with dosage, rainfall, soil type and weed species. White (1967) lists as effective herbicides to control most types of weeds in the eastern and north central states, simazine, atrazine, amitrole-T, 2,4,5-T, 2,4,5-T mixed with 2,4-D, casoron, cacodylic acid and paraquat. The same author in 1975 includes asulam, glyphosate and 2,4,5-TP to the ones mentioned above regarding them as "the most commonly mentioned by researchers,

extention workers and forest managers for weed control."

Newton (1973) also points out that the s-triazine herbicides, the phenoxy compounds, picloram, amitrole, dalapon and organic arsenicals may be used safely in reforestation. Dichlorprop (An., 1968) and dicamba (U.S.D.A., 1975) have also been included as chemicals used for site preparation techniques.

The selection of an herbicide will depend on each particular situation. Availability of application equipment, weed species to be controlled, species to be planted and its sensitivity to chemicals, potential hazards to environment, costs and management objectives are variables to be carefully considered if the best possible results are to be obtained.

If the proper herbicide and application technique are selected, weed control in tree plantations will be more economical and effective than mechanical methods (White, 1967). The soil will not be disturbed, reducing the danger of stream siltation and erosion (Newton, 1973). The moisture will be better retained under a mulch of dead weeds than where the vegetation is removed by scalping (Heidmann, 1967). As the dead plant material is decomposed organic matter content of soil will be increased. The increase in organic matter improves physical properties of the soil, increases cation adsorption capacity and supply and availability of nutrients (Brady, 1974).

Persistence of herbicide residues in soil do not

usually constitute a problem in forest management. Combination of herbicides, one giving quick kill and the other giving lasting effect will be desirable so as to obtain control for more than one growing season.

The herbicides simazine and glyphosate (Roundup) were chosen to be used in this study because they had been successfully used in similar experiments (White, 1975). No endorsement of named products is intended.

The Use of Simazine

Simazine, [2·chloro-4, 6-bis(ethylamino)-*s*-triazine] or Princep is a member of the diamino-*s*-triazine herbicide family which has been successfully used for site preparation. Princep is a registered trademark of CIBA-Geigy.

The *s*-triazine herbicides are used for selective pre-emergence and post-emergence control of grasses and broadleaved weeds, being in general more effective against the latter. Most of them are applied to the soil where they are readily absorbed by the roots and translocated upwards to the leaves via the transpiration stream. They are classified as inhibitors of photosynthesis by interference with the Hill reaction: the evolution of oxygen from water in the presence of chloroplasts and one electron acceptor. Inhibition of other metabolic processes are also considered to occur (Moreland *et al*., 1959; Ashton and Crafts, 1973; Kearney and Kaufman, 1975). The plant hormone metabolism may be influenced since at subtoxic

levels stimulation of growth was shown to occur. The nitrogen metabolism is also thought to be affected.

The usual phytotoxic symptoms are foliar chlorosis followed by necrosis. Depending on the concentration used, increased greening of the leaves or even no change can occur (Ashton and Crafts, 1973). Selective weed control with triazines is achieved by either physiological tolerance or herbicide placement.

Anderson (1977) recommends simazine for nonselective vegetation control in non-crop areas at rates of 5.6 kg to 44.8 kg per hectare (5 to 40 lb/a), depending on the weeds to be controlled. Hovind (1959) using 2.0 kg/ha (1½ lb/a) of simazine obtained only 35% grass control while 3.4 kg/ha (3 lb/a) gave 55% control and a mixture of simazine at 2.0 kg/ha (1½ lb/a) and dalapon at 8.7 kg/ha (7½ lb/a) controlled 99% of the grasses. Heidemann (1967) applying simazine at 11.2, 22.4 and 44.8 kg/ha (10, 20 and 40 lb/a) killed 80% of perennial grasses. White (1967) testing the efficiency of various chemicals for pre-planting weed control in heavy quack-grass used simazine alone and in combination with other herbicides. With simazine alone better control was obtained at 9.0 kg/ha (8 lb/a) than at 4.5 kg/ha (4 lb/a). Of the combinations amitrol-T at 18.7 l/ha (2 gal/a) plus simazine at 4.5 kg/ha (4 lb/a) gave the best results. The same author (1975) reports effective control of vigorously growing grasses when simazine at 3.4 kg/ha (3 lb/a) was used

in combination with glyphosate at 1.7 kg/ha (1.5 lb/a).

Residual activity is essential for weed control and soil sterilization. In forest management persistence in soil is a desireable characteristic, for control of unwanted vegetation can be maintained for a longer period of time. A complete review of the persistence of triazine herbicides in soil is provided by Sheets (1970). Among the triazine herbicides, persistence is related to chemical structure. Those with a chloro substituent, as is the case for simazine, are less persistent than those with a methoxy substituent. Differences in persistence have also been observed among the chloro substituted triazines with simazine being usually the more persistent.

Persistence is affected by soil, weather and climate, the rate of application, the interval between applications and the formulation of herbicide applied. Effects of soil type are difficult to assess due to complicating influences of climate. While it is a fact that persistence varies among soils,it is difficult to determine the exact causes for the differences (Sheets, 1970). Weather and climate influence the rate of disappearance through their effects on volatilization, surface runoff, erosion and leaching. These processes do not alter persistence since the herbicide molecules continue to exist in other parts of the environment. Persistence is altered through the effects of weather and climate on photochemical, chemical and biological degradation. Herbicides can also disappear due

to uptake by plants. Longer persistence may also result from subsurface than surface application.

The Use of Glyphosate

Glyphosate (N-(phosphomomethyl)glycine) or Roundup is a water soluble herbicide which may be used for control of herbaceous and deciduous vegetation prior to the planting of tree seedlings and also for the control of annual and perennial weeds, woody brush and deciduous trees as a conifer release treatment. Roundup is a registered trademark of Monsanto Company. When applied to the foliage of actively growing plants, glyphosate is readily translocated throughout the plant.

Jaworski (1972) investigated the possible sites of action of glyphosate. Results suggested that it interferes with the biosynthesis of phenylalanine, more specifically with the metabolism of chorismic acid in the aromatic aminoacid biosynthetic pathway. Sprankle *et al*. (1975) studying absorption, action and translocation of glyphosate concluded that respiration and photosynthesis are either slowly inhibited or are only affected after some other plant process has been inhibited.

Contact of glyphosate with foliage or green stems of desirable trees must be avoided since severe injury or death may result. Lund-Hoie (1976) found that the tolerance of *Picea abies* to Roundup depends on the stage of growth with a high degree of tolerance during mature

growth stage and less during shoot elongation.

Supplemental labeling for the experimental use of Roundup in silvicultural site preparation and conifer release recommends application of 1.2 to 11.7 l/ha (½ to 5 quarts/a), depending on the weeds to be controlled. For conifer release 1.2 to 7 l/ha (½ to 3 quarts/a) may be applied with the lower rates for more susceptible conifers.

Lund-Hoie (1975) reports glyphosate as being an alternative to pre- and post-emergence herbicide for the control of unwanted vegetation in forest plantations in Norway. A rate of 500 g/ha was optimum to control broad-leaved weeds and brushes while 1 kg/ha was the optimum rate for control of undisturbed perennial grasses. White (1975) reports the use of Roundup as a preplant and directed spray in established conifers at a rate of 1.7 kg/ha (1.5 lb/a) with increased effectiveness when used in combination with 3.4 kg/ha (3 lb/a) of simazine.

In experiments to control herbaceous weeds in western Oregon, excellent selective control has been obtained with Roundup at rates of 2.3 l/ha (1 quart/a) or less (Newton, 1977). In field plantations control of mixed perennial weeds resulted when 3.4 Kg/ha (3 lb/a) of atrazine mixed with 1.2 and 2.3 l/ha (1 and 2 pints/a) of Roundup were sprayed. Roundup alone did not provide satisfactory residual control. For site preparation 2.3 l/ha (2 quarts/a) of glyphosate was effective against most species of deciduous brushes.

Combinations of glyphosate with other pre-emergence herbicides will slow down or reduce its effect according to Monsanto (1974). However increased effectiveness has been reported when glyphosate was used in combination with simazine (White, 1975; Newton, 1977), atrazine (Newton, 1977) and also with terbuthylazin (Lund-Hoie, 1975).

Glyphosate undergoes complete and rapid degradation in soils. Rueppel et al. (1977) studying soil degradation of the herbicide concluded that biodegradation by soil microflora rather than chemical breakdown is the major degradation pathway. The rate of dissipation in three representative soil types (Ray silk loam, Norfolk sandy loam and Drummer silty clay loam) was measured. Complete biodegradation was observed in 112 days for Drummer and Ray soils. In the Norfolk soil degradation was slower. The results agree with actual field studies by Sharp (as mentioned by Rueppel et al., 1977) on different soil types where one average half life of two months was observed.

Importance of Seedling Quality for Successful Regeneration

Newton (1973) advises that the proper choice of species and size of the planting stock in combination with the use of herbicides are the key factors for a successful regeneration. Large seedlings usually tolerate more abuse from animals. Drought hardy stock is less likely to need weed control in the following years.

Chapmann and Wray (1957) indicate the advantages

of transplants over seedlings for Christmas tree plantations. Transplants are larger and sturdier than seedlings of the same age and usually develop more woodiness. They also tend to have larger and better root systems. These characteristics make them hardy and more able to survive. Bell and White (1966) however, warn that a large planting stock will not always give the best results. The larger the seedling at planting time the greater will be the planting shock. While it is also true that they may better withstand weed competition.

Koslowski (1971) points out the importance of handling with bareroot transplants. Exposure of the roots may affect survival and growth.

Lavender (1964), investigating the effect of date of lifting and cold storage of Douglas fir seedlings concluded that seedlings lifted after buds began to swell in the spring and submitted to any period of cold storage were adversely affected as evidenced by reduced growth and poor field survival.

More detailed discussion about seedling quality is presented in the Results and Discussion section.

Silvical Characteristics of Scotch Pine

Scotch pine (*Pinus sylvestris* L.) is the most widely distributed conifer in the world, growing naturally from the Atlantic in the west, across Europe and Asia to the Pacific Ocean in the east and from Scandinavia to the

Mediterranean. It is one of the most adaptable tree species, growing in the most diverse climates (Steven and Carlisle, 1959). Introduced into the United States and Canada as a timber tree it fell into disfavor, but rapidly won popularity as a Christmas tree, especially in the Lake States. It is the most common Christmas tree species in Michigan. It prefers well drained sandy loam soils. Scotch pine grows rapidly, the normal Christmas tree rotation being 5 to 7 years. Site preparation is required to assure survival and good shape of the trees. Fertilizing at time of planting is not recommended since good quality planting stock, competition control and careful planting techniques will result in satisfactory development and 85 to 90% survival (Bell and White, 1966). Controlling weeds after planting is important to maintain the growth and foliage color (Chapman and Wray, 1957).

Brown (1969) studying variations in survival and growth of different provenances of Scotch pine found that during the period of most active height growth root growth was relatively slight. It was not until after terminal shoot growth had slowed down or ceased that root growth took place. Growth of the seedlings was dependent initially on food materials stored in the seed, then on currently produced photosynthate used primarily for top growth. Survival was closely correlated with the length of the root system at the time of transplanting and the growth of new roots after transplanting. During the early

part of the growing season neither the amount of root present at transplanting nor new growth after transplanting was sufficient to supply moisture to the actively growing trees and survival was very low.

Plant Moisture Stress as Related to Competition

The basic idea of competition control is to improve the seedling environment. This vegetation manipulation causes many changes, and one of the most important is increased moisture availability.

A seedling's moisture status is dependent on soil moisture supply, duration of dry period, vegetational cover and transpirational forces acting in the seedling. The transpirational losses by competing vegetation are considered to be more important than evaporation for most soils (Newton, 1973). The same author (1964a) demonstrated that the rate of moisture depletion of the top 3 feet of soil was a linear function of vegetative cover. Decreasing the amount of vegetation by the use of chemicals conserved considerable moisture, resulting in better survival and vigor of several coniferous species tested.

The use of a portable pressure bomb to measure plant moisture stress was demonstrated by Waring and Cleary (1967). The theory behind it is described by Ritchie and Hinckley (1975). Sampling errors may vary from less than $\pm$ 1 atm to $\pm$ 10 atm depending on the degree of stress. Measurements of plant moisture status in conifer needles

is reviewed by Ritchie and Hinckley (1975). They concluded that needles may be preferable for they are a better indicator of the water potential in the photosynthetizing and transpiring tissues. They also point out the advantages of smaller samples as less gas usage and easier recognition of the point of external and internal pressure balance.

CHAPTER III

DESCRIPTION OF STUDY AREA

The study was conducted at the Tree Research Center facilities of Michigan State University. The experimental area is located along the western boundary.

Climatic Description

The summer is mild and the winter fairly cold. Precipitation is evenly distributed during most of the year, showing a midsummer decline. The normal annual precipitation is about 31 inches. The average frost free period is approximately 160 days, generally from May 3 to October 10. The mean annual temperature is 8°C (47°F) with a winter (January) mean of -4°C (24°F) and a summer (July) mean of 20°C (69°F). The average annual wind velocity is 4 Km per hour (7 miles/hour) with an average maximum of 9 Km per hour (14 miles/hour).

Topographic and Soil Description

The study was installed in a level to gently sloping field on glacial ground moraine. The experimental plots were placed on level areas on a hill top (Kalamazoo sandy loam soil) and in a lower area (Metea sandy loam soil).

The Kalamazoo series is a member of the fine-loamy, mixed, mesic family of Typic Hapludalfs. They are well drained soils with a sandy loam to loam plow layer. A typical profile as described by the Soil Conservation Service for Kalamazoo County, Michigan, has a dark grayish brown Ap horizon, dark reddish brown sandy clay loam and gravelly sandy loam Bt horizon containing considerable gravel, and dominantly brown B3 horizon of loamy sands, sands and gravels. The runoff is slow on level areas. Permeability of the upper part of the profile is moderate and of the lower part is rapid.

The Metea series is a member of the loamy, mixed, mesic family of Arenic Hapludalfs. A typical profile as described by the Soil Conservation Service for Fulton County, Indiana, has a dark grayish brown loamy sand A horizon, and a B2 horizon that is yellowish brown loamy sand in the upper part and dark yellowish brown clay loam in the lower part. The soil is well drained and runoff is slow. Permeability is very rapid in the sand upper layers and moderate in the lower layers. Moisture supplying capacity varies with the depth of the loam material.

History

The Tree Research Center is an 8 ha area of former agricultural land. The natural vegetation of the experimental area consisted mainly of quackgrass (*Agropyron repens*), yellow foxtail (*Setaria lutescens*), broad leaf plantain (*Plantago major*), wood sorrel (*Oxalis europea*), cinquefoil (*Potentilla* sp.) and wild vetch (*Vicia angustifolia*). The area had not been used for the previous three years. No chemicals were applied during this period. The weeds were mowed periodically during the growing season.

CHAPTER IV

MATERIALS AND METHODS

Experimental Design

The size of the available area and differences in soil and slope, required the use of a Randomized Complete Block design with seven replications for each of the five treatments listed below.

Treatment 1 - no weed treatment, with the weeds shading the seedlings.

Treatment 2 - Weeds clipped around each seedling to prevent shading. This treatment was chosen as the control treatment.

Treatment 3 - Weed treatment with simazine and glyphosate.

Treatment 4 - Weed treatment with glyphosate.

Treatment 5 - Mechanical weed control.

Weed control treatments were applied in such a way so as to keep the plots free of competing vegetation for the entire length of the first growing season.

The following comparisons of treatments were of special interest in the study:

1) Treatments 1 and 2 with treatments 3, 4, and 5.

This comparison evaluates competition control as a method to increase survival and growth in the first year.

2) Treatments 3, 4 and 5.

Through these comparisons three methods of competition control are evaluated.

3) Treatment 3 with treatment 4.

Differences between them would be due to residual effects of simazine.

4) Treatment 1 with treatment 2.

Evaluates the effects of competition for light.

Study Establishment

Sixty-four trees were planted in a 1 x 0.9 m (3½ ft. x 3 ft) spacing in each treatment plot. The measurement plot consisted of at least 36 trees, marked with flags at the beginning and end of each row. The buffer consisted of one row of trees on all sides.

A composite soil sample of five 6-inch cores were taken from each plot and analysed for percent organic matter and estimated nitrogen release (ENR); available P, exchangeable K, Mg and Ca, soil pH, cation exchange capacity and percent base saturation of cation elements. Percent organic matter, available P and Mg, soil pH and cation exchange capacity were chosen to be the most appropriate soil characteristics for a cluster analysis and subsequent blocking of the plots.

The cluster analysis procedure used was that described by Ward Jr. (1963). According to the results obtained a set of seven homogeneous blocks were selected and the treatments randomly assigned within each block. The total number of treatment plots was therefore, thirty-five. Initially, 46 plots were layed out, each with an area of 41 m^2 (439 ft^2).

Three thousand 9-12" (∿23-30cm) "Vans 35 Scotch pine" seedlings were bought from Vans Pines Inc., West Olive, Michigan. The seedlings were graded for size and apparent bud conditions. Very small seedlings and seedlings without viable buds were discarded. The remaining trees were stored in a cold room until the time of planting on May 15. The "forester tree planter" planting machine from Utility Tool and Body Company Inc., Clintonville, Wisconsin, was used. This machine consists of a continuous slit planter utilizing a coulter blade and rubber packing wheels attached to a four-wheel tractor. It was difficult to maintain the same spacing within rows, therefore, not all plots had exactly the same number of trees.

All treatments except mechanical weed control were applied after the trees had been planted. For treatment 1 the plots were left undisturbed, the idea being that the seedlings would be shaded by the surrounding vegetation. For treatment 2 the weeds around the trees were clipped with a rotary type mower at about the bud height to prevent shading. Treatments 3 and 4 were designed to test chemical weed control. Treatment 3 consisted of one application of

Roundup (41% water soluble) on May 27 at a rate of 1.7 kg/ha (1.5 lb/a), followed by one application of simazine 80% wettable powder (Princep) on June 2nd at a rate of 2.2 kg/ha (2 lb/a). Treatment 4 consisted of one application of Roundup,(41% water soluble), also on May 27 at a rate of 1.7 kg/ha (1.5 lb/a). A three gallon capacity hand sprayer utilizing CO_2 cartridges at 30 lb pressure, delivering 187.1 l/ha (20 gal/a), with a nozzle number 8002 was used.

All herbicides were applied as directed spray and care was taken not to spray over the trees to avoid injury. At the time of spraying the weather was sunny with little or no wind.

To meet treatment specifications reapplications of Roundup were made in June and July for both treatments 3 and 4. At these times a tin can was used to protect the trees because the buds were growing actively and severe injury could occur.

The plots for treatment 5 were cultivated prior to planting, using a tractor mounted cultivator to work the soil to a depth of 6 inches. To keep the area free of weeds during the growing season a 5 HP "Trojan II" rototiller was used. Weeds around the seedlings were pulled by hand.

Treatment 3, where the herbicide simazine was sprayed was subject to an additional study of the persistence of this chemical in the soil. Composite soil samples at two

depths, 0 to 3 inches and 3 to 6 inches were taken 30, 60 and 120 days after spraying. The samples were extracted by partition chromatography technique using a hexane-acetone solvent system, as described in Appendix A. The recovery of the extraction procedure determined by fortification of a soil sample with 4 ml of a standard simazine solution (20 ppm in benzene) was 78%.

The extract was cleaned up using the method described by Mills _et al_. (1972).

The residues were quantitatively evaluated by gas chromatography using a Coulson electrolytic conductivity detector model Tracor 560.

Initial Tree Evaluation

In early July all seedlings in the measurement plots were classified for bud condition, diameter and depth of planting. Conditions of the buds and diameter class were used as an index of seedling quality. The purpose of this classification was to assess the effects of seedling quality and depth of planting on survival and growth at the end of the first growing season. Buds were examined for physical conditions, dormancy and stage of development; each tree receiving a code name and number according to its characteristics as described in Table 1.

In the same way, three diameter classes were characterized as shown in Table 2.

Regarding depth of planting, seedlings were

Table 1. Bud Condition, Codes and Characteristics Used to Evaluate Seedling Quality

Code Number	Code Name	Description
1	Dormant	Buds did not develop
2	Broken	Damaged physically
3	Elongating	1 to 2.5 cm in size
4	Candles	More than 2.5 cm in size, without needles
5	Leaders	More than 2.5 cm in size, with needles
6	Secondary	Only secondary buds were developing

Table 2. Diameter Class Codes Used to Evaluate Seedling Quality

Code	Diameter Class (cm)
Small	0.1 - 0.4
Medium	0.41 - 0.59
Large	0.60 or larger

classified as described in Table 3. The criteria used in this classification were based on the relative height of the tree above ground. A seedling was considered shallow planted when the uppermost part of the root system was visible. A seedling was considered deeply planted when the length of the stem without needles was less than 1/3 of the total height of the tree above ground. All other trees were considered normally planted. This procedure was used to evaluate planting technique.

Table 3. Coding Used for the Evaluation of Depth of Planting

Code	Depth of Planting
0	Shallow
1	Normal
2	Deep

Measurements

At the end of the first growing season growth measurements and seedling characteristics were recorded. Characteristic were measured that would represent the total growth of the trees. For each tree, the initial height, from the soil surface up to the first branches, the final height, from soil surface to the tip of the tree and the new growth, the difference between final and initial height were recorded. A caliper was used for measuring

diameter. The number of lateral branches for each tree was recorded, as well as the number of dead trees in each plot. A final evaluation was made for each individual tree based on growth performance as described in Table 4.

Table 4. Codes and Characteristics Used to Evaluate Growth Performance of Scotch Pine Seedlings at the End of the First Growing Season

Code Number	Code Name	Description
0	Dead	Dead
1	No Growth	Buds did not Elongate
2	Primary	Only primary bud developed
3	Laterals	Only lateral branches developed
4	Primary + 1-3	Primary bud and 1-3 lateral branches developed
5	Primary + 4-6	Primary bud and 4-6 lateral branches developed
6	Primary + > 6	Primary bud and 7 or more lateral branches developed

A comparison between initial and final evaluation was used to assess the effect of seedling quality on growth performance.

To measure the degree of moisture stress imposed to trees subject to different competition control methods, predawn pressure bomb measurements were taken on August 22. Plant moisture stress readings were taken on three treatments: 1) Control, 2) Chemical weed control with

Roundup and 3) Mechanical weed control. The readings were taken from 4:10 to 6:35 AM, when plant moisture is in equilibrium with soil moisture. Two representative trees on each plot were selected and the plant water potential in bars was read using a fascicle removed from the new growth, approximately 5 cm below the tip.

Statistical Analysis

Data were analyzed on the CDC 6500 computer at Michigan State University. The SPSS: Statistical Package for the Social Sciences (Nie *et al.*, 1970) was used. Analyses of variance (Snedecor and Cochran, 1967) were performed to analyse the differences among treatment means for survival, initial height, final height, height growth, diameter and plant moisture stress measurements. Analyses of variance were also performed for trees separated according to initial diameter class. The equality of the means were tested by F test at .05 probability level. Tukey's multiple comparisons procedure at .05 probability was used to compare treatment means.

Frequency tables were prepared to relate initial and final tree characteristics, survival and initial tree evaluation. The independence of the variables was tested by a Chi-square test.

Pearson correlations were used to evaluate the relationships of plant moisture stress to height growth, plant moisture stress to survival and plant moisture stress to

diameter at the end of the growing season.

A disappearance curve, showing the relationship between concentration of simazine residues and time was constructed.

CHAPTER V

RESULTS AND DISCUSSION

Results obtained in the experiment present evidence that control of competing vegetation during the first growing season increases survival, height growth and diameter of Scotch pine seedlings. No significant differences were observed among the different methods of competition control or between shading and not shading.

Results for survival and growth, as well as those related to the importance of seedling quality, plant moisture stress and simazine residues in the soil are presented and discussed in detail.

Analyses of variance tables are enclosed as Appendix B.

Survival and Growth

Survival

Highly significant differences among treatments were found for survival. The results of the Tukey's multicomparison test for survival are presented in Table 5. Higher percent survival resulted on treatments where competing vegetation had been removed. No significant

Table 5. First Year Field Survival of Scotch Pine Seedlings with 5 Methods of Weed Control

Treatments	Survival* %	
Mechanical	87	a
Glyphosate	84	a
Glyphosate + simazine	81	a
Unshaded control	65	b
Shaded	61	b

*Means with the same letter are not significantly different at α = .05 level.

differences were observed between the methods of competition control employed.

Survival as Related to Initial Diameter Classes

Seedlings with large diameters had the best survival, followed by the medium size diameter. Seedlings with smallest diameters had the poorer survival. Percent survival for seedlings separated by initial diameter class can be seen in Table 6. Results are for the entire experiment, regardless of treatment.

The analysis of variance showed that the treatments did not influence survival of the large diameter seedlings. They had the highest percent survival in all treatments. For trees with medium and small diameter there was a significant difference among treatments. Results for first year

Table 6. Number of Trees and First Year Survival for Small, Medium and Large Planted Scotch Pine Seedlings

Initial Diameter Class	Code	Number of Seedlings	Survival* %
Small	0	370	72
Medium	1	732	87
Large	2	70	97

*Chi-Square significant at 1% probability level.

survival of medium and small diameter seedlings are shown in Table 7. Percent survival was higher on treatments were competing vegetation was removed. For small seedlings however, the mean survival for treatment 3 where the competing vegetation was removed with Roundup and simazine was not significantly different from treatments 1 and 2 where competing vegetation was not removed.

Survival as Related to Bud Conditions and Depth of Planting

Results of Chi-square test showed that survival was dependent on bud conditions as described in the initial tree evaluation and also on initial diameter size but not on depth of planting. First year survival according to bud conditions and depth of planting is shown in Tables 8 and 9 respectively.

Trees whose primary or secondary buds had already

Table 7. First Year Field Survival of Medium and Small Diameter Scotch Pine Seedlings with 5 Methods of Weed Control

Treatment	Initial Seedling Diameter Class Medium		Small	
	Survival* %			
Mechanical	94	a	81	a
Glyphosate	92	a	80	a
Glyphosate + simazine	91	a	76	a b
Unshaded control	78	b	68	b
Shaded	73	b	57	b

*Means for a given seedling size with the same letter are not significantly different at $\alpha = .05$ level.

Table 8. Number of Trees and First Year Survival of Scotch Pine Seedlings of Various Initial Bud Conditions

Bud Conditions Code Name	Code Number	Number of Seedlings	Survival* %
Dormant	1	64	34
Broken	2	14	70
Elongating	3	153	77
Candles	4	234	96
Leaders	5	459	98
Secondary	6	47	90

*Chi-square significant at 1% probability level.

Table 9. Number of Trees and First Year Field Survival of Scotch Pine Seedlings According to Depth of Planting

Depth of Planting		Number of	Survival*
Code Name	Code Number	Seedlings	%
Shallow	0	20	83
Normal	1	557	83
Deep	2	393	82

*Chi-square non significant.

started developing by early July had better survival than those still dormant or with any physical damage.

Height

The total height as well as height growth was significantly higher in treatments where competing vegetation had been removed. No significant differences were detected between the methods of control used. There were also no differences between control and treatment 1. The first year height and height growth are shown in Table 10.

The analyses of variance performed for seedlings separated according to initial diameter size for both total height and height growth showed that trees with medium and small diameter sizes performed better in treatments where weeds had been removed. Again the method of weed control used had no influence on the results. Total height and height growth of medium and small diameter

Table 10. First Year Total Height and Height Growth of Scotch Pine Seedlings with 5 Methods of Weed Control

Treatment	Total Height* (cm)		Height Growth* (cm)	
Mechanical	29	a	12	a
Glyphosate	29	a	13	a
Glyphosate + simazine	27	a	12	a
Unshaded control	23	b	6	b
Shaded	21	b	6	b

*Means with the same letter are not significantly different at α = .05 level.

seedlings are shown in Tables 11 and 12 respectively. For seedlings with large initial diameter there was no significant difference between treatments at 5% probability.

Table 11. First Year Total Height of Medium and Small Diameter Scotch Pine Seedlings with 5 Methods of Weed Control

Treatment	Initial Seedling Diameter Class			
	Medium		Small	
	Total Height* (cm)			
Mechanical	30	a	26	a
Glyphosate	30	a	25	a
Glyphosate + simazine	29	a	22	ab
Unshaded control	24	b	20	b
Shaded	23	b	18	b

*Means for a given seedling size with the same letter are not significantly different at α = .05 level.

Table 12. First Year Height Growth of Medium and Small Diameter Scotch Pine Seedlings with 5 Methods of Weed Control

Treatment	Initial Seedling Diameter Class: Medium — Height Growth* (cm)		Small	
Mechanical	12	a	8	a
Glyphosate	12	a	8	a
Glyphosate + simazine	11	a	7	a
Shaded	5	b	3	b
Unshaded control	5	b	3	b

*Means for a given seedling size with the same letter are not significantly different at $\alpha = .05$ level.

Diameter

The same general trend was observed for diameter at the end of the first growing season. Trees with the largest diameter were found to be in plots without competing vegetation, and they were significantly different from those where vegetation had not been removed. This is shown in Table 13.

Analysis of variance performed for trees separated according to initial diameter size showed that for seedlings with large initial diameter, weed control had no effect in the final diameter. Seedlings with medium and small initial diameter had comparatively higher final diameter when competition from weeds was absent, as shown

Table 13. First Year Diameter of Scotch Pine Seedlings with 5 Methods of Weed Control

Treatment	Diameter* (cm)	
Mechanical	7	a
Glyphosate	7	a
Glyphosate + simazine	7	a
Unshaded control	5	b
Shaded	5	b

*Means with the same letter are not significantly different at α = .05 level.

Table 14. First Year Diameter of Medium and Small Initial Diameter Scotch Pine Seedlings with 5 Methods of Weed Control

	Initial Seedling Diameter Class			
Treatment	Medium		Small	
	Diameter* (cm)			
Mechanical	9	a	7	a
Glyphosate	9	a	6	a
Glyphosate + simazine	8	a	6	a b
Unshaded control	7	a b	4	b
Shaded	8	b	4	b

*Means for a given seedling size with the same letter are not significantly different at α = .05 level.

in Table 14.

There are many factors involved in the competitive process and one of the most important is certainly moisture consumption. Moisture deficiencies illustrate interaction of environmental factors that play a vital role in the survival of planted seedlings. Koslowski (1971), views survival and growth of trees as being dependent more on availability of water than anything else.

As water is readily absorbed from the soil, nutrients are also being absorbed and circulated and therefore growth is vigorous as long as there are no other limiting environmental factors. As the soil dries, nutrient absorption is reduced and leaf water deficits develop because transpiration is higher than absorption. Photosynthesis and other physiological processes are affected and growth of meristems is reduced. If rain does not recharge the soil, internal water stress becomes so intense that growth may cease prematurely (Zahner, 1968).

Newton (1964a), studying the influence of herbaceous vegetation on coniferous seedling habitat showed that the rate of moisture depletion was a direct function of the amount of vegetation. Lane and McComb (1948) investigating soil moisture consumption by tree seedlings and grass came to the conclusion that grasses can rapidly reduce the available soil moisture and in consequence retard the development of roots resulting in a decrease in top growth and increase in mortality. Similar results of better

survival and growth following competition control for other coniferous species have been obtained; Holt *et al.* (1973) and Voeller *et al.* (1974) for loblolly pine, Larson and Schubert (1969) for ponderosa pine, Lambert *et al.* (1972) and Wittenkamp and Wilde (1964) for red pine. The latter authors concluded that a 300 percent increase in yield was due to elimination of competing vegetation and a consequent increased supply of moisture.

Although the soil moisture consumption has not been followed in this first growing season, it is not improper to regard it as the most important factor involved in the outcome of this study since the effects of other soil characteristics were controlled by the layout of the experiment. Results of plant moisture stress will be discussed in another section.

The method used to control unwanted vegetation did not have any influence on the responses obtained. Although trees subjected to mechanical weed control (T5) generally had the best responses, they were not significantly different from the responses obtained with chemical weed control. Cost factors and soil disturbance caused by cultivation should be considered in the event of selecting a practice.

Treatments 1 and 2 (control) were not significantly different from each other. This suggests, for the particular site studied, competition for light is not strong enough to affect growth and survival of seedlings.

The results also present evidence of the importance of seedling quality in artifical regeneration. Trees with larger diameter at the time of planting had better survival and growth, regardless of the treatment applied. Seedlings whose buds started developing earlier and with no physical damage had better survival. Wakeley (1954) working with southern pines noted that high physiological quality appears to result in formation of new roots and consequent favorable water balance in seedlings shortly after planting. He also points out that although it is difficult to evaluate accurately the physiological conditions of the seedlings, various techniques in the nursery may affect their physiology.

Stone (1955) used the absence of root development as a criterion to indicate an unsatisfactory physiological condition of seedlings. He reasoned that if the root system did not increase in size at a fairly rapid rate, the seedling would die of drought when the moisture content of the soil surrounding the roots approached the wilting point. Lack of top development, would probably not become critical during the first year after planting. He concluded that the ability of seedlings to produce roots could not be associated with external morphological differences.

As mentioned earlier, Lavender (1964) reported deleterious effects of cold storage and early lifting on physiology of Douglas fir seedlings. For this experiment seedlings were submitted to cold storage for 10 days.

Further studies would be needed to assess the effects of such factors on seedling physiology and consequent performance in the field.

The conditions of the buds as described in the initial tree evaluation were determined by their external appearance with no additional physiological basis.

The depth of planting did not influence survival, suggesting that this is not an adequate measure of the adequacy of the planting technique.

Relationship Between Initial and Final Seedling Characteristics

The results of Chi-square test indicate a significant relationship between the final classification with bud conditions and initial diameter class but not with depth of planting.

This final tree evaluation summarized the growth performance of each tree. Table 15 shows the number of trees in each bud condition class and percent of each class with final tree classification. Table 16 shows the same for initial diameter size and final tree classification.

Again it can be seen that seedlings with buds that had already started development by early July, the ones designated as elongating, "candles" and "leaders," had the best growth performance, developing a main bud and 3 to 6 lateral branches by the end of the first growing season. Sixty-six percent of the seedlings with dormant

Table 15. Number of Scotch Pine Seedlings of Various Initial Bud Conditions and Percentage with Various Final Tree Condition

Initial Bud Condition	Number of Seedlings Measured	Percent of Trees with Final Tree Condition*						
		Dead	No Growth	Primary	Laterals	Primary + 1-3	Primary + 4-6	Primary + > 6
Dormant	190	66	4	1	4	7	15	3
Broken	20	30	-	-	30	5	30	5
Elongating	199	23	1	< 1	8	20	42	6
Candles	245	5	-	-	10	17	56	10
Leaders	267	2	1	< 1	6	17	51	24
Secondary	52	10	-	-	64	11	11	2

*Chi-square significant at 1% probability level.

Table 16. Number of Scotch Pine Seedlings with Initial Diameter Size and Percentage with Various Final Tree Condition

Initial Diameter Class	Number of Seedlings Measured	Percent of Trees with Final Tree Condition*						
		Dead	No Growth	Primary	Laterals	Primary + 1-3	Primary + 4-6	Primary + > 6
Small	370	29	1	2	9	17	36	6
Medium	732	13	1	< 1	10	15	46	15
Large	70	3	-	-	13	7	37	40

*Chi-square significant at 1% probability level.

buds died. As would be expected, 30% of the trees with broken buds developed only lateral branches, but another 30% managed to develop a main bud and 3 to 6 lateral branches and 30% died. Sixty-four percent of the trees that had only secondary buds developing by early July, ended up with only lateral branches.

The results for diameter show the same trend as discussed earlier. Seedlings with large initial diameter had better growth performance, developing a main bud and many branches. Forty-six percent of the seedlings with medium initial diameters developed a main bud with 3 to 6 lateral branches while only 37% of the ones with small diameter did so; another 29% of them died.

These results emphasize the importance of seedling quality, expressed in terms of diameter and bud conditions, on the growth performance during the first growing season.

Plant Moisture Stress

Plant moisture stress was measured in treatments 2 (control without shading), 4 (weed control with roundup) and 5 (mechanical weed control). The highest readings were in the control plots, with a mean of 4.8 bars. This result however was not significantly different from that obtained for treatment 4--weed control with roundup with an average of 3.2 bars. The lowest stress was found to take place where weeds were removed mechanically with an

average of 2.9 bars, and it was significantly different from the control plots but not from the chemical weed control plots. These results can be seen in Table 17.

Table 17. Water Stress of Scotch Pine Seedlings with 3 Methods of Weed Control

Treatment	Plant Moisture Stress* (bars)
Unshaded Control	4.8 a
Glyphosate	3.2 a b
Mechanical	2.9 b

*Means with the same letter are not significantly different at $\alpha = .05$ level.

A negative correlation was obtained between plant moisture stress and height growth (-0.7268), plant moisture stress and final diameter (-0.4087), and plant moisture stress and survival (-0.3102).

The use of the pressure chamber technique has become a standard method for assessing plant water status in the field. Pressure chamber determinations are estimates of the total water potential of the xylem sap. Measurements just before dawn are a function of soil moisture if it is assumed that during the night there is no transpiration because the atmospheric demand for water is low and the stomata are closed and therefore equilibrium exists between water potential in the plant and the soil (Ritchie and Hinckley, 1975). The plant moisture stress measured

therefore is the same as soil moisture tension. As would be expected plant moisture stress was higher in the control plots where competitive vegetation had not been removed and consequently the transpirational losses were higher.

The method of competition control did not significantly influence moisture stress. One could postulate that mechanical weed control, where the soil is exposed, would result in higher plant moisture stress due to increased evaporation. More intensive investigation using more accurate techniques is needed to provide a better understanding of competition and moisture relations.

Growth is dependent on cell division and elongation and ultimately on the supply of carbohydrates from photosynthetic tissue; both processes are intimately linked to the water balance in a plant (Hsiao, 1973). This would explain the negative correlation found between plant moisture stress and height growth and diameter.

Sands and Rutter (1959) studied the growth of *Pinus sylvestris* in relation to soil moisture tension. Compared with plants growing in soil at 0.1 atm (0.1013 bars), growth in the first year was significantly reduced when the soil tension was 0.3 atm (0.3039 bars). The effects of soil moisture tension on growth were due mainly to variations in net assimilation rate. Jarvis and Jarvis (1963) also investigated the growth response of several species of forest trees, including *Pinus sylvestris*, to water regime. The results obtained for Scotch pine were similar

to those obtained by Sands and Rutter (1959).

Simazine Residues in Soil

The disappearance curve for simazine is shown in Figure 1. The initial surface treatment of 2.2 Kg/ha (2lb/a) was calculated to be approximately equivalent to a concentration of 2.2 ppmw mixed uniformly in the surface 6 inches of the soil. The logarithm of the concentration in nanograms per gram of dry soil (ppb) plotted against time conforms to a pseudo first order reaction consisting of two phases. The concentration of simazine decreased rapidly during the first phase. During the second phase, dissipation continued at a slower, ever decreasing rate. Only 1.5% of the simazine applied remained in the 0-3 in. depth after 120 days. The amount of simazine in the 3-6 in. depth increased during the first 30 days and remained approximately constant for the next 30 days. After this period, simazine concentration decreased continuously to almost undetectable levels 120 days following application. The average concentration of simazine in the two depths of soil can be seen in Figure 2.

The dissipation of simazine from both depths might have been the result of leaching, microbial degradation or adsorption to organic and/or inorganic soil colloids. Plant uptake may also account for dissipation.

Similar disappearance curves, consisting of two distinct phases, have been obtained for simazine by other investigators (Roadhouse and Birk, 1961; Talbert and

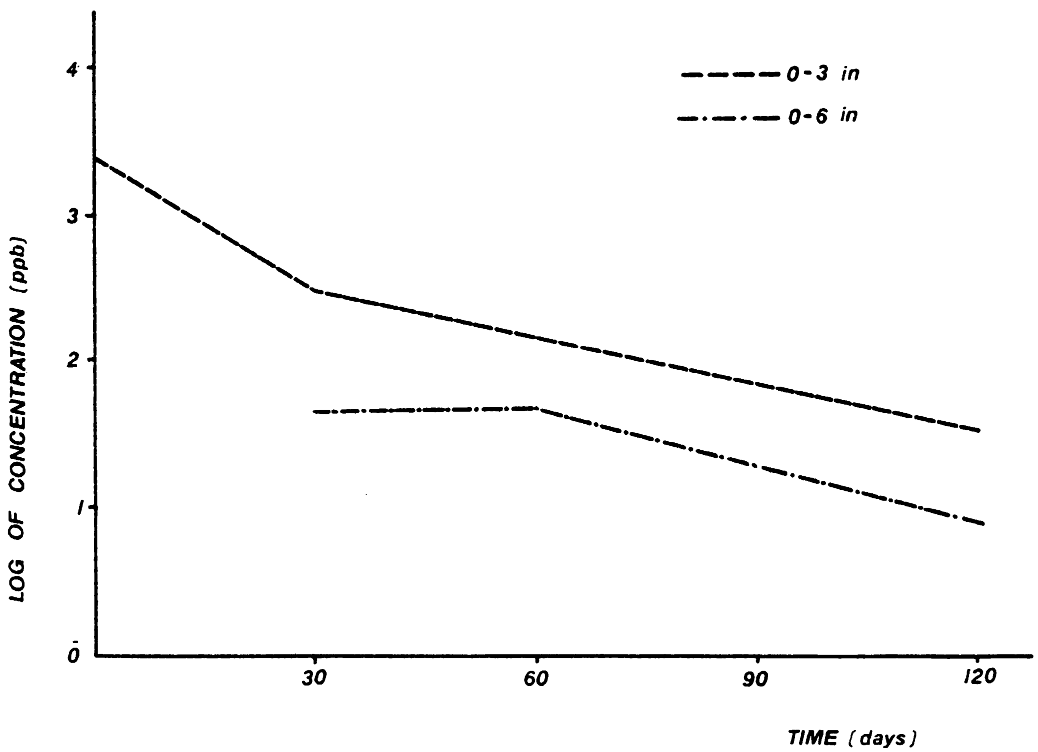

Figure 1. Curves showing the disappearance of simazine from two depths of a sandy loam soil after application of 2.2 Kg/ha (2 lb/a). Points are average of seven replications.

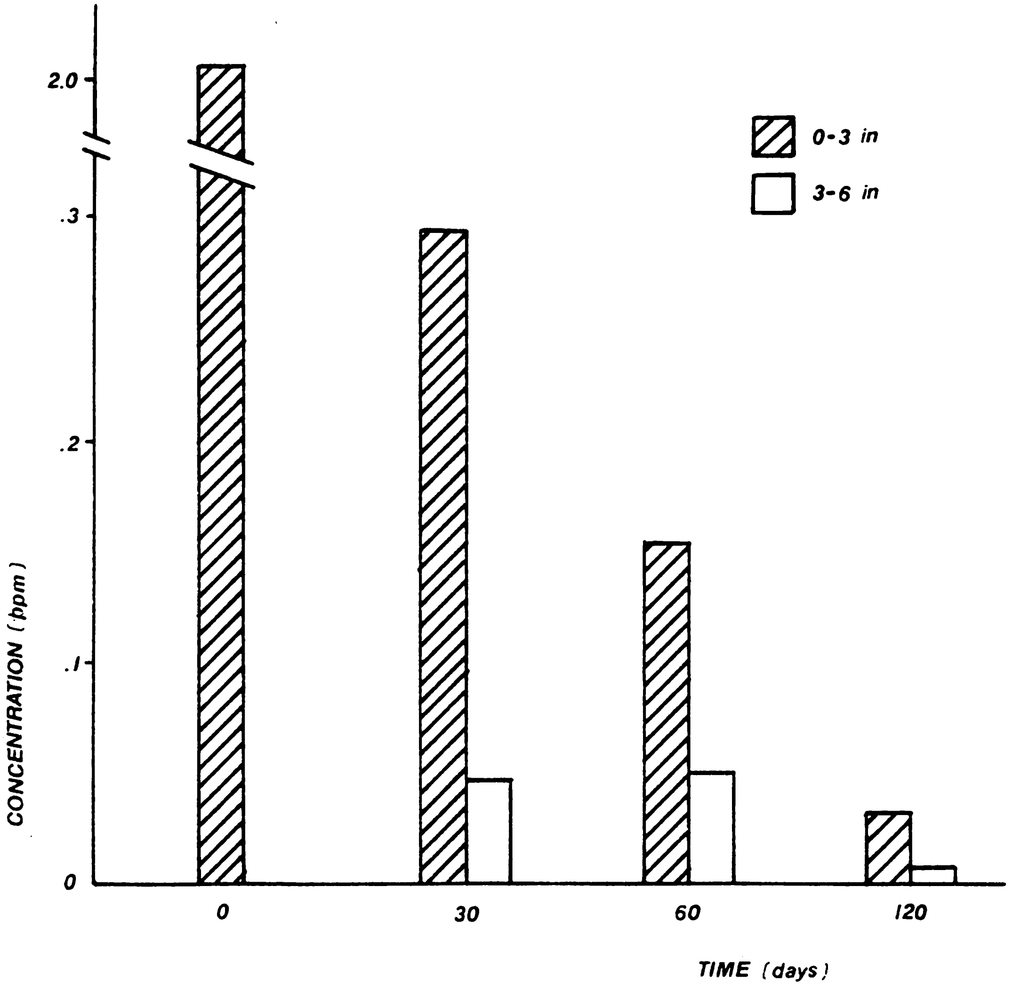

Figure 2. Average concentration of simazine in two depths of a sandy loam soil following application of 2.2 Kg/ha (2 lb/a).

Fletchall, 1964). Others have shown the existence of a lag phase in the disappearance of simazine (Burnside _et al_., 1961; Holly and Roberts, 1963). This lag phase is usually attributed to unfavorable weather conditions or adaptation of organisms that are effective in degredation.

Some studies have indicated relative resistence of simazine to leaching (Ashton, 1961; Roadhouse and Birk, 1961; Harris, 1967). Burnside _et al_. (1961) studying leaching of simazine in a silt loam soil found that the depth to which simazine moved was not great but it increased with amount of water applied.

The majority of evidence indicates that slow microbiological decomposition is the principal process involved in the dissipation of simazine (Burnside _et al_., 1961; Rabag and McCollum, 1961; Talbert and Fletchall, 1964; Kaufman _et al_., 1965). Inactivation has been shown to occur during the warm moist period of the year and cease during dry, cool periods, coinciding with favorable conditions for microbial growth.

A number of investigators have correlated the phytotoxicity of triazine herbicides with soil properties (Sheets _et al_., 1962; Nearpass, 1965; Upchurch, 1966; Hance _et al_., 1968).

The most important soil properties appear to be organic matter, soil acidity and clay content. Uptake and degredation of simazine by red and white pine seedlings has been studied by Freeman _et al_. (1964) and Dhillon _et_

al. (1968). The importance of soil properties and plant uptake in the dissipation of simazine, however, requires more detailed investigation than was possible in the present study.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The establishment of a new timber stand requires creation and maintenance of favorable conditions for growth. Failures of reforestation programs have often been associated with the competitive influence of herbaceous vegetation that compete with the seedlings for moisture, space, nutrients and light. Manipulation of existing vegetation has been shown to minimize the severity of the habitat and improve survival and growth of the seedlings.

The primary objective of this study was to examine the effects of competition control on survival and field growth of Scotch pine seedlings at the end of the first growing season.

Seedlings were machine planted and subjected to five treatments: 1) No competition control, 2) elimination of shading from weeds, controlling competition for light, 3) competition control with simazine + glyphosate, 4) competition control with glyphosate and 5) mechanical weed control.

Competition control had a pronounced effect on

seedling growth and survival. Increased survival, height growth and diameter resulted from competition control with simazine + glyphosate, with only glyphosate and with mechanical weed control. No significant differences were observed among these three methods of competition control. Other factors such as cost and environmental disturbances should be considered in selecting a practice. Elimination of shading from weeds did not increase survival or growth, indicating that competition for water is likely to be the most important competitive factor on this particular site. Nutrient differences were taken into account by the experimental design used.

Plant moisture stress measurements in three representative treatments (control, competition control with glyphosate and mechanical weed control), showed that moisture stress was higher where competing vegetation had not been removed and lower where competition was controlled mechanically. This is an indication of the relationship between competition control and soil moisture availability. More detailed investigations are needed to provide a better understanding of the moisture relations for that site. Soil moisture relations should be thoroughly investigated as well as effects of sunshine and humidity.

The individual tree evaluation, done shortly after planting, and based on diameter size and bud conditions was used as an index of seedling quality. Results showed that seedlings with large diameter size (0.60 cm or more)

always had the best survival and growth regardless of competition control. Buds with good physical appearance also resulted in better survival. Weeding resulted in significant increased survival and growth of medium and small seedlings.

The results suggest that high quality planting stock and control of competing vegetation assure better survival and growth of Scotch pine seedlings during the first growing season and that most of the response would be on medium and small seedlings.

The same responses were obtained with different methods of competition control. Cost analysis would be advisable before selecting a method.

The planting technique, evaluated by the depth of planting did not show significant influence on survival.

A secondary objective of this study was to determine the persistence of the herbicide simazine in the soil as well as its rate of disappearance. Only 1.5% of the applied rate of 2.2 kg/ha (2 lb/a) remained in the top 0-3 in. of soil after 120 days. In the same period concentration of simazine in the 3-6 in. depth decreased to almost undetectable levels. Results indicate that if control of vegetation is required for more than one growing season higher rates of simazine should be applied. Further investigations would be needed to assess influence of soil properties, microbial degradation and uptake of herbicide by Scotch pine on the dissipation of simazine from the

soil. These are important factors when control of unwanted vegetation is needed for longer periods.

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APPENDICES

APPENDIX A

PROCEDURE FOR EXTRACTION OF SIMAZINE RESIDUES FROM SOIL SAMPLES

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PROCEDURE FOR EXTRACTION OF SIMAZINE RESIDUES FROM SOIL SAMPLES

a) Weight approximately 50 g of soil, add 10 ml of distilled water and let stand over night.

b) Add 80 ml hexane-acetone (1:1) solvent, shake for 15 minutes and decant liquid into a separatory funnel.

c) Repeat the above procedure two more times using 40 ml of solvent. Use vacuum filtration after the last shaking.

d) Add 15 ml of 1% NaCl in water to the separatory funnel, shake for 10 seconds. Discard the water layer (lower layer).

e) Dry the hexane layer with 15-20 g of anhydrous Na_2SO_4. Wash the funnel two times with 5 ml hexane. Add wash to extract.

f) Concentrate the filtrate using a rotatory evaporator to about 2 or 3 ml. Put the concentrate in a 10 ml volumetric flask and add hexane washings to bring to 10 ml.

g) Proceed to clean-up of extract.

The recovery of the extraction procedure was

determined by fortification of a soil sample with 4 ml of a standard simazine solution (20 ppm in benzene). The recovery was 78%.

APPENDIX B

ONE-WAY ANALYSES OF VARIANCE TABLES

APPENDIX B

ONE-WAY ANALYSES OF VARIANCE TABLES

Table B1. Analysis of Variance for Survival

Source	DF	SS	MS	F-Ratio
Treatments	4	3802.0148	950.5037	28.1596**
Blocks	6	129.5674	21.5946	
Residual	24	810.1003	33.7542	
Total	34	4741.6825		

**Significant at 1% probability level.

Table B2. Analysis of Variance by Initial Diameter Size for Survival

Source	DF	SS	MS	F-Ratio
		SMALL		
Treatment	4	2834.7144	708.67.86	4.1556**
Block	6	499.2668	83.2114	
Residual	24	4092.7659	170.5319	
Total	34	7426.7471		
		MEDIUM		
Treatment	4	2437.3804	609.3451	9.3455**
Block	6	334.8886	55.8148	
Residual	24	1564.8564	65.2024	
Total	34	4337.1257		
		LARGE		
Treatment	4	436.2037	109.0509	1.9950 ns
Block	6	348.8971	58.1495	
Residual	24	819.9270	54.6618	
Total	34	1605.0278		

**Significant at 1% probability level.

ns - non significant

Table B3. Analysis of Variance for Initial Height

Source	DF	SS	MS	F-Ratio
Between groups	4	413.6537	103.4134	5.3348**
Within groups	965	18706.3313	19.3848	
Total	969	19119.9850		

**Significant at 1% probability level.

Table B4. Analysis of Variance for Total Height

Source	DF	SS	MS	F-Ratio
Treatment	4	355.3439	88.8360	33.0342**
Blocks	6	75.0819	12.5136	
Residual	24	64.5411	2.5892	
Total	34	494.9669		

**Significant at 1% probability level.

Table B5. Analysis of Variance by Initial Diameter Size for Total Height

Source	DF	SS	MS	F-Ratio
		SMALL		
Treatment	4	255.2121	63.8030	8.4981**
Block	6	91.7602	15.2934	
Residual	24	180.1899	7.50791	
Total	34	527.1622		
		MEDIUM		
Treatment	4	292.2135	73.0534	17.6584**
Block	6	22.6440	3.7740	
Residual	24	99.2889	4.1370	
Total	34	414.1464		
		LARGE		
Treatment	4	157.6566	39.4141	1.6357 ns
Block	6	178.7929	29.7988	
Residual	24	361.4366	24.0958	
Total	34	697.8861		

**Significant at 1% probability level.

ns - non significant

Table B6. Analysis of Variance for Height Growth

Source	DF	SS	MS	F-Ratio
Treatment	4	295.5874	73.8969	35.6980**
Block	6	18.0491	3.0082	
Residual	24	49.6812	2.0700	
Total	34	363.3177		

**Significant at 1% probability level.

Table B7. Analysis of Variance by Initial Diameter Size for Height Growth

Source	DF	SS	MS	F-Ratio
		SMALL		
Treatment	4	191.2175	47.8044	11.2439**
Block	6	33.1278	5.5213	
Residual	24	102.0382	4.2516	
Total	34	326.3835		
		MEDIUM		
Treatment	4	376.9671	94.2418	33.4665**
Block	6	28.9800	4.8300	
Residual	24	67.5842	2.8160	
Total	34	473.5313		
		LARGE		
Treatment	4	200.1018	50.0255	3.4631 ns
Block	6	34.7119	5.7853	
Residual	24	216.6826	14.4455	
Total	34	415.4963		

**Significant at 1% probability level.

ns - non significant

Table B8. Analysis of Variance for Diameter at the End of the First Growing Season

Source	DF	SS	MS	F-Ratio
Treatment	4	35.5927	8.8982	32.5655**
Block	6	3.0635	.5106	
Residual	24	6.5577	.2732	
Total	34	45.2139		

**Significant at 1% probability level.

Table B9. Analysis of Variance by Initial Diameter Size for Diameter at the End of the First Growing Season

Source	DF	SS	MS	F-Ratio
		SMALL		
Treatment	4	40.4325	10.1081	7.3387**
Block	6	13.6094	2.2682	
Residual	24	33.0569	1.3774	
Total	34	87.0988		
		MEDIUM		
Treatment	4	25.1521	6.2880	35.6211**
Block	6	.9502	.1584	
Residual	24	4.2366	.1765	
Total	34	30.3389		
		LARGE		
Treatment	4	15.0109	3.7527	2.3910 ns
Block	6	18.9481	3.1580	
Residual	24	23.5426	1.5695	
Total	34	57.5016		

**Significant at 1% probability level.

ns - non significant

Table B10. Analysis of Variance for Plant Moisture Stress Measurements

Source	DF	SS	MS	F-Ratio
Treatment	2	13.8017	6.9008	4.8351**
Blocks	6	12.0062	2.0010	
Residual	12	17.1268	1.4272	
Total	20	42.9347		

**Significant at 1% probability level.

APPENDIX C

COMMON, TRADE AND CHEMICAL NAME OF HERBICIDES AND RESPECTIVE MANUFACTURES

Appendix C. Common, Trade and Chemical Name of Herbicides and Respective Manufacturers

Common Name	Trade Name	Chemical Name	Manufacturer
Amitrole	Amizol, Weedazol	3-amino-1,2,4-triazole	Amer. Cyanamid, Amchem.
Amitrole-T	Cytriol, amitrole-T, Amitrol-T	3-amino-1,2,4-triazole plus ammonium thiocynate	Amer. Cyanamid, Amchem.
AMS	Ammate	ammonium sulfamate	DuPont
Asulam	Asulox	methyl sulfanilylcarbamate	Rhodia
Atrazine	A Atrex	2-chloro-4-(ehtylamino)-6-(isopropylamino)-s-triazine	CIBA-Geigy
cacodylic acid	Phytar, Rad-e-cate	hydroxydimethylarsine oxide	Ansul, Vineland
dalapon, radapon	Dowpon	2,2-dichloropropionic acid	Dow
dicamba	Banvel	3,6-dichloro-o-anisic acid	Velsicol
dichlobenil	Casoron	2,6-dichlorobenzonitrile	Thompson Hayward
dichlorprop	several	2-(2,4-dichlorophenoxy)propionic acid	Boots, Rhodia
diuron	Karmex	3-(3,4-dichlorophenyl)-1,1-dimethylurea	DuPont
fenuron	Dybar	1,1-dimethyl-3-phenylurea	DuPont

Appendix C. (continued)

Common Name	Trade Name	Chemical Name	Manufacturer
glyphosate	Roundup	N-(phosphonomethyl)glycine	Monsanto
monuron	Telvar	3-(p-chlorophenyl)-1,1-dimethylurea	DuPont
paraquat	Ortho Paraquat	1,1'-dimethyl-4,4'bipyridinium ion	Chevron
picloram	Tordon	4-amino-3,5,6-trichloropicolinic acid	Dow
simazine	Princep	2-chloro-4,6-bis(ethylamino)-s-triazine	CIBA-Geigy
sodium arsenite	Arcadian	sodium arsenite	Allied Chem.
sodium chlorate	Sodium Chlorate	sodium chlorate	Pennwalt
TCA	TCA	trichloroacetic acid	Dow
2,4-D	several	(2,4-dichlorophenoxy)acetic acid	Dow, Rhodia, others
2,4,5-T	Esteron 245	(2,4,5-trichlorophenoxy) acetic acid	Dow
2,4,5-TP	Silvex, Kuron, Weedone, 2,4,5-TP	2-(2,4,5-trichlorophenoxy) propionic acid	Dow

Source: Anderson, 1977