ESTABLISHING PLANTATIONS OF EASTERN WHITE PINE AND HYBRID POPLAR FOR A SHADING STUDY ON WHITE PINE WEEVIL CONTROL

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By Marc J. Linit

An Abstract of the Thesis Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science (in Forestry). May, 1975

White pine plantations in the Orono, Maine area were sampled to determine the level of weevil damage. Approximately 40% of the white pine growing in an unshaded habitat were weevil damaged. White pine planted in close spacings exhibited less weevil damage than adjacent white pine planted at wider spacings. White pine growing in a shaded habitat were damaged by the weevil less often than white pine growing in an unshaded habitat.

Plots containing white pine seedlings and hybrid poplar cuttings were established in Hartland, Maine and Veazie, Maine for a shading study on the silvicultural control of the white pine weevil, Pissodes strobi, Peck. The plots will eventually vary in the intensity of shade they produce dependent upon the number of poplar cuttings planted within each plot. Four different shading conditions will result from an unshaded plot, a light-shade plot, a medium-shade plot, and a heavy-shade plot.

The plots were established in order to develop a practical method of growing white pine free of weevil damage on abandoned agricultural sites. Results of this study will not be known for a number of years and hence this study is concerned with the establishment of the tree species in the shade plots.

The success of hybrid poplar cutting establishment is closely associated with site characteristics. Cutting establishment was successful on the moist, rockless soil at the Veazie site, but was hampered on the well drained, rocky soil at the Hartland site.

Four herbicides were tested to control weed and grass competition around white pine seedlings in order to facilitate establishment. After two consecutive years of application, each herbicide was assessed for 1) effectiveness in controlling competing vegetation and 2) toxicity to white pine seedlings. Regression analysis was used to evaluate herbicide toxicity.

Each of the four herbicides were applied at three application rates, resulting in twelve herbicide treatments. The wettable powders simazine and atrazine applied at the rate of 4 lb. a.i./acre (4.5 kg./ha.) provided the best results of all treatments tested. Combination treatments of simazine + atrazine wettable powders had a highly toxic effect on the white pine seedlings. Granular treatments of simazine were difficult to apply and provided less effective weed and grass control at equivalent application rates than the other three herbicides which were wettable powder formulations.

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INTRODUCTION

The white pine weevil, *Pissodes strobi* (Peck), (Coleoptera: Curculionidae) is a major insect pest of North American forest plantations. It is known to attack all pines and spruces in the northern regions of the continent. Among the species most often attacked are Norway spruce (*Picea abies* (L.)), Scotch pine (*Pinus sylvestris* L.), and jack pine (*Pinus banksiana* Lamb.). Eastern white pine (*Pinus strobus* L.) is the preferred host.

Eastern white pine is one of the most important saw timber species in the Northeast, however, once damaged by the white pine weevil its potential as a saw timber tree is reduced. Attack by the weevil seldom results in death of the host tree. Injury occurs as the weevil larvae feed beneath the outer bark of the terminal leader. Larval feeding causes complete girdling and eventual death of the terminal leader and a corresponding reduction in growth. After the death of the terminal leader one or more of the living lateral branches assumes vertical growth and becomes the new leader. The process results in crooked or forked trees. White pine subjected to successive attacks over a number of years become multiple stemmed and worthless for saw-log production.

It is the purpose of the research being instituted with this study to develop a practical method of reducing the incidence of white pine weevil damage to white pine. This is attempted by planting white pine in association with hybrid poplar. The rapid growth of the poplar will form an overstory providing the pine with a shaded habitat in which to grow. Shade is known to discourage weevil oviposition.

The purpose of this project is not to investigate the beneficial aspects of shading which has been demonstrated in numerous studies but rather to develop a practical method of utilizing the shading concept.

OBJECTIVES OF STUDY

The specific objectives of this study were as follows:

1. To determine the extent of weevil damage to white pine growing in shaded habitats and unshaded habitats at various planting densities,
2. To develop a practical method of weevil control by growing white pine in the shade of associated hybrid poplar,
3. To develop practical methods of controlling competing vegetation around white pine seedlings and hybrid poplar cuttings to facilitate their establishment on abandoned field sites.

LITERATURE REVIEW

White Pine Weevil

W. D. Peck, Professor of Natural History and Botany at Harvard University first described the white pine weevil as an important forest insect in 1817. Since that time the white pine weevil has been extensively studied. The life history and general biology is well known and has been described in the literature (Belyea and Sullivan 1956, Hastings and Godwin 1970, MacAloney 1930). The complex of natural enemies has likewise been described (Harman and Kulman 1967, Steiner 1930, Taylor 1928, 1929a, 1929b).

The economic losses attributable to the white pine weevil have been well documented and have been a major factor in discouraging intensive management of white pine throughout the Northeast.

Successful attack by the white pine weevil causes two types of loss: (1) destruction of the terminal leader results in forked or multiple stemmed trees, causing a reduction in recoverable volume of lumber, (2) weevil injury causes lumber degrade due to defects such as cross grain, large knots, loose knots, red rot, and compression wood.

Waters, McIntyre, and Crosby (1955) determined the volume loss of white pine due to weevil damage in New Hampshire. They found an average loss of 13% in pole size trees (5.0-8.9 inches d.b.h.), 40% in the saw-log portions of trees (9 inches d.b.h. and over), and 70% in the portion above saw-log limits of merchantability.

Translated into actual volumes the above losses amounted to 35 million cubic feet (450,000 cords) from potential merchantable pole timber trees, 2.16 billion board feet from the saw-log portions of saw timber trees, and 116 million cubic feet (1,486,000 cords) from material other than saw-logs.

An Ontario study of the value loss in white pine found that weevil damage reduced the volume yield by 3-21% and the value of lumber by $10-100 per M. bd. ft., with the average reduction in value being 25% (Brace 1972). Ostrander and Stoltenberg (1957) tabulated data showing the estimated loss in white pine lumber value per M. bd. ft. resulting from weevil injury according to the number of injuries per log.

Height losses due to the death of a successfully weeviled leader was studied by Morrow (1965). He compared the internodal growth of weeviled and unweeviled white pine and found the loss in height growth to be approximately 60% of the average leader growth for each weevil attack.

When a lateral branch sweeps upward to replace a weeviled leader the wood becomes brittle and causes boards containing it to check badly. The more rapidly the bole straightens after the leader is killed the less defect will be present (Spurr and Friend 1941).

At the time that Peck wrote about the white pine weevil, its destructive habit was not as widespread as it was soon to become. Although he clearly understood the importance of this insect and its potential as a destructive agent in white pine timber production, it was not until the early part of the twentieth century that the weevil was to be commonly considered a serious pest (Belyea and Sullivan 1956).

During the ninteenth century large areas of land were cleared for agricultural use. About 1850, farmers in New York and New England began to abandon their farms. This trend reached a peak between the end of the Civil War and 1880. The abandoned fields reverted to forest cover, often being reforested almost entirely by white pine. The stands were often poorly stocked with the result that numerous trees were repeatedly weeviled. In addition to natural stands, many white pine plantations were established in reforestation programs in the early part of the twentieth century. Both types of stands provided the weevil with abundant food, and most observers agreed that weevil population levels increased in response to the increase in food. The percentage of infested white pine was greater than in the preceeding half century (MacAloney 1930).

Field observations of natural stands and plantations began to yield information about the biology and habits of the weevil. These observations formed the basis for understanding individual tree susceptibility and comprise the fundamental principles for recommended control measures to this day. Hopkins and Blackman wrote that mixed stands of white pine and hardwoods represent an unfavorable condition for weevil injury (MacAloney 1930). Graham (1918) recognized that in very dense stands weevil injury was absent and that the percentage of weeviled trees increased as the density of the stand decreased. He concluded that the most effective way to reduce weevil damage was through close plantings. Graham further recognized that while trees growing in full sunlight were often severely weeviled, white pine growing in association with hardwoods was found to be damaged less. The level of injury was shown to decrease with increasing shade from the associated hardwoods. These observations were reinforced by MacAloney (1930).

In the 1920's recommendations were made by Graham for a silvicultural system to reduce weevil damage to white pine plantations by providing shade for the young pine during the period that they were most susceptible to attack, that is until they attained a height of 20-30 feet or were about 15-20 years old (Belyea and Sullivan 1956). A warning was given that the amount of shade tolerated by the pine would vary with site and that excessive shade would retard growth.

Belyea (1923) studied plantations of white pine and Scotch pine in New York. He observed a mixed plantation of alternate rows of white and Scotch pine as well as an adjacent plantation of pure white pine. He found that weevil damage to white pine was reduced by almost 40% in the mixed plantation. Belyea concluded that the Scotch pine acted as a trap and recommended that similar mixed planting be continued as a means of reducing weevil damage.

MacAloney (1930) published the results of intensive field studies of weevil biology and behavior based on observations of a large number of sample plots. The plots were established in both natural stands and plantations of white pine in the Northeast and the Maritimes. He concluded that the most advantageous and economical method of growing damage free white pine was to plant it in mixture with a species that has economic value. MacAloney found several mixtures of both hardwoods and conifers that would be successful in protecting white pine from weevil damage, and thought that local conditions should dictate which mixture should be used. He further advised that the accompanying species should be capable of more rapid growth than the white pine if the two species were to be planted the same year. If the accompanying species was not capable of outgrowing the white pine during the first few years it should be established prior to the white pine.

Since the 1920's, much attention in the United States and Canada has been given to attempts at growing weevil free white pine by planting in mixture. Unfortunately, in most cases such attempts have had only moderate success. Until recently little research has been undertaken to understand why shade affords white pine protection from weevil attack. Early attempts at growing white pine in mixture were merely empirical exercises. Researchers were aware of the beneficial effects of shade but did not understand the reasons.

Such an empirical study was conducted from 1935-1948 at the Petawawa Forest Experiment Station in Ontario (Belyea and Sullivan 1956). Observations of weevil attack in open grown natural stands and in white pine beneath various overstories were made. These observations were in general agreement with that already known from earlier studies. The study found that planting white pine beneath an overstory of aspen or other hardwood would reduce weeviling, but the survival of the white pine was poor. Subsequent trials involving the underplanting of white pine beneath an overstory of aspen (Populus tremuloides Michx.) or other hardwood met with mixed success. Clements (1966) describes an attempt to establish white pine seedlings beneath thinned and unthinned aspen stands. The white pine did not become successfully established. Other investigators claim successful establishment of white pine seedlings beneath hardwood canopies (Geerinck, Getchell and Chapman 1954, Logan 1962, Skilling 1953). The Petawawa study made the further observation that weevil attack is more severe on white pine with thick, long leaders than on those with thin, short ones.

In spite of the abundance of empirical knowledge, it was still unclear as to whether the relationship between shade and the reduction in weevil attack is a direct one between the weevil and its physical environment, an indirect one involving the effect of shade on the growth and vigor of an understory pine, or a combination of both.

Sullivan (1959, 1960, 1961) conducted much research in an effort to investigate these relationships. He studied the effect of physical factors on the activity and development of the weevil (1960) and found that once the adult weevil is on the terminal leader the amount of feeding, copulation, oviposition, or inactivity is dictated by the existing climate. Sullivan (1959) found bark temperature of the terminal leader to be the physical factor with the greatest regulatory effect. Other factors affecting adult weevil activity were solar radiation and atmospheric moisture. In general, adult weevil activity begins when bark temperatures reach 8°C (46°F) and increases with increasing temperature up to 32°C (90°F). Above 32°C adult weevil activity decreases rapidly until at 35°C (95°F) activity ceases.

Oviposition is the key stage in weevil activity that results in damage to white pine. Sullivan (1959) found that of all weevil activity, oviposition operates over the narrowest temperature range. He found the percentage of the weevil population in the process of oviposition rises exponentially within the temperature range 10-20°C (50-84°F). The percentage decreases rapidly between 29-35°C (84-95° F). Very little oviposition occurs below 20°C (68°F). This results in a temperature conducive to weevil oviposition of 20-29°C (68-84°F). Further study indicated that oviposition is most common at temperatures of 25-29°C (77-84°F), when these temperatures are accompanied by a relative humidity of 20-55%. These confinements of optimum temperature and relative humidity represent a major limitation to weevil oviposition in white pine stands being shaded from above.

Sullivan (1961) then compared open grown and shaded white pine stands. These stands were studied with respect to the feeding and oviposition behavior of the adult weevil as well as terminal leader characteristics of the white pine. He found that under open grown conditions there were an equal number of empty feeding punctures and punctures containing eggs. Punctures occurred only on the terminal leader and were often clustered near the tip of the leader. By comparison, punctures on shaded white pine revealed that the percent of punctures containing eggs was only 15-27%, and that the punctures were not limited to the terminal leader. Punctures containing eggs were distributed along the main stem of the past 4-5 years growth. For weevil larvae to complete development successfully they must aggregate within the leader and feed together. Isolated individuals who fail to contact the main feeding aggregate are drowned in pitch. If oviposition levels are low and/or scattered along the main stem the chances of forming a feeding aggregate are low.

The microenvironment of a shaded habitat discourages but does not eliminate weevil attack, however, when combined with certain terminal leader characteristics, elimination of oviposition is indeed more likely

Sullivan (1961) observed that terminal leaders with a diameter of 4 mm. or less were rejected as oviposition sites by adult weevils. The number of leaders weeviled increased as diameter of the leader increased to a point where 80% of the terminal leaders with a diameter of 9 mm. were attacked. By measuring the diameters of leaders found growing in both open and shaded habitats, Sullivan determined that the diameter classes preferred by the adult weevil for oviposition were not present in shaded white pine stands. He found the average diameter of terminal leaders of open grown white pine to be 9.3 mm. while the average diameter of shaded white pine terminal leaders was found to be only 3.9 mm. The shaded terminal leaders were clearly too small to be preferred oviposition sites. Thus, it is apparently a combination of the temperature preference for oviposition and a preference for large terminal leaders as oviposition sites that is responsible for the low incidence of weevil damage to shaded white pine stands.

Direct control measures to reduce injury to white pine already attacked by the weevil have been numerous. Walden (1915) stated that the only present remedy for control of the weevil in white pine stands was to cut the infested leaders and burn them early in July before the adults emerged. MacAloney (1930) supported this recommendation and added that infested leaders be placed in a screened box that would not allow adult weevils to escape but would allow parasites to return to the stand. Holdsworth (1943) reported success in reclaiming weeviled white pine by clipping infested leaders and either burning them or placing them in wire cages. Other workers have recommended similar treatment (Dirks 1964, Rhodes 1963).

Cline and MacAloney (1931, 1935) recommended a different approach to reclamation of weeviled white pine. Weeviled, dominant white pine were girdled to allow selected, undamaged codominant and intermediate white pine to become crop trees.

Experiments directed at chemical control of the weevil have been undertaken since the early part of the century and continued to this day. One early attempt at chemical control using lime-sulphur was reported to be successful (Walden 1916). Other early attempts included the use of kerosene, creosote, carbolineum, sulphur, and calite (Graham 1916). Lead arsenate proved to be successful and was used for a long time until it was eventually replaced as a control method by DDT (Graham 1916, Potts, Cline and

McIntyre 1942, Shenefelt 1951, Walden 1916). Control with DDT proved highly successful (Connola 1961, Connola, McIntyre and Yops 1955, Connola and Smith 1964) and was widely used for a number of years until it was banned by the Environmental Protection Agency in December, 1973. Attempts at killing overwintering adults in the duff have been made by Hastings (1956) and Nichols (1968). Recently, successful control has been obtained using methoxychlor (DeBoo and Campbell 1972, Sundaram et al. 1972).

Recent approaches to control include sterilization of adult weevils with gamma radiation (Jaynes and Godwin 1957) and breeding genetically resistant white pine (Connola 1966, Kriebel 1954, Plank and Gerhold 1965, Santamour 1965, Stroh 1964, Stroh and Gerhold 1965, Van Buijteren and Santamour 1972, Wright and Gabriel 1959). None of these projects have lead to specific recommendations useful in practical control in the field.

Establishment of White Pine Seedlings and Hybrid Poplar Cuttings

Establishment of tree species on abandoned fields requires control of weed and grass competition for high survival and maximum growth. Much work has been done with chemical control of competitive vegetation using the selective herbicides atrazine and simazine. These chemicals are absorbed through the roots and kill susceptible plants by interferring with the photosynthetic process. They are closely related but atrazine is more soluble in water, acts faster, and decomposes more rapidly than simazine (Ahrens 1974). Research concerning the uptake, distribution, and physiological effects of these herbicides on different tree species, including white pine, is presented by Freeman (1963) and Freeman, White, and Bukovac (1964).

Effective control of competing vegetation by herbicides depends on proper penetration of the chemical into the soil. The majority of weed seed germinates in the upper two inches of the soil (Poulsen 1965), therefore, penetration of the herbicide is desired to this depth only so that tree roots below will not be affected.

Even after successful establishment, tree growth has been found to be adversely affected by competition from weeds and grasses. Wilde (1970, 1971) studied the yield of plantations of three species of pine, including white pine, in relation to site index and weed biomass. He calculated that each kilogram of weed biomass present over the years in a plantation reduces the production of merchantable wood by 0.07 kilograms. In plantations supporting heavy competitive vegetation, Wilde found that the loss of timber over a 40 year rotation approaches 16 cords per acre.

Atrazine and simazine have been effective in controlling weeds and grasses in forest nurseries and plantations (Dumitrescu, Strimbei and Donca 1964, Gathy 1961, Poulsen 1965, Zentsch 1960). It is agreed that these chemicals can be used safely with most coniferous species but their use with hardwoods is questionable. Gathy (1961) states that hardwoods are safe only when deeply rooted.

Atrazine is available only as a liquid or wettable powder, while simazine is also available in a granular form. The liquid and wettable powder forms are faster acting than the granular form which must dissolve before entering the soil. The granular form is longer lasting in the soil (Ahrens 1974). Dumitrescu et al. (1964) found that the action of granular simazine is closely related to the amount of rainfall immediately before and after application. They recommend that granular herbicides be used only in the spring when rain is plentiful.

Atrazine and simazine are capable of effective and safe weed and grass control with white pine seedlings, however, the use of these chemicals with poplar cuttings has been detrimental.

Schreiner (1945), Ford, Williamson, and Cunningham (1952), and Cunningham (1954) have shown conclusively that the successful establishment of hybrid poplar plantations from dormant cuttings requires adequate site preparation and subsequent weed and grass control. Although Gathy (1961) includes poplar cuttings as one of the more resistant hardwoods, most workers have not had success using atrazine or simazine for weed and grass control in poplar plantations. Uhlig (1964) found both atrazine and simazine to be harmful to poplar cuttings when applied in sufficient dosages to kill the more persistent weeds. He found that even when no visible damage is apparent, the growth of poplar cuttings on sites treated with an herbicide was less than that of cuttings on sites that were mechanically weeded. Jodal and Gojkovic (1967) applied simazine in poplar nurseries at the rates of 2, 3, and 5 kg./ha. (approx. 1.7, 2.6, and 4.4 lbs./acre). This treatment caused such serious reductions in height and diameter growth of poplar that its use was not recommended.

Cunningham and Sowers (1965) compared survival and growth of newly planted hybrid poplar cuttings treated with simazine with cuttings that were cultivated. Simazine was applied at the rates of 1, 2, 4, and 6 lbs./acre. Survival and growth were compared over two years. The growth of cuttings on the simazine treated plots never approached that of those on the cultivated plots. They concluded that simazine is not a satisfactory substitute for cultivation in hybrid poplar plantations.

Other herbicides have been used for weed and grass control in poplar plantations. Gunther (1963) recommended the use of Dowpon, while Magnani (1969) reported successful weed control with Gramoxone and Herbidal + Zealan.

Vidali (1969) obtained successful weed and grass control using strips of black plastic. A machine was used that smoothed the soil, laid down a plastic strip, and inserted poplar cuttings through the plastic. After two seasons, poplars mulched with plastic exhibited increased growth over poplars that were not mulched. Kolster (1969) also tested the effectiveness of mulching with plastic strips. He obtained better weed control using chemicals than with plastic sheets.

Cuttings of hybrid poplar have been used extensively throughout the world in reforestation programs. When planted on a good site, poplar cuttings are capable of high survival and rapid growth. Root initiation in poplar cuttings occurs along the entire portion of the stem that is below ground level. This reaction is attributed to the absence of light (Regonese, Rial and Sonvico 1971). There is some indication that large-diameter cuttings survive and grow more rapidly than small-diameter cuttings and that long cuttings survive better than short ones. Briscoe (1963) had better rooting success with cuttings taken from the butt of a branch than with cuttings taken from the branch tip. Zakhriev, Iliev, and Kolarov (1972) studied planting success of poplar cuttings with respect to length (15 or 25 cm.), thickness (thick or thin), and position in the shoot from which they came (bottom, middle, top). They determined that long (25 cm.) cuttings taken from the bottom or middle of the shoot were capable of better growth than the other cuttings tested.

Sekawin (1972) studied the relationship between water loss in poplar cuttings and survival. A close correlation ($r^2 = 0.861$) was found between speed of water loss and survival of the cuttings. He compared survival of cuttings planted immediately with cuttings stored seven days before planting and found the former to be more successful.

The importance of proper preparation of cuttings has been demonstrated. Hejmanowski (1966) compared rooting success and height growth of cuttings with different types of lower cuts. His statistical evaluation revealed the most successful cuttings tested had a lower cut made at a 45° angle, 2-3 mm. above a bud.

The method of planting cuttings has been shown to affect rooting success. Brown and Carter (1971) found that inverted cuttings were inferior in number and length of roots, shoot length, and size and appearance of leaves. They planted ninety inverted cuttings, only four survived beyond six months. Walter and Piesnack (1957) varied the depth to which cuttings were placed in the soil when planted. Poplar grown from cuttings buried vertically in the soil so the top was covered with 1-2 cm. of soil exceeded in survival percentage, height, weight of foliage, and diameter growth those planted with the top bud protruding 1-2 cm. above the soil surface.

SAMPLING WHITE PINE PLANTATIONS FOR WEEVIL DAMAGE

Plantations in the Orono area were sampled to determine the extent of weevil damage to white pine growing in a variety of habitats. White pine growing in open habitats but differing in age and spacing, as well as white pine growing beneath an overstory of hardwood, were sampled and compared for levels of weevil damage.

Young, open-grown plantations of white pine established within the past ten years on abandoned agricultural sites were observed. The pine ranged in size from 4-12 ft. (1.22-3.67 M.) depending on the age of the plantation. Seven plantations, all located within thirty miles of Orono, were chosen for sampling. In each plantation, three samples of one hundred trees were taken to assess the percentage of white pine that exhibited weevil damage. Trees were tallied as either exhibiting weevil damage or not exhibiting weevil damage. No effort was made to count the number of weevil attacks on each tree. The results of these samples are presented in Table 1.

The percentage of weeviled white pine ranged from 20.7-57.3%. The average for all plantations sampled was 38.7%. The fact that more than one white pine of every three tallied exhibits evidence of weevil damage indicates the need for a sound, practical method of weevil control if white pine is to be managed intensively for saw-log production.

Plantations of white pine in the Dwight B. Demeritt Forest (University of Maine) were sampled to determine if close planting successfully reduced weevil damage. These plantations were

Table 1. Percentage of white pine that exhibit weevil damage: results from seven young open grown plantations in the Orono, Maine area.

Plantation #	Sample 1	Sample 2	Sample 3	Mean
1	40	51	58	49.7
2	14	12	36	20.7
3	27	38	37	34.0
4	38	51	43	44.0
5	59	54	59	57.3
6	24	13	37	24.7
7	36	41	44	40.3
				$\bar{X}$ = 38.7

established in 1949 and are currently 20-30 ft. (6.10-9.15 M.) in height.

Stands with spacings of 4 x 4 ft. (1.22 x 1.22 M.), 6 x 6 ft. (1.83 x 1.83 M.), and 8 x 8 ft. (2.44 x 2.44 M.) were sampled. Except for an infrequent hardwood growing within the stand, there was no overstory to produce shade. The only shade developed from adjacent pines, thus one would expect less weevil damage in the closer plantings since more shade was developed within this stand.

Every fifth tree within the stands were sampled. Outside rows and pines growing beneath a hardwood were ignored. Each pine sampled was rated according to the following classification:

Class A - No visible signs of weevil damage,
Class B - At least 18 feet of the bole is free of weevil damage,
Class C - More than 12 feet but less than 18 feet of the bole is free of weevil damage,
Class D - Less than 12 feet of the bole is free of weevil damage.

This classification was designed to place white pine according to their ability to produce saw-logs of 12 feet, 18 feet, more than one saw-log, or no saw-logs. Results of this sample are presented in Table 2. It is evident that dense stands of white pine produce more saw-log trees than open, widely spaced stands. These results support those of many other investigators including Graham (1918) who felt that one way to reduce weevil damage to white pine is through close plantings.

To complete the observation of weevil damage to white pine stands, an overtopped stand of alternate rows of red pine and white pine in the Dwight B. Demeritt Forest was sampled. The pine are about 30 ft. in height and grow beneath an overstory of aspen (*Populus tremuloides* Michx.), gray birch (*Betula populifolia* Marsh.), paper birch (*Betula papyrifera* Marsh.), and red maple (*Acer rubrum* L.). As before, every fifth white pine was sampled for evidence of weevil damage and classified in the same manner as the previous stands. Results of this sample are presented in Table 3. The beneficial effect of shade as a deterrent to weevil attack is obvious. Almost 65% of the white pine growing beneath the hardwood canopy were Class A or Class B trees. Put into practical terms, this indicates that about two-thirds of the shaded white pine are productive saw-log trees.

This stand was planted at a 6 x 6 ft. spacing counting both red pine and white pine. It is evident that shade developed by an overstory species is more successful in reducing the level of weevil attack within a stand than is close plantings with no overstory shade. These observations are in agreement with the findings of many early researchers who correctly pointed out the beneficial aspects of shade as a discouraging factor in weevil attack on white pine.

Table 2. Percentage of white pine grown at different spacings in each of four weevil damage classes: Orono, Maine (1973).

Spacing (ft.)	Class A	Class B	Class C	Class D	Number Tallied
4 x 4	3.6	25.4	43.6	27.3	110
6 x 6	0.0	32.2	32.2	35.5	31
8 x 8	0.0	0.0	38.7	61.3	31

Table 3. Percentage of white pine grown in a shaded habitat in each of four weevil damage classes: Orono, Maine (1973).

Spacing (ft.)	Class A	Class B	Class C	Class D	Number Tallied
6 x 6	3.8	60.4	22.6	13.2	53

Damage Classes

Class A - No visible signs of weevil damage,
Class B - At least 18 feet of the bole is free of weevil damage,
Class C - More than 12 feet but less than 18 feet of the bole is free of weevil damage,
Class D - Less than 12 feet of the bole is free of weevil damage.

ESTABLISHMENT OF SHADE PLOTS FOR WEEVIL CONTROL

Plantations were established as a first step toward the development of a practical method of growing white pine free of weevil damage by planting it in association with hybrid poplar cuttings, that are capable of rapid growth. This research is concerned with the determination of the optimum spacing of white pine and hybrid poplar for maximum control of white pine weevil oviposition. One unshaded plot and three plots that will eventually vary in intensity of shade were established in both Hartland and Veazie, Maine. The level of shade that can be expected to develop in each of the shaded plots will be determined by the number of poplar planted in each of the plots. The optimum level of shade will be that intensity with sufficient poplar stems to discourage weevil oviposition without causing an unnecessary reduction in the growth of the white pine. It is anticipated that one of the shaded plots will approach this optimum.

The poplar will be allowed to grow until the white pine attains a height of 18-20 ft. (5.49-6.10 M.). At that time a merchantable butt log on the white pine would be insured. The poplar would then be harvested to best meet local demand either as pulpwood or saw timber. The release cutting would allow the white pine to achieve more rapid growth. The white pine would then be past the most susceptible period for weevil attack and should weevil attack occur, at least a butt log would be assured.

Hartland, Maine - 1973

Site Description. White pine weevil control shade plots were established on land owned by the University of Maine. The site is located on Huff Hill off Route 23 west of Hartland, Maine (Somerset County). Plots were laid out in an abandoned agricultural field that has a slope of 3-8% with a northerly aspect (Fig. 1). The field supported dense vegetative growth (Fig. 2) and had been harvested for hay as recently as 1971. The predominate vegetative growth consisted of timothy (*Phleum practeuse*), quack grass (*Agropyron repera*), sorrel (*Oxalis montana*), meadowsweet (*Spiraea latifolia*), tufted vetch (*Vicia cracia*), and goldenrod (*Solidago* spp.). The soil type is a Plaisted gravelly loam. This is a well drained glacial till containing many rocks. It dries out rapidly in late spring and remains dry throughout the summer.

Origin and Storage of Planting Stock. The hybrid poplar cuttings were obtained from two sources. Approximately half (hybrid cross not known) were supplied by General Clayton Totman of Waldoboro, Maine; the remainder came from the forest nursery at the University of Maine. The white pine seedlings were obtained from the Maine Forest Service Nursery at Greenbush and were grown from seed collected in Penobscot County.

Both the white pine seedlings and the poplar cuttings were stored in the basement of the university nursery shed before planting. The poplar cuttings were stored at this location for more than a month, the white pine seedlings for about three weeks. Although the basement was cool it was not ideal for storage of planting stock.

Figure 1. The planting site at Hartland, Maine looking north.

Figure 2. Dense growth of the competing vegetation characteristic of the Hartland site. A few of the taller two-year-old hybrid poplar can be seen extending above the vegetation.

Many of the poplar cuttings had already broken their buds by the time they were removed from the basement for planting.

Physical Layout of Shade Plots. Four plots were established, three shaded plots and one unshaded plot. Each of the three shaded plots measured 4 x 3 chains (80.48 x 60.36 M.) with one minor exception (Fig. 3). Due to the edge of the forest growth, the northeast corner of the heavy-shade plot was not planted. The non-planted area measured 1 x 0.5 chains (20.12 x 10.06 M.). The three shade plots were adjacent with the heavy-shade plot occupying the lower (northern) end of the field and the light-shade plot and medium-shade plot following in succession moving up the slope. The unshaded plot measures 2 x 6 chains (40.24 x 120.72 M.) thereby equalling the 12 square chain area of each of the shaded plots. This long rectangular shape was designed so that the unshaded plot would overlap each of the shaded plots. White pine established naturally in other parts of the field exhibited weevil damage, thus indicating a viable weevil population in the area. The weevil will probably infest the unshaded plot throughout, thus the physical layout of the plots gives a relatively balanced opportunity for the weevil to disperse into all three shaded plots.

The spacing of the white pine and hybrid poplar in each of the four shade plots is presented in Figure 4.

Site Preparation. Site preparation consisted of the removal of a three foot diameter circle of sod from the location at which every tree was to be planted. This was accomplished using a grub hoe.

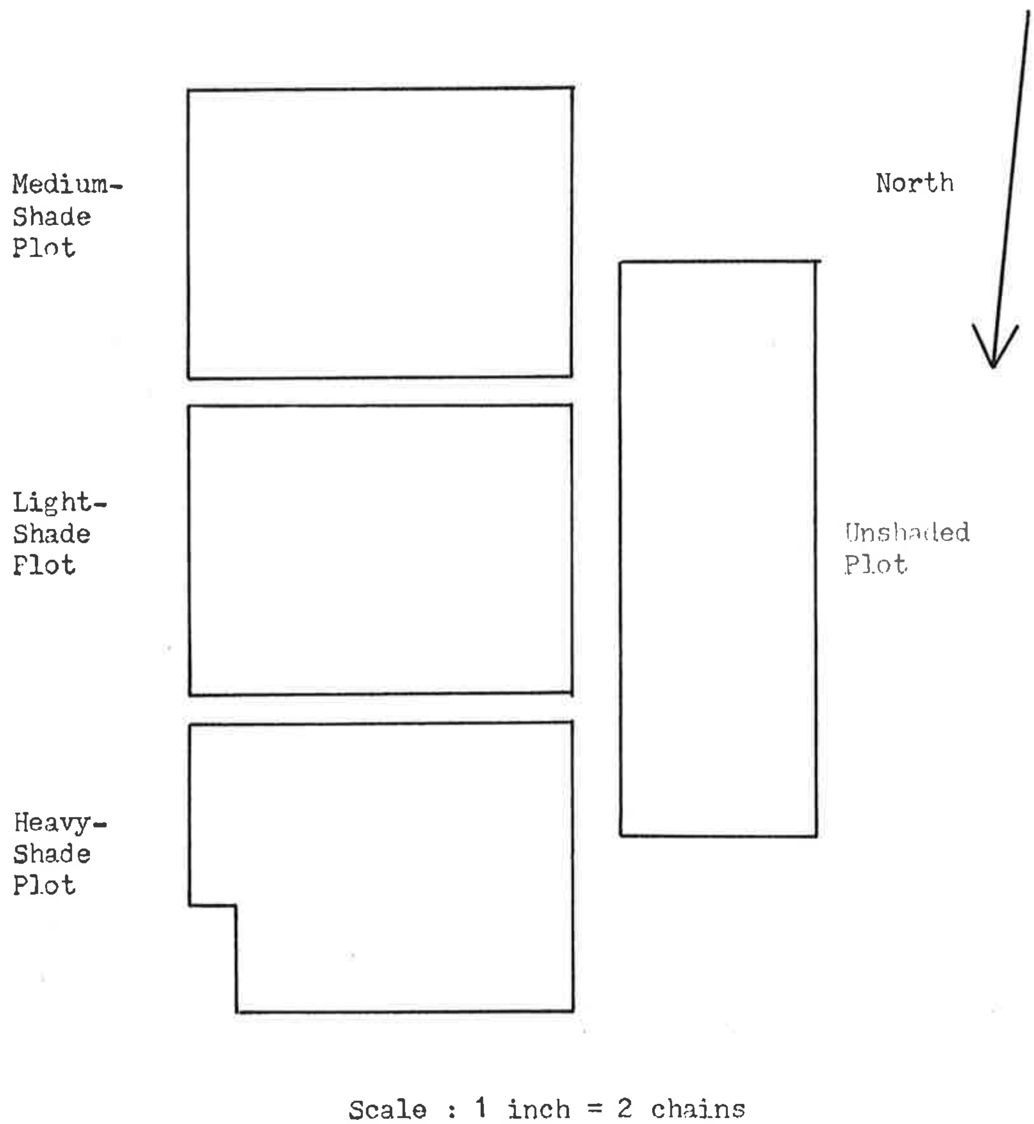
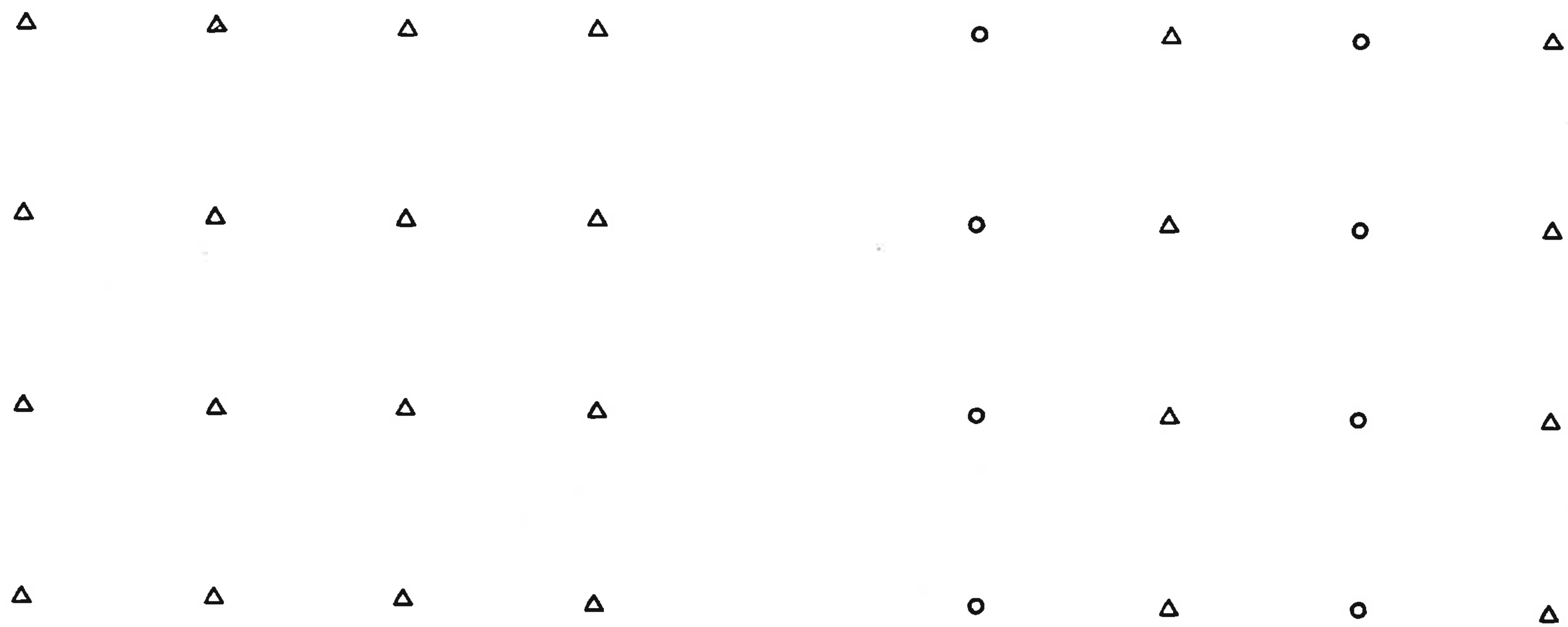


Figure 3. Physical layout of weevil control study shade plots in Hartland, Maine.



Unshaded Plot — White Pine 8 x 8 ft.

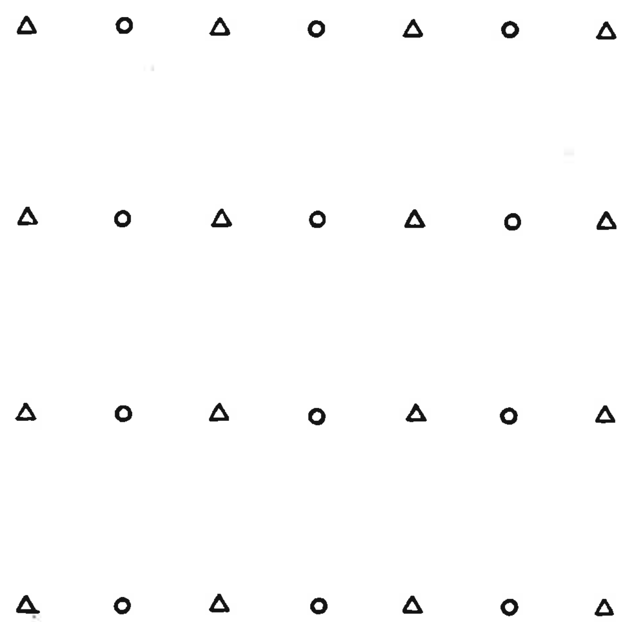
Light-Shade Plot — White Pine 8 x 16 ft.
Hybrid Poplar 8 x 16 ft.

Figure 4. A graphic depiction of the spacing arrangements of the four shade plots in Hartland and Veazie, Maine.

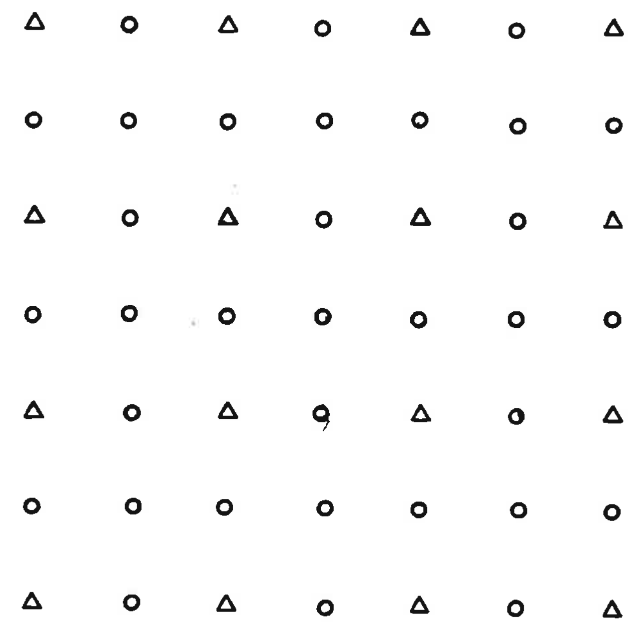
SCALE: 1 inch = 8 feet

△ White Pine

o Hybrid Poplar



Medium-Shade Plot White Pine 8 x 8 ft.
Hybrid Poplar 8 x 8 ft.



Heavy-Shade Plot White Pine 8 x 8 ft.
Hybrid Poplar 4 x 4 ft.

Figure 4 (continued)

SCALE: 1 inch = 8 feet

△ White Pine

○ Hybrid Poplar

The sod was removed to reduce competition from weeds and grasses and facilitate establishment of the trees.

Planting Techniques. Planting started on May 6 and was completed on June 3. Because student labor was used to plant, only weekends could be utilized as work days. This prolonged the planting past the ideal planting season.

The white pine seedlings were placed in a hole made by a grub hoe, being careful that all the roots were covered by soil. The hybrid poplar cuttings were 8-12 inches (20.32-30.48 cm.) in length. Range poles were used to make a hole in the ground. The cuttings were placed in the holes leaving at least two buds remaining above the soil. To insure contact between the soil and the portion of the cutting below the ground, the soil was pushed back against the cutting. Due to the rockiness of the soil (Fig. 5), it was often difficult to plant the cuttings more than 4 inches (10.16 cm.) into the soil. It is thought that shallow planting was very detrimental to the survival of the cuttings.

Weed and Grass Control. In mid-June herbicides were applied around the white pine to control competing vegetation and thus facilitate establishment. Four herbicides were used, one on each shade plot as follows:

Unshaded Plot	Simazine Wettable Powder (Princep 80W)
Heavy-Shade Plot	Simazine Granular (Princep 4G)
Medium-Shade Plot	Atrazine Wettable Powder (AAtrex 80W)
Light-Shade Plot	Simazine + Atrazine Wettable Powders

A detailed study of the herbicides used to control vegetation

Figure 5. The rocky Hartland site.

around the white pine is presented in the following section.

Poplars, including the hybrid varieties, have been found to be quite sensitive to herbicide toxicity during the first two years following planting. Poplar is also known to be adversely affected by competing vegetation during the early years of establishment. Weed and grass control is essential for survival and vigorous growth of poplar. During the first summer at Hartland the poplar cuttings were weeded by hand. This provided good weed control but with more than 3,000 poplar to be tended it became impossible to keep up with the growth of the weeds and grasses. Hand weeding was continued throughout the summer but it was decided to seek alternative methods of control for use the following summer.

Establishment of Herbicide Test Strips. An experiment to test an alternative to hand weeding the poplar was set up in October. It was thought that a fall application of herbicide to the soil where poplar were to be planted the following spring might provide good control of weeds and grasses without being toxic to the cuttings. During the winter some of the herbicide would be leached from the soil and it was hoped it would then be less toxic to the poplar when they were planted the following spring.

To test this a series of herbicide strips were established. Each strip measured 4 x 25 ft. (1.22 x 7.62 M.). Twelve herbicide treatments and one control strip (no herbicide) were tested. Two sets of herbicide test strips were established, one at each end of the field. The following herbicide treatments were tested:

Simazine Wettable Powder	4 lb.a.i./acre 6 lb.a.i./acre 8 lb.a.i./acre
Atrazine Wettable Powder	4 lb.a.i./acre 6 lb.a.i./acre 8 lb.a.i./acre
Simazine Granular	4 lb.a.i./acre 6 lb.a.i./acre 8 lb.a.i./acre
Simazine + Atrazine Wettable Powders ..	2+2 lb.a.i./acre 3+3 lb.a.i./acre 4+4 lb.a.i./acre

Survival of White Pine Seedlings and Hybrid Poplar Cuttings. Growth of the white pine during the first summer was good. By the end of the summer the pine looked vigorous and healthy. Seventy-six percent of the white pine survived the first growing season (Table 6). Most of the poplar cuttings broke their buds and put out leaves, but their growth was disappointing. While 72% survived the first summer, most of these had grown only a few inches and did not appear to be vigorous. The most vigorous poplar attained a height of almost two feet (0.61 M.) the first summer, but these comprised only a small minority. Many of the smaller poplar were found with leaf clippings on the ground, apparently feeding damage caused by rodents. As the more vigorous poplar grew above the competing weeds and grasses, many were browsed by deer (Fig. 6).

Hartland, Maine - 1974

Site Preparation. Site preparation the second year at Hartland consisted of hand weeding around all of the poplar cuttings

Figure 6. A deer browsed poplar cutting about 2 ft. (0.61 M.) in height at the Hartland site.

whether they were found alive or dead. No site preparation was conducted around the white pine seedlings.

Replanting Dead White Pine Seedlings and Hybrid Poplar Cuttings. Estimates of white pine and hybrid poplar mortality was made from the 1973 survival survey. The winter of 1973-74 was one that had little snowfall, thus the ground was bare for most of the winter. Losses due to frost heaving were high for both the white pine and the poplar. In addition, many of the poplar died subsequent to being girdled by rodents. All of the dead white pine were replaced, but due to the unexpected high winter mortality, that exceeded my estimates, the dead poplar in the medium-shade plot were not replaced as the available cuttings were exhausted. This plot will be replanted in the spring of 1975.

Origin and Storage of Planting Stock. The hybrid poplar cuttings used to replace the dead cuttings were clipped from the hybrid poplar of General Clayton Totman in Waldoboro, Maine. The white pine seedlings were obtained from the Maine Forest Service Nursery at Greenbush. Both the white pine seedlings and the poplar cuttings were stored under refrigeration at the Forest Service Nursery until planting was to begin.

Planting Techniques. Planting techniques were the same as used the previous year.

Weed and Grass Control. The herbicide applications for control of weeds and grasses around the white pine seedlings were identical to the previous year.

In early July, the foliar herbicide glyphosate was applied to control competing vegetation around the poplar cuttings. Glyphosate was applied at the rate of 0.5 lbs.a.i./acre (0.6 kg./ha.) using a hand sprayer. A two-foot section of stove pipe was placed over the cuttings during spraying to protect the tree. A two-foot (0.61 M.) diameter circle was treated around each poplar. The bottom edge of the stove pipe was curled outwards to form a lip that would catch any herbicide dripping off the pipe as it was removed from the poplar.

Assessment of herbicide activity was made two weeks following the application of glyphosate. At that time evidence of weed and grass killing was obvious with no apparent damage to the poplar. No further application of glyphosate was needed during the summer since a major portion of the growing season was already past. Control throughout the remainder of the summer was good.

At the time of the application of glyphosate the competing vegetation had attained a height of about one foot. To avoid drifting of spray the nozzle of the sprayer was circulated within the vegetative growth.

Herbicide Test Strips. In late May, each of the herbicide test strips established and treated the previous autumn were planted with five poplar cuttings. At the beginning of September each strip in each of the two replications was rated for effectiveness of weed and grass control. In addition, the number of poplar still alive was determined. Herbicide effectiveness was rated numerically from 1-5 according to the following breakdown:

1 - Excellent Control ; no weeds or grasses growing,
2 - Good Control ; a few weeds or grasses present but not detrimental to the cuttings,
3 - Fair Control ; herbicide activity evident but weeds and grasses not adequately controlled, detrimental to the cuttings,
4 - Poor Control ; herbicide activity barely evident, weeds and grasses showing little sign of herbicide treatment,
5 - No Control ; no evidence of weed and grass control.

The two replications differed significantly in site. Replication A was established on the low end of the field in very heavy vegetation that included an abundance of goldenrod (Fig. 7). Replication B was adjacent to the southern edge of the unshaded plot at the upper end of the field. This area supported sparse vegetation (Fig. 8). Control of the sparse vegetation in Replication B ranged from fair to excellent. Control of the dense vegetation in Replication A was fair to non-evident (Table 4). In addition, there was no visible effect of the herbicides on the goldenrod growing in Replication A.

Poplar survival on Replication A was poor. This was due to the combined effect of the competing vegetation and herbicide toxicity. No poplars survived through the summer even on the control strip which had no herbicide treatment. Survival on Replication B was slightly better. Herbicide toxicity was apparent here as the control strip had four of the five poplar still alive at the end of the summer. None of the herbicide-treated strips did as well. It

Figure 7. Herbicide test strips: Replication A

Figure 8. Herbicide test strips: Replication B

Table 4. Effectiveness of herbicide treatments and survival of hybrid poplar cuttings on test strips at the Hartland site in 1973-74.

Herbicide Treatment*	Replication A		Replication B	
	Effective-ness**	Number Poplar Alive (5 planted)	Effective-ness**	Number Poplar Alive (5 planted)
AA 80W 4 lb./ac.	3	1	2	1
PG 4 lb./ac.	3	2	3	0
P 80W 4 lb./ac.	5	1	3	0
P 80W + AA 80W 4 lb./ac.	5	0	3	3
AA 80W 6 lb./ac.	4	0	2	1
PG 6 lb./ac.	2	0	3	2
P 80W 6 lb./ac.	5	0	2	1
P 80W + AA 80W 6 lb./ac.	5	0	1	1
AA 80W 8 lb./ac.	3	0	2	0
PG 8 lb./ac.	3	1	2	2
P 80W 8 lb./ac.	4	2	1	1
P 80W + AA 80W 8 lb./ac.	3	1	1	0
Control Strip	5	0	5	4

*Herbicide Treatments

AA 80W - Atrazine Wettable Powder 80% Active Ingredient

PG - Simazine Granular 4% Active Ingredient

P 80 W - Simazine Wettable Powder 80% Active Ingredient

Table 4. (Continued).

**Effectiveness Ratings

1 - Excellent Control ; no weeds or grasses growing
2 - Good Control ; a few weeds or grasses present but not detrimental to the poplar cuttings
3 - Fair Control ; herbicide activity evident but weeds and grasses not adequately controlled, detrimental to poplar cuttings
4 - Poor Control ; herbicide activity barely evident, weeds and grasses exhibit only faint signs of herbicide activity
5 - No Control ; no evidence of weed or grass control.

was apparent that simazine and atrazine when applied in the autumn previous to planting were still toxic to poplar cuttings planted the following spring.

Survival of White Pine Seedlings and Hybrid Poplar Cuttings. Surveys of tree survival on the shade plots in September indicated that after two growing seasons and replacement of dead trees, 70% of the white pine seedlings were alive but only 43% of the poplar cuttings survived (Table 7). It must be remembered that the medium-shade plot was not replanted with poplar cuttings in 1974.

Veazie, Maine - 1974

Site Description. White pine weevil control shade plots were established on land owned by the University of Maine. The site was a four acre (1.62 ha.) field located in Veazie between Route 2 and the Bangor and Aroostook Railroad tracks. The site is low lying and retained considerable moisture throughout the summer. The soil consists of the Buxton and Elmwood series which are marine soils and are almost completely free of rocks. Silts and fine sandy loams cover an underlying layer of clay that holds water near the ground surface and accounts for the poor drainage of the site.

The site was formerly in agricultural use and supported vegetation similar to that found at the Hartland site. The dominant weed and grass species were timothy (Phleum practeuse), quack grass (Agropyron repera), sorrel (Oxalis montana), meadowsweet (Spiraea latifolia), and tufted vetch (Vicia cracia).

This site has been used for various research studies conducted by the university in the past. The field was partitioned into sixteen contiguous blocks measuring 100 ft. (30.49 M.) per side. Eight of the plots were already being used in other studies. One vacant plot supported such heavy herbaceous and woody growth that it could not be used in this study.

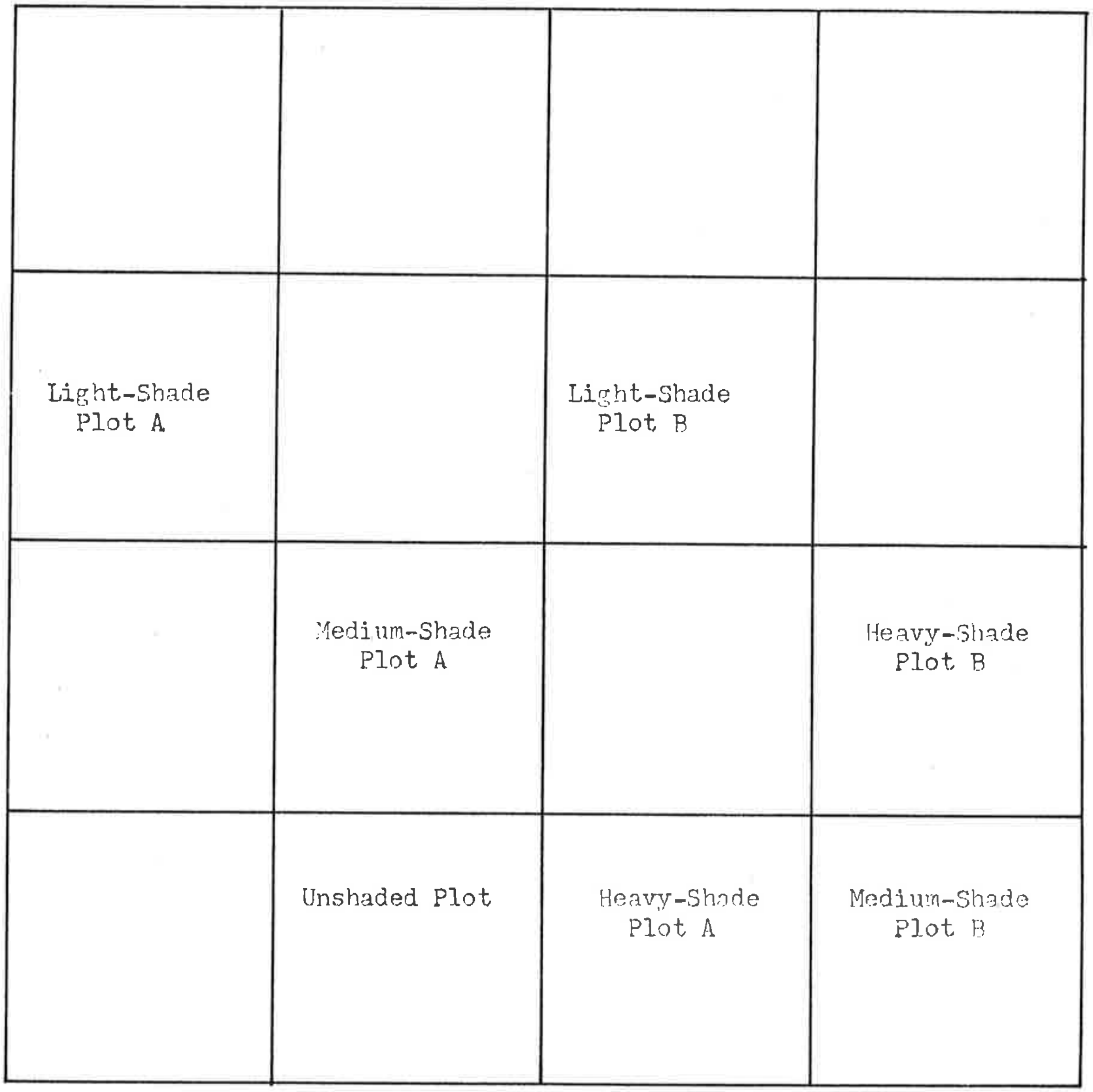
Origin and Storage of Planting Stock. The hybrid poplar cuttings planted at this site were obtained from two sources. Half of the cuttings were from the hybrid poplars of General Clayton Totman in Waldoboro, Maine. The remainder were obtained from hybrid poplars growing in the forest nursery at the University of Maine. The white pine seedlings were obtained from the Maine Forest Service Nursery at Greenbush.

The poplar cuttings were brought to the Greenbush nursery and placed under refrigeration with the white pine seedlings. The seedlings and the cuttings remained under refrigeration until the day before they were to be planted.

Physical Layout of Shade Plots. There were seven plots available for use in this study. Since each plot was much smaller than the plots established in Hartland, two plots were established for each shade condition. This left room enough for only one unshaded plot (Fig. 9). The combined area of the two plots for each shade condition was about 40% of the area of the larger Hartland plots. The area of the single unshaded plot at Veazie is only 20% of its Hartland counterpart. The spacings of the white pine and

Figure 9. Physical layout of weevil control study shade plots in Veazie, Maine.

Scale : 1.5 inches = 100 feet



hybrid poplar within each shade plot was identical to the corresponding plots in Hartland (Fig. 4).

The white pines established on many of the adjoining plots were weevil infested, insuring a viable weevil population in the area.

Site Preparation. Site preparation consisted of removing the sod from a circle three feet in diameter only where the poplar cuttings were to be planted. The herbicide control of weeds and grasses around the white pine in Hartland was successful to the point where it was thought that the removal of sod was unnecessary for successful establishment.

Planting Techniques. The white pine seedlings were planted in the same manner as in Hartland. Planting of the poplar cuttings was easy because the Veazie site was free of rocks and the ground was extremely wet and soft at the time of planting. The poplar cuttings were just pushed into the soft soil without any need for holes to be made. This method insured that there was contact between the soil and the portion of the cutting beneath the ground.

Weed and Grass Control. Herbicides were applied to the area around the white pine prior to planting. The same four herbicides used in Hartland were applied in the following manner:

Heavy-Shade Plot	A	Atrazine Wettable Powder (AAtrex 80W)
	B	Simazine Wettable Powder (Princep 80W)
Medium-Shade Plot	A	Atrazine Wettable Powder (AAtrex 80W)
	B	Simazine Wettable Powder (Princep 80W)

Light-Shade Plot	A	Simazine Granular (Princep 4G)
	B	Simazine Granular (Princep 4G)
Unshaded Plot		Simazine + Atrazine Wettable Powders

The herbicide applied to the heavy-shade plots and the light-shade plots were applied to a circle four feet in diameter. The herbicide used on the medium-shade plots and the unshaded plot were applied in a strip three feet wide covering the entire row of white pine. The wettable powders were applied with a hand sprayer and the granular formulation, with a shaker jar.

Weeds and grasses around the poplar cuttings were controlled by hand. Glyphosate was being tried in Hartland but it was felt it should not be used in Veazie unless it proved successful.

Survival of White Pine Seedlings and Hybrid Poplar Cuttings. Surveys were made of white pine and poplar survival in September. Poplar survival was 87% and white pine survival 90% (Table 8). During the survey it was observed that a large number of dead poplar exhibited signs of damage by rodents as evidenced by either girdling of the cuttings or by leaf clippings on the ground next to the cutting. Between 50-85% of the poplar cutting mortality on these plots was due apparently to rodent damage (Table 5).

Poplar Cutting Establishment Tests. Trials testing the effect of simazine and atrazine on the survival and growth of poplar cuttings were completed. One row in each of the herbicides used on the white pine was chosen as a test row for poplar cutting survival in soil that had recently been treated with these

Table 5. Mortality of hybrid poplar cuttings due to rodent damage on four shade plots: Veazie, Maine 1974.

	Heavy A	Heavy B	Light A	Light B
Number cuttings in plot	507	494	78	78
Number of cuttings dead	60	37	14	34
Percent mortality	11.83	7.49	17.95	43.59
Number cuttings damaged by rodents	30	25	12	28
Percent cuttings damaged by rodents	5.92	5.06	15.38	35.90
Percent mortality due to rodents	50.00	67.57	85.71	82.35

herbicides. In these rows poplar cuttings were planted within the treated area near a pine. Observations of the poplar were made throughout the summer. Many of the cuttings survived initially and did break their buds and put out leaves. By the end of the summer however, every poplar in the test rows was dead.

A test was conducted to determine survival and growth of poplar cuttings planted in dense vegetation without site preparation or weed and grass control. Twenty-five poplar cuttings were planted at the end of May. No treatment or cultivation was undertaken during the summer. In early September, 14 of the 25 cuttings were alive. The average growth of the untreated cuttings was less than the weeded poplar in the adjacent shade plots but they were vigorous and healthy in appearance.

Discussion and Conclusions

From Tables 6, 7 and 8 it is evident that early survival of poplar cuttings was much higher at the Veazie site than at the Hartland site. This resulted from a combination of effects including both physical site characteristics and planting technique.

Lack of experience handling the planting stock and in planting was responsible in part for the greater poplar mortality at Hartland than at Veazie. In 1973, the cuttings were stored for over a month in the nursery shed basement to await planting. Although the basement temperature was cooler than the outside temperature, it was not cool enough to keep buds of the cuttings from breaking dormancy. By the time the cuttings were removed from

Table 6. Percentage of white pine seedlings and hybrid poplar cuttings surviving at the end of the first growing season: Hartland, Maine, 1973.

Plot	Pine Survival (%)	Poplar Survival (%)
Unshaded	75.03	---
Light-shade	58.50	49.65
Medium-shade	66.54	67.09
Heavy-shade	95.94	78.32
Total	76.08	72.43

Total number of white pine - 2751

Total number of hybrid poplar - 3558

Table 7. Percentage of white pine seedlings and hybrid poplar cuttings surviving at the end of the second growing season: Hartland, Maine, 1974.

Plot	Pine Survival (%)	Poplar Survival (%)
Unshaded	76.86	---
Light-shade	41.75	20.47
Medium-shade	62.50	20.62*
Heavy-shade	87.57	60.45
Total	70.75	43.24

*Medium-shade plot was not replanted with poplar cuttings in 1974.

Total number of white pine - 2751

Total number of hybrid poplar - 3558

Table 8. Percentage of white pine seedlings and hybrid poplar cuttings surviving at the end of the first growing season: Veazie, Maine, 1974.

Plot	Pine Survival (%)	Poplar Survival (%)
Unshaded	92.90	---
Light-shade A	87.18	82.05
Light-shade B	92.31	56.41
Medium-shade A	84.62	83.33
Medium-shade B	89.94	93.59
Heavy-shade A	93.49	88.17
Heavy-shade B	89.35	92.51
Total	90.01	87.68

Total number of white pine - 1001

Total number of hybrid poplar - 1469

the basement and taken to Hartland for planting only a few of the cuttings had failed to put out leaves.

The cuttings were taken to Hartland when planting began and kept there throughout the planting period. Although stored in a shaded location, the cuttings probably lost considerable moisture. This was particularly true of the cuttings planted in the medium- and light-shade plots as they were the last planted. The cuttings were stored in Hartland during planting because of the difficulty in reaching the planting site. Since reaching the site involved a walk of about 0.5 miles from the road, all the cuttings were carried in and stored there until they were planted.

Experience and a readily accessable location reduced the problems of planting the Veazie site. Cuttings were clipped at Waldoboro, Maine and placed the next day under refrigeration at the Maine Forest Service Nursery in Greenbush. The cuttings were kept at the nursery until planting was to begin. At that time only half were taken and they were planted promptly during the next three days. When these were all planted the remainder were taken and they were also planted within a few days. The planting process was facilitated because the Veazie site was within five miles of the university and was easily accessable from the road. The Hartland site by contrast involved a fifty mile drive and was inaccessable from the road.

Inexperience in handling poplar cuttings prior to planting was no doubt responsible in part for the poor survival of the cuttings during the first year at Hartland, but differences in physical site characteristics appear to have been more important in explaining the better success of poplar establishment at Veazie. The planting sites at Veazie and Hartland differed in two important characteristics, soil moisture and rockiness. The Hartland site was dry most of the summer and extremely rocky while the Veazie site was moist throughout the summer and virtually clear of rocks. Poplar is capable of better growth on a moist site such as that found in Veazie.

The rockiness of the Hartland soil hampered cutting establishment. Poplar cuttings initiate rooting along the entire portion of the cutting in the soil. At Hartland, due to the rocks, most cuttings could be placed only about four inches (10.16 cm.) into the ground. At Veazie, the cuttings were placed well into the soil (8-9 inches) leaving only 1-2 inches (2.54-5.08 cm.) exposed. This gave each Veazie cutting approximately twice the area from which to root. Rooting is a crucial step in the establishment and survival of any cutting. The advantage gained by the cuttings planted at Veazie is obvious.

Differences in site characteristics are reflected in the growth of the cuttings. The established poplar in Hartland put out a few leaves the first year but did not grow appreciably (Fig. 10). The cuttings planted at Veazie averaged growth of approximately one foot (0.30 M.) during their first summer (Fig. 11) and were larger and more vigorous than most of the two year old cuttings at Hartland.

Figure 10. Poor growth typical of many poplar cuttings in Hartland.

Figure 11. Average growth of one year old poplar in Veazie. A vigorous poplar about 1 ft. (0.30 M.) in height.

The need for weed and grass control during the establishment of poplar cuttings was reaffirmed. It was shown that the use of systemic herbicides to obtain such control failed. No poplar planted in soil recently treated with simazine and/or atrazine survived to the end of the summer. Survival was not much improved when cuttings were planted in soil treated with herbicides the autumn previous to planting. These trials indicate clearly that simazine and atrazine are toxic to newly planted poplar cuttings.

Poplar cuttings planted in sod with no weed and grass control during the summer had a survival rate of 56%. This was considerably lower than the hand-weeded poplar in the adjacent shade plots which had an average survival of 87%. The weeded poplar were also more vigorous and larger at the end of the summer. Control of competing vegetation was found to be essential for the successful establishment and vigorous growth of poplar cuttings.

The foliar herbicide glyphosate was tried as an alternative to hand weeding around the poplar planted at the Hartland site in 1974. When carefully applied using a stove pipe to protect the cuttings during application, this chemical provided effective control of vegetation with no harmful effect to the poplar cuttings. Based on the Hartland trial of glyphosate the following recommendations may be made regarding its use. For weed and grass control glyphosate should be applied around poplar cuttings at the rate of 0.5 lbs.a.i./acre (0.6 kg./ha.) in a circular area having a radius of 1.5 ft. (0.46 M.). Application should be made when the competing vegetation has greened and begun to grow, usually around mid-June. The initial spray application should be made when the weeds and grasses attain a height of six inches, with a followup application at the same rate later in the summer if the vegetation becomes reestablished. Such a spray program will provide good weed and grass control that is more effective, considerably easier, and less costly than hand weeding.

It appears that poplar cuttings can be successfully established as a shade tree to discourage attacks by the white pine weevil on white pine provided planting sites are carefully chosen and competing vegetation is controlled. The Hartland site represents a poor planting site for poplar cuttings because of its dry, rocky soil. A favorable planting site for poplar cuttings is one that has a deep, moist soil without excessive rocks to impede root development. The planting site at Veazie combines these characteristics and poplar survival and growth were expectedly good.

THE USE OF SIMAZINE AND ATRAZINE FOR WEED AND GRASS CONTROL TO FACILITATE ESTABLISHMENT OF WHITE PINE SEEDLINGS ON ABANDONED FIELDS

Introduction

The establishment of white pine, *Pinus strobus* L., seedlings on abandoned fields is facilitated if a method of weed and grass control is implemented. Plantations consisting partly of white pine were established in Hartland, Maine in 1973 in a study designed to control white pine weevil attacks on white pine.

Four herbicides were used to help the establishment of the pine on these plots; simazine wettable powder (Princep 80W), atrazine wettable powder (AAtrex 80W), simazine granular (Princep 4G), and a combination of equal parts simazine and atrazine wettable powders. These herbicides are systemic and are taken up by plants through the roots. Each of the four herbicides was applied to one of the four shade plots established in Hartland. In addition, each herbicide within each plot was applied at three rates of application. This made a total of twelve herbicide treatments in all. The herbicides were applied in the spring of 1973 and 1974.

Each of the herbicide treatments was evaluated with respect to (1) the ability to control the competing vegetation after the first and second years of application and (2) evidence of herbicide toxicity to the pine seedlings.

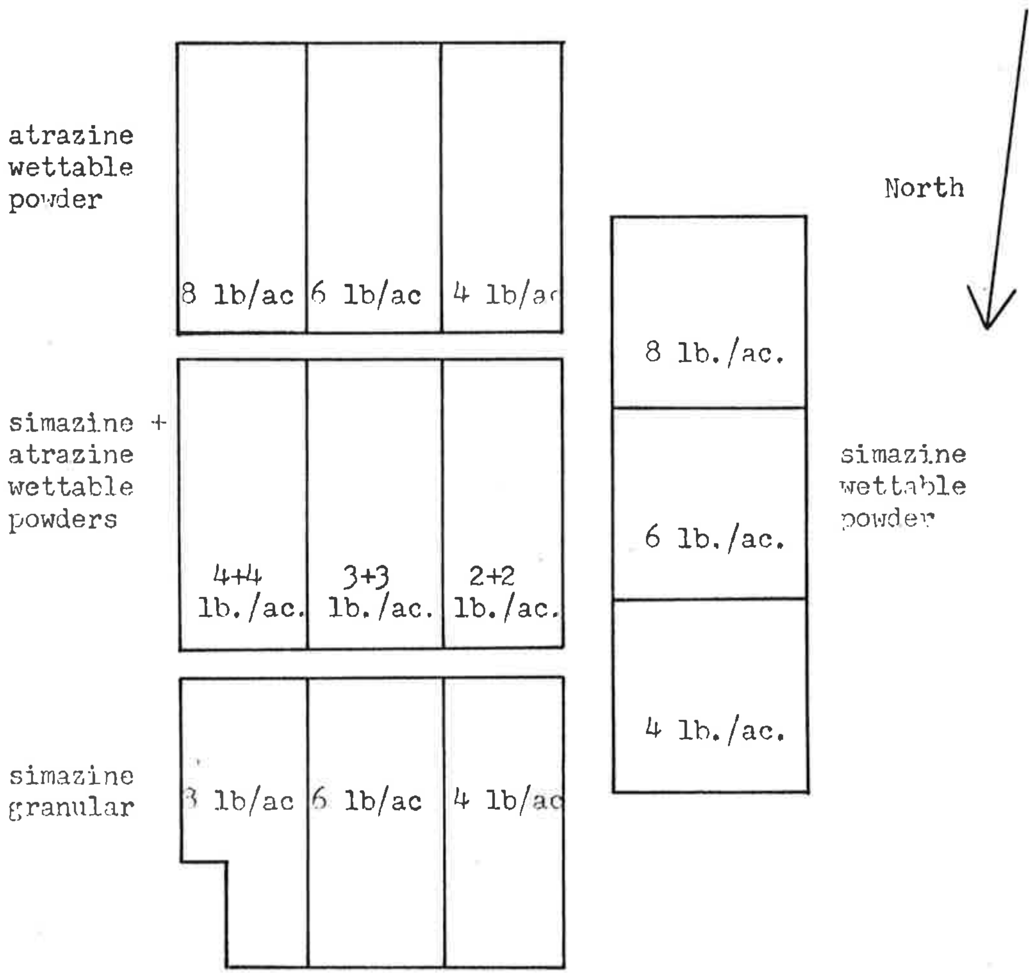
It should be noted that the herbicide study was made in conjunction with the establishment of shade plots for the white pine weevil control study. It was important that all the white pine be given the utmost care in order that successful establishment might be obtained. For this reason, no control plot for the herbicide study was possible. The number of white pine varied within the shade plots depending on the spacing at which they were planted. This results in an uneven number of trees for each of the herbicide treatments. If plots had been established solely for the purpose of herbicide research, these weaknesses in experimental design would have been avoided.

Methods

Each of the four shade plots established in Hartland, Maine in 1973 was assigned an herbicide to control weeds and grasses around the white pine seedlings planted in those plots. In addition to being assigned an herbicide, each plot was divided into three subplots with each subplot receiving a different rate of application of the respective herbicide. The plots received the following herbicides (Fig. 12):

Unshaded Plot	Simazine Wettable Powder (Princep 80W)
Heavy-Shade Plot	Simazine Granular (Princep 4G)
Medium-Shade Plot	Atrazine Wettable Powder (AAtrex 80W)
Light-Shade Plot	Simazine + Atrazine Wettable Powders

The rates of application of each herbicide on the three subplots within each plot was 4 lbs.a.i./acre (4.5 kg./ha.), 6 lbs. a.i./acre (6.7 kg./ha.), and 8 lbs.a.i./acre (9.0 kg./ha.) respectively (Fig. 13). The combination of simazine + atrazine



Scale : 1 inch = 2 chains

Figure 12. Physical layout of the twelve herbicide subplots in Hartland.

wettable powders was applied at the rates of 2+2 lbs.a.i./acre (2.2+2.2 kg./ha.), 3+3 lbs.a.i./acre (3.3+3.3 kg./ha.), and 4+4 lbs.a.i./acre (4.5+4.5 kg./ha.) to the three subplots of the light-shade plot. The wettable powders contained 80% active ingredient (a.i.) while the granular formulation of simazine contained 4% active ingredient.

In the spring of 1973, the herbicides were applied approximately two weeks after the white pine seedlings were planted. The wettable powders were applied using a hand sprayer. A circular area with a diameter of two feet (0.61 M.) was sprayed around each pine. In order that an even distribution of the herbicide throughout the subplots could be obtained the following method of application was implemented. The ground area within each subplot was calculated, this varied between subplots as each subplot contained a different number of white pine seedlings. The amount of herbicide needed to treat each subplot at the respective rate of application was measured in the lab and placed in a labeled glass jar. In the field, the herbicide was diluted with enough water so that from two to three complete applications within the subplot were possible. It was hoped that by spraying each seedling within the subplot a number of times an even distribution of the herbicide would be obtained.

The granular formulation was applied using a glass jar with holes punched in the top. The treatment area was also a circle with a two-foot diameter around each pine. Application was made by shaking the herbicide filled jar over the desired area. As with the application of the wettable powders, the granular simazine was applied in two to three applications within each subplot in an attempt to insure an even distribution of each of the application rates.

In the spring of 1974 dead white pine seedlings were replaced. Each of the twelve herbicide treatments was applied to the same subplots in an identical manner as the previous year.

Evaluation of the effectiveness of weed and grass control by each of the herbicide treatments was made in September 1973 and September 1974. Surveys were made of seedling mortality in each of the subplots. Because the number of rows in each subplot, as well as the number of white pine within the rows varied, white pine mortality was recorded as the percent of mortality per row. This mortality count was taken to determine the difference in white pine susceptibility to the various rates of application of the different herbicides used, and to detect any difference in white pine susceptibility to the different herbicides themselves.

Every white pine in all four shade plots was examined. Each tree was tallied as being either alive or dead. White pine that had set a bud for the next years growing season were tallied as live trees. White pine that had not developed at least one bud or white pine that had buds that had wilted and died were tallied as mortality (Table 9).

No formal system for rating the degree of weed and grass control obtained by each of the herbicide treatments was used.

Table 9. Percent mortality of white pine seedlings for each herbicide subplot in Hartland, Maine in September 1973 and 1974.

Herbicide (Plot)	Application Rate	1973	1974
Simazine wettable powder (unshaded plot)	4 lb./ac.	17.30	10.03
	6 lb./ac.	20.08	20.70
	8 lb./ac.	37.87	38.41
Atrazine wettable powder (medium-shade plot)	4 lb./ac	13.26	15.53
	6 lb./ac.	45.00	45.00
	8 lb./ac.	43.41	52.65
Simazine + Atrazine wettable powders (light-shade plot)	2+2 lb./ac.	30.40	38.40
	3+3 lb./ac.	40.00	69.33
	4+4 lb./ac.	54.40	64.80
Simazine granular (heavy-shade plot)	4 lb./ac.	4.36	7.64
	6 lb./ac.	4.00	14.80
	8 lb./ac.	3.76	15.48

During the mortality counts the overall effectiveness of each treatment was assessed and recorded.

During the survey of white pine mortality in 1974 it was noticed that a higher rate of white pine mortality was associated with the higher rates of each herbicide application. Some of the white pine treated with a 6 or 8 lbs.a.i./acre application for two consecutive years were burned, a sign of herbicide toxicity (Fig. 13).

The regression of the percent of white pine mortality per row on the rate of application was calculated for each of the four herbicides used. The regression lines were obtained by using the percent mortality of each row at each application rate as a separate observation. This resulted in multiple values of mortality at each herbicide application rate.

The regression lines were compared for equality of slope and elevation in order to detect any significant differences between the four herbicides with respect to toxicity to white pine seedlings.

Results

The effectiveness of each herbicide treatment in controlling the competing vegetation around white pine seedlings was assessed and recorded at the end of both years that the herbicides were used. Each of the four herbicides was evaluated at each of the three application rates. Comparisons of effectiveness between corresponding rates of the different herbicides can be made but certain physical variations within the planting site must be kept in mind.

Figure 13. A white pine seedling being burned by two consecutive years of an 8 lb./acre herbicide application.

The weeds and grasses at the lower (northern) end of the field constitute very dense growth. The density of this vegetative competition decreases gradually as one approaches the upper (southern) end of the field. Variation in the density of the competing vegetation was negligible from east to west within each of the three shade plots. This means that the heavy-shade plot was in the area of the densest growth followed by the medium and light-shade plots in order. There was little difference in vegetative growth between the subplots within any of these three shade plots.

The unshaded plot lies on the other side of an access road where the vegetation differs somewhat. This part of the field had not been cultivated recently and supported more woody vegetation than the rest of the field. The weed and grass competition was not as dense as in the other plots. The vegetation does become sparse towards the southern and upper end of the field so the 4 lb./acre treatment was in the densest competitive growth and the 8 lb./acre treatment in the sparsest.

During the first summer of herbicide application, simazine wettable powder (unshaded plot) gave adequate control of weeds and grasses at 4 lbs./acre and good control at 6 and 8 lbs./acre. Simazine granular (heavy-shade plot) was ineffective at 4 lbs./acre, ineffective to adequate at 6 lbs./acre, and gave good control at 8 lbs./acre. It should be remembered that this plot lies in the area of densest weeds and grasses. Atrazine wettable powder (medium-shade plot) gave good weed and grass control at 4 lbs./acre and excellent control at both of the higher rates of application.

The combination of simazine + atrazine wettable powders (light-shade plot) provided adequate control at 4 lbs./acre, good control at 6 lbs./acre, and excellent control at 8 lbs./acre. The ratings of the effectiveness of the twelve herbicide treatments were not intended to be quantitative, but rather to reflect the weed and grass control capabilities of each with respect to the others.

In 1974 each subplot received identical applications of the herbicides. All twelve herbicide treatments provided excellent control even in the densest vegetation (Fig. 14).

The following regression equations were calculated for each herbicide used (Fig. 15). The rate of herbicide application was the independent variable and the percent white pine seedling mortality per row was the dependent variable.

Simazine Wettable Powder
$Y = -19.45 + 7.09X \qquad r^2 = 0.578 \qquad F = 65.68^{**}$

Simazine Granular
$Y = 0.31 + 2.07X \qquad r^2 = 0.141 \qquad F = 4.92^{**}$

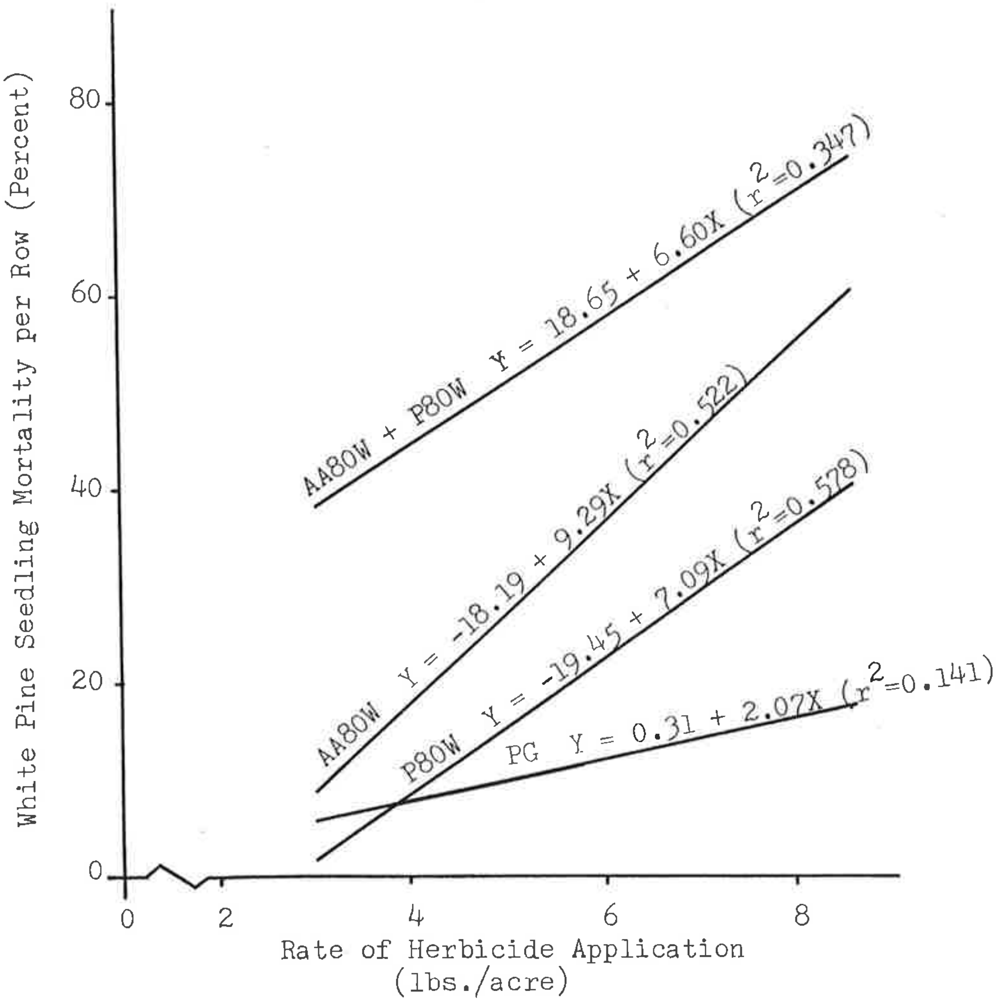
Atrazine Wettable Powder
$Y = -18.19 + 9.29X \qquad r^2 = 0.522 \qquad F = 32.79^{**}$

Simazine + Atrazine Wettable Powders
$Y = 18.65 + 6.60X \qquad r^2 = 0.347 \qquad F = 7.44^{**}$

Procedures to determine equality of slope and elevation of the regressions were applied according to Zar (1974). Tests for equality of slope indicate that only the slope of the simazine granular regression differs significantly at the .05 level from the other regressions. The three remaining regressions were found

Figure 14. Weed and grass control around a white pine seedling characteristic of all herbicide treatments after two consecutive years of application.

Figure 15. The relationship of white pine seedling mortality to rate of herbicide application after two consecutive years of treatment.



Simazine wettable powder - P80W
Atrazine wettable powder - AA80W
Simazine granular - PG

not to differ significantly with respect to slope. The regressions having equal slopes were then compared with respect to elevation. The regression for the combination of simazine + atrazine wettable powders was found to be significantly higher in elevation than both the simazine wettable powder line and the atrazine wettable powder line at the .05 level. There was no significant difference between the simazine wettable powder regression and the atrazine wettable powder regression in either slope or elevation at the .05 level (Appendix A, Table 10).

Residuals for all four regression lines were plotted. The residuals for the simazine granular line indicate that a logarithmic transformation might improve the coefficient of determination and achieve homoscedasticity (Appendix B, Fig. 16, 17). Prior to running any transformation Bartletts test for homogenity of variances was run. This test showed that all four regression lines were heteroscedastic (Appendix C, Table 12) and indicated that a data transformation might yield a regression line that explained more of the variation within the data.

It was decided to perform a log and arcsine transformation on each regression. Plotting of residuals indicated that at least the granular simazine line might be improved by a log transformation. Arcsine transformations are recommended when the data used are in percentages as is the case in this study. These transformations were calculated by the REGR package program and run on an IBM/370 at the University of Maine (Appendix D).

Discussion

Effectiveness of the first year application of the herbicides appears to be closely correlated to the density of the competing vegetation. For each of the herbicides, control of weeds and grasses was better the first year at the higher application rates. This would naturally be expected. Simazine granular provided the least effective control at all application rates followed by the combination of simazine + atrazine wettable powders and then atrazine wettable powder. This appears to be a function of the density of the competing vegetation as this is the order that the corresponding shade plots would fall if arranged from the densest competing vegetation to the sparsest vegetative growth.

It is difficult to separate the first year effectiveness of these herbicides because of the variation in vegetative density. I feel however, at each rate of application the wettable powders will give superior control than the granular formation. Observation throughout the summer revealed that the granular formation was slow to dissolve and indeed some remained undissolved through most of the growing season. This had the effect of reducing the actual application rate that entered the soil.

Following the second year application of herbicides, it was found that all twelve herbicide treatments, even those applied to the densest growth of competing vegetation provided excellent control of weeds and grasses. This indicated the possible presence of a residual level of herbicide in the soil from the previous years application. This residual effect was evident even on the 4 lb./acre treatments that did not provide satisfactory control during the first summer.

The possibility of increasing the effectiveness of weed and grass control through the combination of simazine + atrazine wettable powders was not shown at the rates tested. During both years this combination herbicide provided control comparable to the other treatments at each application rate tested. Further tests utilizing lower application rates would be necessary to determine if a synergistic effect does in fact exist.

The relationship of increased white pine seedling mortality and higher rates of herbicide application for two years is shown by the regression developed for each herbicide. A strong linear relationship was found between toxicity and high application rates for all the wettable powder herbicides. The regression for the granular formation of simazine does not explain a large portion of the variation in white pine seedling mortality.

The regressions were not improved appreciably by either of the transformations. The log transformation for the simazine granular regression line did improve the form of the residuals, however, it caused a decrease in the coefficient of determination. It also caused the F value to drop from .05 significance to .10 significance. This tradeoff is largely academic as this regression line explains less than 15% of the variability and thus is a poor predictor of white pine seedling mortality.

The low coefficient of determination is due to the application of the herbicide itself. Unlike the wettable powders that could be diluted in water to insure an even distribution, the granular herbicide had to be applied with a shaker jar. Although every effort was made to obtain an even distribution of the herbicide, the uneven flow of the granular particles from the jar caused the actual application rate around each seedling to vary widely above and below the target level. I feel it is this variance and the slow rate of decomposition that accounted for the low coefficient of determination of this regression line.

Analysis of the equality of slope and elevation of the regression lines indicates that the granular formulation differs significantly in slope from the other regression lines. This means that at each rate of application the level of white pine seedling mortality increases but at a slower rate than the increase exhibited by the other regression lines. When the three remaining regression lines were compared for equality of elevation the combination of simazine + atrazine wettable powders was found to be significantly higher in elevation than either of the wettable powders alone.

Although no synergistic effect was evident with regard to effectiveness in controlling weeds and grasses, the combination herbicide appears to have a more detrimental effect on the white pine seedlings than either of the wettable powders alone. This synergistic effect is evident as greater seedling mortality at each of the application rates.

The regression lines for both atrazine wettable powder and simazine wettable powder do not differ significantly in either slope or elevation at the .05 level. There is apparently little difference in the toxicity of these two herbicides when applied as wettable powders to white pine seedlings.

Conclusions and Recommendations

The separate treatments of simazine wettable powder and atrazine wettable powder were the most favorable herbicides of those tested to facilitate the establishment of white pine seedlings on abandoned fields. The combination of simazine + atrazine wettable powders exhibited a strong synergistic effect and was found to be highly toxic to the seedlings at all application rates tested. Although the granular formation of simazine was responsible for the lowest percent mortality at all rates tested, the arduous method of applying this herbicide coupled with the difficulty of obtaining an even distribution makes this treatment, particularly on large areas, impractical.

An upper limit of desirable application rates for two consecutive years was found. At 6 lbs./acre all four herbicides were responsible for the burning of some white pine seedlings. At 8 lbs./acre herbicide burning was obvious with all the herbicides. All the herbicides provided excellent control of weeds and grasses at 4 lbs./acre after two years of application. This represents a maximum desirable application rate. None of the herbicides provided excellent control at this rate during the first year. This indicates the need for a variable rate of application over a two year period.

I recommend use of either of the wettable powder herbicides. On abandoned fields supporting dense vegetation a first year application of 6 lbs.a.i./acre (6.7 kg./ha.) should be followed by a 2 lbs.a.i./acre (2.2 kg./ha.) application the next year. To control sparser vegetation, a 4 lbs.a.i./acre (4.5 kg./ha.) treatment followed by a 2 lbs.a.i./acre treatment is recommended. The first year application should be made 1-2 weeks after planting the seedlings. The second year application should be made before weed and grass growth initiates, as these are pre-emergent herbicides. Application with a good hand sprayer is efficient and rapidly accomplished. The herbicide should be diluted in enough water so that an even distribution is insured around each seedling.

Finally, the weaknesses in the experimental design of this study must be viewed in the light of practicality. The herbicide study was conducted on plots established for a white pine weevil control study. The herbicide study was adapted to meet the existing layout of the weevil study at the expense of better experimental design. Two obvious design improvements would be the establishment of a control group of white pine seedlings that received no herbicide treatment and maintaining an equal number of seedlings in each herbicide treatment. In spite of these weaknesses, I feel that general trends in herbicide effectiveness and toxicity are apparent, and that the above conclusions and recommendations are valid.

SUMMARY

White pine plantations in the Orono, Maine area were sampled to determine to extent of damage caused by the white pine weevil. It was found that open grown white pine were damaged by the weevil more often than white pine growing in a shaded habitat. In addition, it was found that close plantings of white pine exhibit less weevil damage than adjacent stands planted at a wider spacing. These results were in agreement with what has been reported in the literature.

Shade plots to discourage white pine weevil oviposition on white pine were established in Hartland, Maine, and Veazie, Maine. The results of this research will not be known for a number of years, and hence this study is concerned only with the establishment of the shade plots. It should be remembered that this is an attempt to find a practical method of weevil control. This research is not meant to be a purely academic exercise.

The success of hybrid poplar cuttings, which were used as the shade species in the weevil control study, were found to be closely associated with the site characteristics of the planting area. The survival and growth of the poplar cuttings on a moist and rockless site, such as that found in Veazie, were very good. The dry and rocky soil of the Hartland site was found to hamper cutting survival and growth.

Poplar cutting establishment is facilitated if a method of weed and grass control is implemented. The foliar herbicide

glyphosate applied at the rate of 0.5 lbs.a.i./acre (0.6 kg./ha.) was found to provide effective control of the competing vegetation without being harmful to the poplar cuttings, when the cuttings were protected during spraying by a section of stove pipe.

Four herbicides were tested for weed and grass control around the white pine seedlings on the weevil control shade plots. Each of the four shade plots was assigned an herbicide which was applied at three application rates within the shade plot. Of the twelve herbicide treatments tested, the 4 lbs.a.i./acre applications of simazine and atrazine wettable powders were found to provide good weed control without being toxic to white pine seedlings.

The combination of simazine and atrazine wettable powders was found to have a greater toxic effect on the seedlings at all application rates, than either simazine wettable powder or atrazine wettable powder alone. The combination treatment gave no better control of the competing vegetation than either of the wettable powders alone.

The granular formulation of simazine was found to be difficult and time consuming to apply. In addition, the control of weeds and grasses obtained with this herbicide was not as good as with the wettable powder formulations at each of the rates tested.

Based on the merits of their good weed and grass control and low toxitiy to white pine seedlings at the 4 lbs.a.i./acre application rate, simazine wettable powder and atrazine wettable powder were found to be the most effective herbicides tested. It was recommended that either of these herbicides be used to facilitate establishment of white pine seedlings on abandoned fields. A first year application at a 4 lbs.a.i./acre (4.5 kg./ha.) rate should be followed the next year by a 2 lbs.a.i./acre (2.2 kg./ha.) application.

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APPENDIX A

COMPARISON OF HERBICIDE REGRESSION LINES FOR EQUALITY OF SLOPE AND ELEVATION

ABBREVIATIONS

Simazine Wettable Powder	P80W
Atrazine Wettable Powder	AA80W
Simazine Granular	PG

Table 10. Comparison of herbicide regression lines for equality of slope.

Ho : slope 1 = slope 2

Regression lines	Calculated t	Degrees of Freedom	Hypothesis
AA80W VS. AA80W + P80W	0.924	44	accept
P80W VS. AA80W	1.298	78	accept
P80W VS. AA80W + P80W	0.236	62	accept
PG VS. AA80W	3.859	60	reject
P80W VS. PG	3.797	78	reject
PG VS. AA80W + P80W	2.112	44	reject

Table 11. Comparison of herbicide regression lines for equality of elevation.

Ho : elevation 1 = elevation 2

Regression lines	Calculated t	Degrees of Freedom	Hypothesis
P80W VS. AA80W + P80W	11.481	63	reject
P80W VS. AA80W	0.449	79	accept
AA80W VS. AA80W +P80W	7.893	45	reject

APPENDIX B

Figure 16. Plotted residuals for the simazine granular regression line: Untransformed residuals.

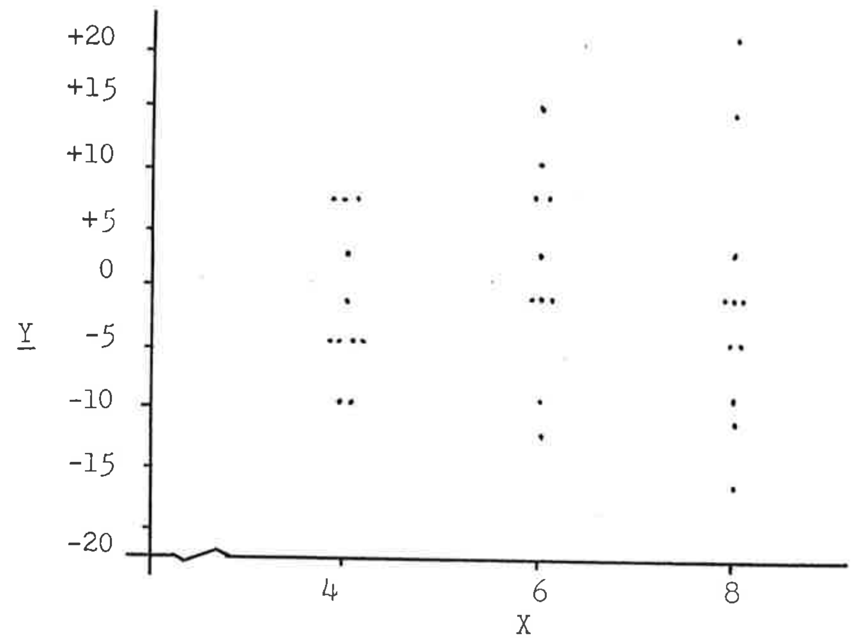
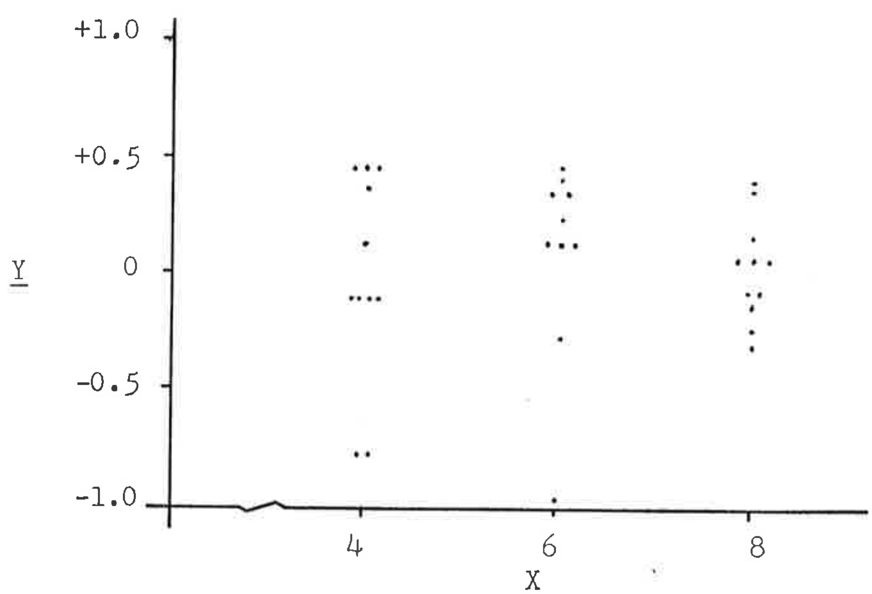


Figure 17. Plotted residuals for the simazine granular regression line: Log transformed residuals.



APPENDIX C

Table 12. Testing the four herbicide regression lines for homogeneity of variances using Bartletts test at the .05 significance level.

Ho: variance 1 = variance 2 = variance 3

Herbicide	Bc	Degrees of Freedom	Hypothesis
Simazine wettable powder	22.71	2	reject
Simazine granular	8.45	2	reject
Atrazine wettable powder	17.41	2	reject
Simazine + Atrazine wettable powders	45.23	2	reject

Chi square value (.05,2) = 5.991

APPENDIX D

COMPARISON OF HERBICIDE REGRESSION LINES USING: UNTRANSFORMED DATA, LOG TRANSFORMATION DATA, AND ARCSINE TRANSFORMATION DATA

SIMAZINE GRANULAR

Y	= 0.31 + 2.07X	r^2 = 0.141	F = 4.92**
Log Y	= 0.49 + 0.08X	r^2 = 0.095	F = 3.14*
Arcsine Y	= 0.12 + 0.03X	r^2 = 0.117	F = 3.97*

ATRAZINE WETTABLE POWDER

Y	= -18.20 + 9.29X	r^2 = 0.522	F = 32.79**
Log Y	= 0.66 + 0.14X	r^2 = 0.522	F = 32.71**
Arcsine Y	= 0.01 + 0.10X	r^2 = 0.528	F = 33.52**

SIMAZINE + ATRAZINE WETTABLE POWDERS

Y	= 18.65 + 6.60X	r^2 = 0.347	F = 7.44**
Log Y	= 1.40 + 0.06X	r^2 = 0.378	F = 8.46**
Arcsine Y	= 0.47 + 0.07X	r^2 = 0.332	F = 6.96**

SIMAZINE WETTABLE POWDER

Y	= -19.46 + 7.09X	r^2 = 0.578	F = 65.68**
Log Y	= 0.19 + 0.17X	r^2 = 0.407	F = 33.00**
Arcsine Y	= 0.10 + 0.09X	r^2 = 0.530	F = 54.05**

APPENDIX E

THE PERCENT MORTALITY OF WHITE PINE SEEDLINGS BY ROW IN HARTLAND, MAINE AFTER TWO CONSECUTIVE YEARS OF HERBICIDE APPLICATION

Table 13. Percent mortality of white pine seedlings by row in Hartland, Maine after two consecutive years of herbicide application; simazine wettable powder (unshaded plot).

4 lb./acre treatment	6 lb./acre treatment	8 lb./acre treatment
0.00	25.00	41.16
17.64	25.00	47.04
5.88	12.50	23.52
11.76	25.00	47.04
17.64	12.50	41.16
11.76	0.00	17.64
17.64	18.75	41.16
11.76	25.00	47.04
11.76	18.75	29.40
5.88	6.25	29.40
0.00	12.50	41.16
5.88	18.75	35.28
5.88	12.50	35.28
17.64	31.25	35.28
23.52	50.00	64.68
0.00	37.50	41.16
5.88		35.28

Table 14. Percent mortality of white pine seedlings by row in Hartland, Maine after two consecutive years of herbicide application: simazine + atrazine wettable powders (light-shade plot).

4 lb./acre treatment	6 lb./acre treatment	8 lb./acre treatment
48.00	72.00	68.00
24.00	72.00	72.00
36.00	80.00	64.00
36.00	84.00	68.00
48.00	72.00	52.00
	36.00	

Table 15. Percent mortality of white pine seedlings by row in Hartland, Maine after two consecutive years of herbicide application: atrazine wettable powder (medium-shade plot).

4 lb./acre treatment	6 lb./acre treatment	8 lb./acre treatment
20.85	16.68	62.55
4.17	45.87	20.85
4.17	50.04	45.87
12.51	41.70	50.04
20.85	41.70	37.53
25.02	75.06	54.21
12.51	70.89	41.70
8.34	45.87	70.89
29.19	41.70	66.72
12.51	20.85	58.38
20.85		70.89

Table 16. Percent mortality of white pine seedlings by row in Hartland, Maine after two consecutive years of herbicide application: simazine granular (heavy-shade plot).

4 lb./acre treatment	6 lb./acre treatment	8 lb./acre treatment
16.00	20.00	8.00
4.00	12.00	16.00
4.00	12.00	12.00
4.00	12.00	20.00
8.00	28.00	16.00
0.00	0.00	16.00
16.00	16.00	12.00
12.00	24.00	31.25
16.00	20.00	6.25
0.00	4.00	0.00
4.00		37.50

BIOGRAPHY

Marc J. Linit was born in Brooklyn, New York on March 1, 1949. He received his early education in the public schools in Brooklyn and was graduated from Midwood High School in June, 1967.

He received his undergraduate education at Ohio University, graduating in June, 1971 with a Bachelor of General Studies degree. He was married to Patricia Helker on July 30, 1971. Following his graduation, Mr. Linit was a teacher of the educable mentally retarded in Marietta, Ohio.

In September, 1972 he enrolled as a special student in forestry at the University of Maine. In July, 1973, Mr. Linit accepted a position as a research assistant in the School of Forest Resources at the University of Maine, and began work on a Master's degree.

Mr. Linit is a member of Xi Sigma Pi. He is a candidate for the Master of Science degree in Forestry.