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THE BEHAVIOR AND IMPACT OF THE PALES WEEVIL IN CHRISTMAS TREE PLANTATIONS

By

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ABSTRACT

THE BEHAVIOR AND IMPACT OF THE PALES WEEVIL
IN CHRISTMAS TREE PLANTATIONS

By

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The pales weevil (*Hylobius pales* (herbst)) is an injurious pest in Christmas tree plantations in Michigan. Behavior and impact of adults on marketability were studied in Christmas tree plantations.

A drop in light intensity to two foot-candles triggers the daily cyclic behavior. Temperatures below 5°C at night curtail or eliminate the nocturnal portion of the cycle. On the ground, adults react differently depending on light intensity and ground-surface temperature. At high light intensity and when surface temperatures are above 40°C the adults exhibit shelter-seeking, telotactic, thermophobic, and photophobic reactions. At higher temperatures the adults become strongly thermophobic and negatively geotactic. Exposure to temperatures above 40°C are lethal to adults.

Of the 786 adults marked, the longest period between marking and recapture was 11 months. Seasonal population changes showed significant (.01 level) fluctuations in adult numbers not explained by temperature, precipitation, adult emergence or migration. Starting in June, adults on the trees at night increase exponentially. At a temperature threshold between 15°C and 17°C, adult numbers vary from 4.4 to 29.0, below which there was a linear relationship. The seasonal population cycle can be used in the timing of pesticide application for control of the pales weevil.

Trees in each plot were graded with and without adult injury in spring and fall using a standard scale. Marketability varied depending on the time of year, tree species, weevil population and method of harvest. The percentage of cull trees was higher in the spring than in the fall when many of the needles on flagged shoots dropped, improving the grade. Eastern white pine improved more by harvest time than did Scots pine or Douglas-fir.

Plantations with high adult weevil populations had the most injury to the trees. Impact also varied with the method of harvest, it was greater with the "choose and cut" method because of the more selectivity of the public, and less when trees were owner selected.

Eastern white and Scots pine stumps with live branches intact were not infested by the weevil. Stumps without branches were infested.

Dedicated to

Sandra Ruth Corneil

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The pales weevil, *Hylobius pales* (Herbst) (Coleoptera: Curculionidae) occurs throughout eastern North America where it injures several species of pine. In the southeastern United States it is injurious to pine seedlings; in the northeastern United States and Canada it is mostly a pest of Christmas tree plantations. Adult weevils feed on the stem, branches and buds causing heavy shoot flagging and deformity which reduces the marketability of the trees.

In Michigan, infestations of the pales weevil occur mostly in the southeastern lower peninsula because of the prevailing method of Christmas tree harvest there. Most growers either select individual trees or allow private individuals to select their own trees, so that a particular plantation may be harvested over a five year period. Thus, numerous fresh pine stumps which are available each year provide an ample supply of breeding material for the pales weevil larvae.

Many methods of controlling the weevil have been recommended in the past, but most methods have originated from the southern states. In the South the pales weevil is a problem to seedlings in recently established plantations, so only a few of the control techniques used there are directly applicable for pales weevil in Christmas tree plantations.

This study was made to examine the weevil's behavior and to examine the impact on Christmas trees in order to develop appropriate management strategies.

LIFE CYCLE AND MAJOR HABITS

The pales weevil, like other native *Hylobius* weevils, has a fairly complex life cycle. The period from first generation oviposition to second generation oviposition of *Hylobius* weevils may be as short as 12 months or as long as 24 months (Peirson, 1921; Finnegan, 1959; Wilson and Millers, 1981). The longevity of the adults complicates the cycle because they may live and oviposit for two seasons, and thus several generations and life stages overlap throughout the year. Also, the life cycle of the pales weevil varies over its extensive range that covers most states and Canadian provinces east of the Mississippi River. And, the weevil's life cycle in the South is somewhat different from that in the North where it is further structured somewhat by the Christmas tree culture. Since this study is concerned mainly with the pales weevil problem in Michigan Christmas tree plantations, only the life cycle and habits of the pales weevil relative to Christmas trees are of concern.

The pales weevil overwinters mainly as adults beneath the litter or to a depth of six inches (15 cm) in the soil at the base of seedlings, stumps or trees. A few weevils, failing to reach full development before cold weather, overwinter as fifth or sixth (last) instars in galleries beneath the bark of pine stumps (Finnegan, 1959).

The adults break hibernation about mid-April. The volatile oils and resins of fresh stumps from trees cut the previous winter attract the adults to the stumps (Finnegan, 1959). They remain near the stumps for about two and one-half months. There they mate, lay eggs and feed on the bark of the stumps and occasionally on nearby seedlings and the shoots of trees. Little injury, however, occurs to the remaining trees during this period, but seedlings may be killed.

Female adults lay about 60 percent of their eggs during the spring following the first overwintering period as adults, and they oviposit the rest during the second spring (Finnegan, 1959). The females burrow three to 12 inches (7.6 to 30.5 cm) and then oviposit in cavities chewed into the inner bark of the roots and root collar of the stumps (Peirson, 1921). The female usually places a single egg in each cavity, but occasionally she may lay two or three there (Finnegan, 1959). She may lay from .02 to 1.46 eggs per day and continues laying for as long as 60 days (Clark, 1975). Oviposition ceases in early June, when the stumps glaze over and stop attracting the adults. Adults are difficult to find from June to mid-August because they hide beneath the litter and other debris, and only a few come out at night to feed on the trees.

The larvae eclose about ten days after oviposition and immediately begin feeding in the cambial area of the stumps or roots. They score the wood more deeply than the inner bark. Larval development occurs from June to mid-August. In Ontario, Finnegan (1959) found five to six larval instars requiring about 47 days for full development. Prior to pupation, the larvae construct one of two kinds of pupal cells. One type consists of a short chamber about 1/8 inch (3 mm) beneath the wood surface, with an entrance hole sealed with excelsior-like wood slivers. The second type is just a depression made in the wood and then loosely covered with frass and wood slivers. Construction of the pupal cell is followed by an inactive pre-pupal stage that lasts about three days. The callow adult appears after about 22 days (Finnegan, 1959).

New adults first emerge about mid-August. During the day the adults hide in the litter or debris near the base of the trees (Peirson, 1921). Then, at night they move to the trees to feed. They chew away the outer bark in irregular patches and feed on the inner bark of the main stems and branches of the host. Hunt and Farrier (1973), found that most adults prefer upper tree bark and twig bark over seedling bark. Adults are numerous and easily found on the trees from mid-August to November.

HOSTS

Several native and exotic conifers are hosts for the pales weevil. The adult weevils will attack trees of all ages although they prefer seedlings and saplings (Hunt and Farrier, 1973). Though adults feed on a wide variety of host trees, they prefer to feed on the bark of eastern white pine, Scots pine and Douglas-fir and breed on the stumps of these same species. These three species plus blue spruce and red pine are most commonly planted for Christmas trees in Michigan.

Scots Pine

Pinus sylvestris L., an exotic pine originally from southern Europe, is the prevalent Christmas tree species in Michigan (Wright, et al., 1976), making up 80 percent of Michigan's total sales. Scots pine is favored by Christmas tree growers because it takes well to plantation culture, shears well, has a dense crown with strong branches, and does not readily drop its needles (Wright, et al., 1976). Because it is one of the favorite hosts of the pales weevil its presence in a Christmas tree plantation may lead to damage on less susceptible tree species nearby. For instance, blue spruce is generally ignored by the pales weevil adult, but is usually injured when Scots pine is nearby.

Eastern White Pine

Pinus strobus L., is also a favorite of Christmas tree growers (Koelling and Wright, 1977), and it has long been recognized as being highly susceptible to attack by the pales weevil (Peirson, 1921; and Finnegan, 1959). Since white pine is native to Michigan, it may be an important source of natural populations (Carter, 1916; Peirson, 1921). The adults readily feed and oviposit on white pine, but the number of larvae developing in the stumps is often curtailed by the competition from the northern pine weevil, *Pissodes approximatus* Hopkins (Finnegan, 1958).

Douglas-fir

Pseudotsuga menziesii (Mirb.) Franco of southern Rocky Mountains origin is another popular Christmas tree species in Michigan (Koelling and White, 1978). When grown on sites with good air drainage, Douglas-fir is also susceptible to injury by the pales weevil adult and its feeding causes reddish-brown shoot flags that persist into winter. The stumps are also readily used as breeding material.

Blue Spruce

Picea pungens Engelm., is another Rocky Mountain species that is commonly used as a Christmas tree (Koelling and Wright, 1977) because it has a symmetrical crown, bluish foliage and good needle retention. Blue spruce is highly resistant to injury by the adult weevil when planted in monoculture and its stumps are rarely used for breeding.

Red Pine

Pinus resinosa Aiton, is occasionally grown for Christmas trees in Michigan (James, 1959; Finnegan, 1959). It is used by the pales weevil both as a food source by the adults and for breeding (Peirson, 1921; Finnegan, 1959).

Other Conifers

There are several other tree species that are used sometimes for Christmas trees in Michigan that are occasional hosts for the pales weevil (James, 1959). These trees include Austrian pine, *P. nigra* Arn., southwestern white pine, *P. strobiformis* Engelm., jack pine, *P. banksiana* Lamb., Norway spruce, *Picea abies* (L.) Karsten, and balsam fir, *Abies balsamea* (L.) Mill. (Peirson, 1921; Finnegan, 1959; Koelling and Wright, 1977).

STUDY AREAS

The study areas were four pales weevil infested privately-owned Christmas tree plantations located in southeastern lower Michigan (Figure 1). Many of the plantations in this area of Michigan are relatively small [less than 100 acres(40 hectares)] and the prevalent method of harvest is single tree selection. Most trees produced are marketed locally or shipped short distances to large cities, but some growers ship as far as Louisiana and Florida.

The four plantations used represent a variety of production sizes, tree species mixtures, methods of harvest, and markets. They also vary in the extent of pales weevil infestation. The statistics of the plantations are as follows:

Fras	Genesee Co.	T8N,R5E,Sec. 2	50 (20)
Kimmel	Tuscola Co.	T11N,R8E,Sec. 1	600 (240)
Rumbold	Genesee Co.	T9N,R5E,Sec. 22	400 (160)
Walk	Tuscola Co.	T12N,R10E,Sec. 14	20 (8)

Fras Plantation

The Fras plantation occupied approximately 50 acres (20 hectares) and was divided into three sections by two large ponds. Two of the sections were planted as a mixture of Scots pine, eastern white pine, Douglas-fir, and blue spruce, the other was just Scots pine.

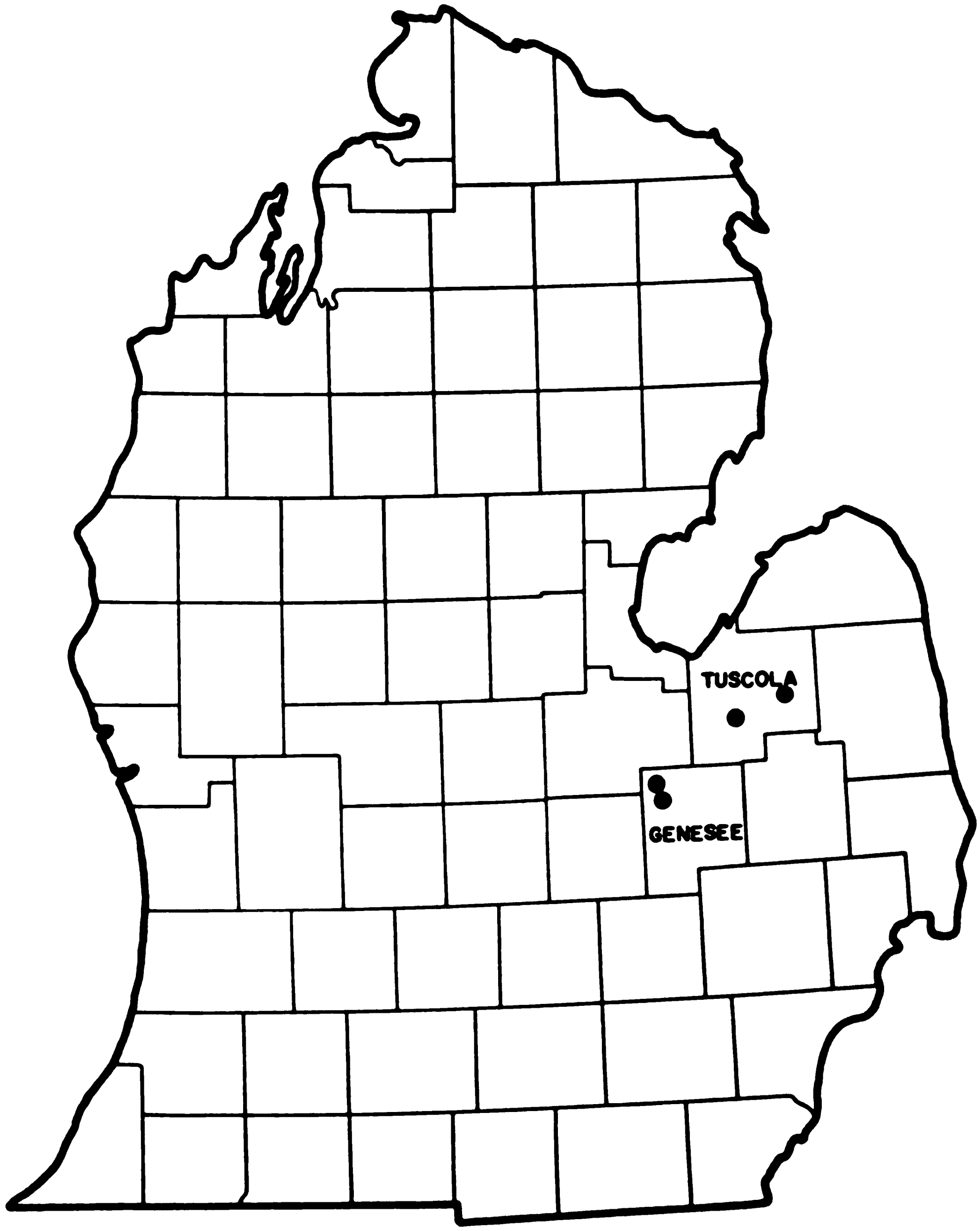

Figure 1. Location of the Four Pales Weevil Infested Plantations Used in This Study

The trees were sheared by the owners and were of excellent quality. New seedlings were planted near freshly cut stumps each spring in order to maintain uniform stocking.

Insects and diseases were controlled when necessary by using a hydraulic sprayer and heavy applications of pesticides. The pesticides were not used for control of the pales weevil.

The owner selected the trees for harvest and sold them to local consumers from the front of his property. Approximately 1,000 trees were sold annually--most were Scots pine. The owner cut the other species only on demand.

One plot[1] was established in each of the three sections. Plot F-1 contained 76 Scots pine trees with an average height of 5.64±.11 feet (1.72±.03m) in the spring of 1979. Plot F-2 contained 111 trees which averaged 4.40±.15 feet (1.34±.05m) tall, and was a mixture of Scots pine, eastern white pine, Douglas-fir and blue spruce. Plot F-3, also a mixture of the same tree species, contained 52 trees averaging 4.35±.24 feet (1.33±.07m) tall.

Kimmel Plantation

The Kimmel plantation was the largest of the four study areas occupying about 600 acres (240 hectares). Scots pine was the major tree species with a small area planted to blue spruce. Four to five thousand trees were shipped to Louisiana and Florida each year.

Shearing and harvest of the trees was done by locally hired students with good training and close supervision. Trees were harvested in late

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[1]Plots were established in 1978 for this study and did not include tree rows immediately adjacent to roads.

October and early November for shipment. After a block of trees was sufficiently harvested, the site was cleared and roto-tilled for spring planting.

Pesticides were applied by a large mist blower only when the owner considered it absolutely necessary. The pine needle scale was the only pest that chemicals were used against during the study period.

Two plots were established; both contained only Scots pine. Plot K-1 contained 78 trees with an average height of 5.13±.07 feet (1.56±.02m). Plot K-2 contained 101 trees with an average height of 5.21±.06 feet (1.59±.02m).

Rumbold Plantation

The Rumbold plantation occupied approximately 400 acres (160 hectares). Scots pine was the main species, but there were several acres of blue spruce and a few acres of mixed Scots pine and eastern white pine.

Tree shearing, weed control and other operations of Christmas tree culture were done mostly by locally hired students, who were given the necessary training but left unsupervised during the operations. Replanting was done after an area was sufficiently harvested out; the site was prepared for more trees with a roto-tiller.

Insect and disease control was mainly applied by a large mist blower. Several pesticidal applications were aimed at controlling the pales weevil, though timing was incorrect.

The method of harvest was by "choose and cut," where private consumers selected and harvested their own trees during the two or three weeks just prior to Christmas. This was the only study plantation using this method of harvest. The sale of 2,000 to 3,000 trees per season was aided by owner-provided horse or tractor-pulled wagons that transported the buyers to and from areas where trees were to be harvested.

Plot R-1 contained 172 trees in the Scots pine and eastern white pine area. Average tree height was 6.04±.09 feet (1.84±.03m). Plot R-2 contained 101 Scots pine trees. This plot was used only in the adult movement study and trees were not measured.

Walk Plantation

Occupying only 20 acres (eight hectares), the Walk plantation was the smallest of the four study areas. The owner sold about 600 trees per year. The major Christmas tree species grown was Scots pine, but there were a few acres of eastern white pine.

The trees were harvested by the owner and sold from the front of the property to local buyers. Being a small operation, shearing was done solely by the owner. Two methods were used to restock the plantation after harvest. Trees with a lower whorl of healthy branches were cut leaving the strongest branch for tip-up culture. In other instances, seedlings were planted in the spring near the new stumps.

The Walk plantation had the largest population of pales weevil and heaviest injury. Pales weevil was absent until the owner shifted from restocking by the stump culture method to planting seedlings. Pesticides were not used in the Walk plantation during the study period.

Two plots were established, both containing only Scots pine. Plot W-1 had 26 trees with an average height of 8.00±.23 feet (2.44±.07m), and Plot W-2 had 57 trees with an average height of 8.04±.11 feet (2.45±.03m).

THE EFFECTS OF LIGHT AND TEMPERATURE ON THE BEHAVIOR AND SURVIVAL OF PALES WEEVIL ADULTS

Studies of the closely related pine root collar weevil, *Hylobius radicis* Buch., revealed that the adults exhibited specific responses to certain light and temperature regimes (Wilson, 1968). These responses are adaptations to keep the adults away from unfavorable temperature locations during the day, and to bring the sexes together at the sheltered tree base, where they mate and the females lay eggs under the litter (Wilson and Millers, 1981). Subsequent studies on this weevil led to the development of a silvicultural method for its control (Wilson, 1967).

This study was undertaken to learn more about adult pales weevil behavior and how behavior and survival are affected by light and temperature.

Methods and Materials

The weevils were observed on the trees at various times during several evenings in August of 1979 in plot K-1. The time of appearance of adults on the stem or branches of the trees were recorded along with light intensity, temperature, wind and precipitation.

Laboratory tests were also made to examine day and night time activity. In two cages, ten male and ten female adults weevils were placed in each of the 16x12x10 inch (41x30x25 cm) cages constructed with plywood frames and nylon screens. The cages were placed on a lab table near the window to observe the weevils' behavior. The light meter was placed on the floor of one cage to measure light intensity. Scots pine twigs inserted in a small dish of moist sand were placed in the center of the cage to provide food and a place to climb for the adults. Crumpled paper toweling placed around the twigs were used to simulate needle litter and to provide shelter for the insects. Light and temperature effects on the adults' daily cyclic behavior were studied by placing the cages outdoors in an open field. Observation on adult movements were made periodically during the day and at dusk.

Field behavior tests were conducted using a 7x7 foot (2.12x2.13 m) grid in a clearing near plot K-1. The grid was oriented North and South and was marked off with string at one foot (30 cm) intervals. The vegetation within the grid consisted of small open patches of sand, abundant grass clumps, small forbs and scattered debris. The conditions were similar to areas between and under the trees except that there was no shade. To the East about five feet (1.5 m), there were several Scots pine Christmas trees, and to the West about 200 feet (60 m), there was a stand of tall bigtooth aspen (*Populus grandidentata* Michx.). There were no trees to the North or South of the grid.

Eight daytime tests were made during the first two weeks of July. Most were run during the early afternoon on sunny days and lasted until the insect died or remained stationary after reaching shelter. One test was run from 1300 hours EST until dusk and another from 2000 hours to 2100 hours. In each test, one to four adults were placed in the center of the grid after they warmed up from being in a cooler. Behavior was observed and recorded continuously. Ground-surface temperature and incident light was recorded with an 11-probe thermistor thermometer and a sensitive light meter. Light intensity was recorded in one foot-c intervals.

Results

Daily Cyclic Behavior

In the evening adults moved to the crown of the pine trees when light intensity became at least two foot-c which, in early August, was around 2000 hours EST. Adults appeared several minutes earlier on trees that had dense crowns, but were not found on the branches of these trees until light became two foot-c. The precise time that adults appeared was also affected by weather conditions. On an evening with heavy overcast, adults started climbing about 45 minutes earlier than the previous evening when the sky was clear. Adults could not be found on rainy nights, windy nights or nights with temperatures below 5°C.

The laboratory observations supported the findings of the field observations. Adults kept in cages remained beneath the paper toweling until light intensity inside the cage fell to two foot-c. At this time a few adults would climb on the cage walls and pine twigs. During the three days of observation, half of the adults were on the cage walls or pine twigs within ten to 20 minutes after the first adults appeared. Once on the walls or twigs, if the lights were turned on, adults became motionless and then gradually they would drop or walk to the paper toweling. After an hour all adults were on the floor of the cage but necessarily hidden beneath the paper toweling.

When the cages were placed outdoors the adult weevils followed the same cyclic pattern, but were also affected by temperature. One evening, when the temperature fell below 5°C, all of the adults remained beneath the paper toweling. During three other evenings, when the temperature was at least 11°C, adults began appearing when light intensity dropped to two foot-c. Temperature did seem to affect the amount of time it took for half of the adults to appear. Half of the adults appeared 25 to 35 minutes after the first adult appeared, whereas in the laboratory, half appeared within ten to 20 minutes of the first adults.

Survival Behavior

Adults, placed in the grid when temperature was below 35°C and light intensity was below 2500 foot-c, remained still for 0.5 to ten minutes before moving. Once movements began, most adults traveled more or less away from the sun (Figure 2A) at an average speed of two cm/minute (Table 1), until shelter was found. One male walked 30 cm towards the sun and hid beneath a grass clump (Figure 2A). Another male walked steadily at three cm/minute for an hour at right angles to the sun until reaching a grass clump (Figure 2A). This male had a small ant (Hymenoptera:Formicidae) attached to an antenna which may have affected its movements. A female began walking ten minutes after being placed in the grid at 1800 hours EST. It walked directly away from the sun at one cm/minute for one hour until reaching a forb clump (Figure 2A), and remained beneath the clump until 2045 hours EST when light dropped to two foot-c then it immediately began walking again. A second female, placed in the grid at 1815 hours EST, began walking in two minutes and moved directly towards a Scots pine tree that was northeast of the grid. It walked steadily for 40 minutes at three cm/minute and hid beneath a grass blade.

A male and female were placed in the grid at 1448 hours EST when the surface temperature was 35°C. They both spent a few seconds orienting and then headed away from the sun toward two nearby Scots

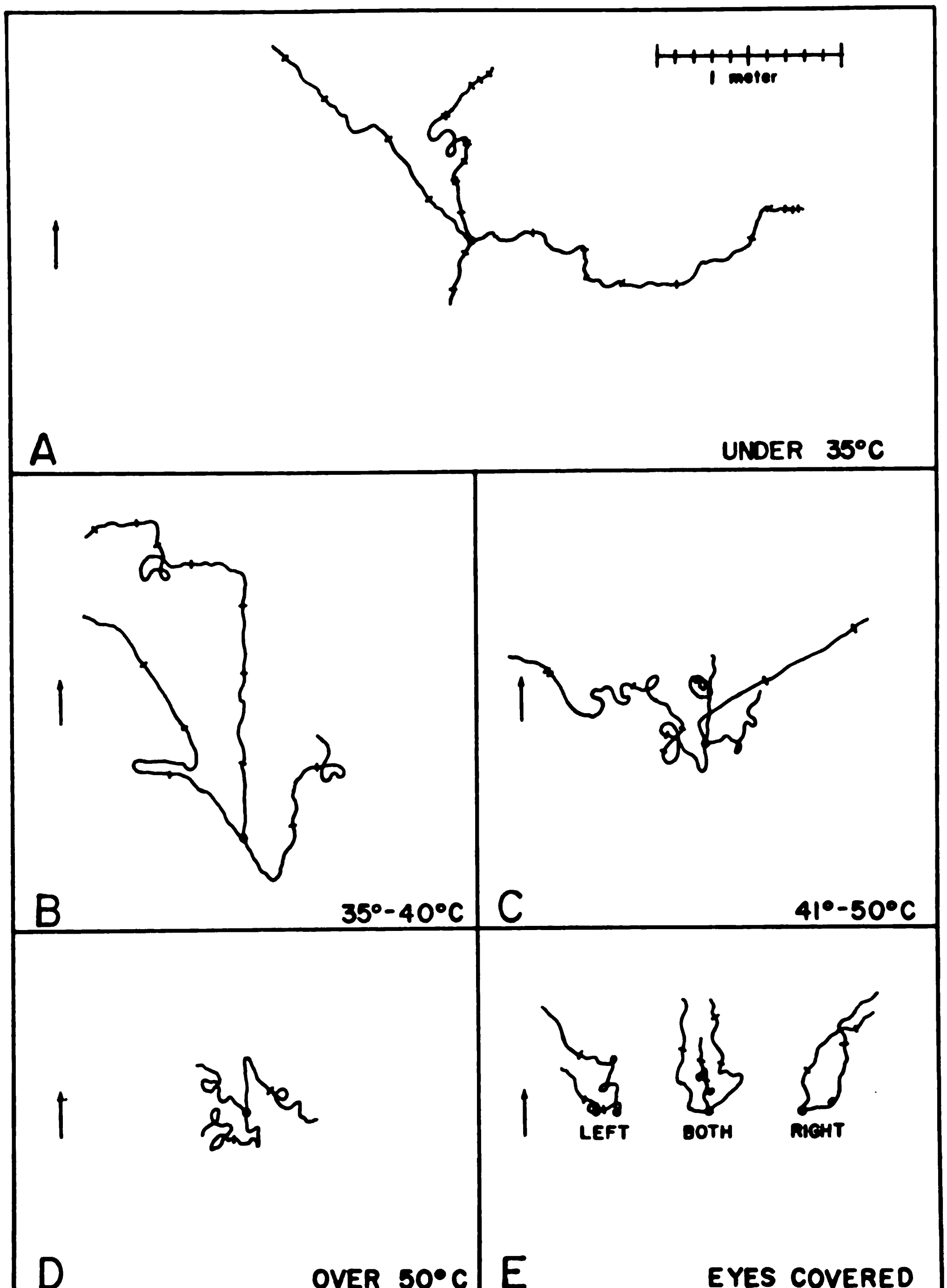

Figure 2. Movement Patterns of Pales Weevil Adults During the Day Under Different Temperature Regimes (A-D); and With Eyes Covered with Opaque Paint (E). Arrows Point Away from the Sun; Short Cross-Marks on the Movement Patterns Indicate Ten Minute Intervals for A, and One Minute Intervals for B-E.

Table 1. Average Distance Covered and Average Speed that Adults Walked under Various Temperature Ranges

Number of Adults	Soil Surface Temperature (°C)	Average Distance (m) ±SE	Average Speed (cm/min) ±SE
4	<35	1.2 ± .35	2.0 ± .53
3	35-40	2.0 ± .52	53.6 ± 8.11
4	41-50	1.5 ± .51	70.5 ± 12.53

pine trees five m north northeast of the grid center (Figure 2B). The male traveled three m and then burrowed beneath some pine needles. Another male was placed in the grid at 1200 hours EST with a soil-surface temperature of 39°C. After a few seconds it started walking towards me, I moved and it turned and traveled towards the Scots pine trees (Figure 2B). The male walked 1.2 m and hid beneath a grass clump. All adults traveled at an average speed of 54 cm/minute (Table 1).

Two males and two females, placed in the grid when surface temperature was between 41°C and 50°C, began moving immediately away from the sun (Figure 2C). They averaged over 70 cm/minute, but made frequent stops beneath grass blades or other shelter. A male and a female walked into areas without shelter and began to circle erratically. The male went into permanent heat stupor after two minutes of being placed in the grid, the female went into permanent heat stupor after two minutes and 20 seconds. Another of the females walked in a straight line for two minutes and climbed a blade of grass. It remained about two cm above the soil surface occasionally climbing down to the ground and then back up. This continued for four hours until the surface temperature was 34°C. It then climbed down, walked a few centimeters and hid beneath a grass clump.

When the surface temperature was above 50°C, sun orientation was bypassed and adults circled rapidly and began erratic leg movements within one minute. In less than two minutes, all three adults entered permanent heat stupor (Figure 2D).

When one or both eyes of an adult were painted, movements were still away from the sun. When one eye was painted, movement was generally in the direction of the covered eye (Figure 2E). Sight was not essential for sun orientation because adults with both eyes painted moved away from the sun (Figure 2E).

Discussion

From June to October, adult weevils of both sexes follow a daily cycle. They remain under the litter near the base of pine trees during the day, and will move about only at night. The stimulus that starts the evening portion of the cycle is a drop in light intensity to about two foot-c.

The response of the pales weevil adult to light and temperature are adaptations to keep them away from unfavorable temperature locations during the day. Adults, exposed on or between trees when both light intensity and temperature are low, react only to light and move at a steady pace. As light intensity increases beyond a threshold, the adults become photophobic and immediately seek shelter away from the sun. When immediate shelter is not available or is unsatisfactory, they become telotactic, moving towards any large upright object, until some type of shelter is found. When the soil-surface temperature exceeds 40°C, adults become photophobic and strongly thermophobic. Survival under these conditions depends more on simply escaping the hot soil surface by climbing cooler objects such as grasses, forbs, sticks, etc., than on obtaining shelter. Those exposed to such heat for more than a few minutes die. Adults forced to climb in order to escape heat do not fly to safety. Instead, they remain a few centimeters above the soil until surface temperatures drop to below 35°C, then they climb down to the soil surface and move away to shelter. They will climb back up if temperature is still above 35°C.

The effects of temperature and light on behavior and survival may indicate why the adults aggregate beneath the trees as do pine root collar weevil adults (Wilson, 1968). For the most part, this is where most adults are found in the summer and fall months. But in the spring most adults are found in the area immediately surrounding stumps produced from the previous season's harvest. This behavioral difference from the pine root collar weevil is an olfactory response to the volatile resins or oils released by the fresh-cut stumps in the spring. Attractants drop off by June which coincides with an increased occurrence of adults at the base of the trees.

Although the survival behavior of the pales weevil adult closely resembles that of the pine root collar weevil, basal pruning (the removal of the lower branches and the litter at the base of the trees) would probably not curtail this insect as it does with pine root collar weevil infestations. The basal pruning treatment does not directly reduce adult feeding damage to the trees, but rather, reduces successful oviposition at the base of living pines (Wilson, 1967). The pales weevil breeds in pine stumps and rarely in living trees so the treatment would be ineffective in preventing oviposition.

ADULT MOVEMENTS AND SEASONAL POPULATION CHANGES

Marked pales weevil adults have been found to fly as far as seven miles for breeding material (Bullard and Fox, 1969). In the South, adult populations build up for the first year and a half after harvest and then they mass migrate as breeding material is depleted (Peirson, 1921; Bullard and Fox, 1969). In northern Christmas tree plantations breeding material is produced continuously over a number of years, although it is attractive to the adults only through the first June after a harvest. Therefore, mass migrations are thought not to occur (Finnegan, 1959). Because adults can remain in a Christmas tree plantation for a number of years, the seasonal changes in populations may differ from the South. This study was made to examine adult movements and the seasonal population changes of the adults in Christmas tree plantations.

Methods and Materials

Adult movements and population changes were studied in all plots during the summers of 1978 and 1979. One-inch (2.5 cm) thick discs of Scots pine stem were place within each permanent plot. The discs were placed on the ground in small depressions, similar to that used by Ceisla and Franklin (1965). The discs were spaced approximately 12 feet (3.7 m) apart in alternating rows of trees in one or two areas in each plot. The number of discs varied from 24 to 32 in each plot, depending on the size of the plot and the number of trapping areas.

The discs were checked one to three times at one to seven day intervals. They were replaced weekly.

Adults captured under the discs were marked and replaced. They were marked with painted dots as described by Cross and Mitchell (1964), or with consecutive numbers. Different colors of paint designated month and plot. Plot, date, sex and disc location were recorded for each new and recaptured adult. Records of daily minimum and maximum temperature and precipitation for 1978 were obtained from official Climatological Data stations in Caro and Flint, Michigan.

Because trapping was not directly associated with the damage to the Christmas trees, the number of adults on the trees at night was recorded during the summer of 1980. Starting around 2200 hours EST, ten trees in plot K-1 were selected and examined for the number of adults present. The branches and stem of each tree were shaken three times and adults falling on a cloth sheet placed beneath the tree were counted. Temperature at 2200 hours EST was recorded on a hygrothermograph in a white-wooden shelter placed in the middle of the plot.

Results

Adult Movements

The percentage of the 698 adults marked in 1978 that were recaptured was 40.8 percent and 39.4 percent of the 188 adults marked in 1979. These adults were recaptured only once or twice (Table 2) and were generally found at the same disc where they were marked. Many of the adults recaptured more than twice were found at a single disc on several dates. For example, a male marked on June 26, 1978 in plot R-1 was recaptured 11 times, five times at one disc and six at another, from June 26 until August 11. The longest time of recapture was 11 months,

Table 2. Percentage of Males, Females and Total Adults by the Number of Times Recaptured in 1978 and 1979

Times Recaptured	1978 (N=285) Male %	Female %	Both %	1979 (N=74) Male %	Female %	Both %
1	61.0	65.6	63.2	58.1	55.8	56.8
2	15.6	21.4	18.2	16.1	25.6	21.6
3	11.0	9.9	10.5	6.5	14.0	10.8
4	2.6	2.3	2.5	6.5	2.3	4.1
5	3.9	-	2.1	6.5	-	2.7
6	2.6	0.8	1.8	6.5	-	2.7
7	0.6	-	0.4	-	2.3	1.4
8	1.3	-	0.7	-	-	-
9	0.6	-	0.4	-	-	-
11	0.6	-	0.4	-	-	-

one female marked in July 1979 was recaptured in June 1980. No other adults marked the previous year were recaptured the following year.

During 1978 and 1979, adults were recaptured only in the plot in which they were marked, but four adults moved from the one trap area to the other trap area of the same plot. Most recaptures occurred over short distances within a plot. During 1979, four females and one male in plot W-1 were recaptured over short distances (Figure 3). Because the Scots pine discs provided food, shelter and oviposition material, adults could remain at one disc for several days after disc placement as occurred with insects marked A, B, and C (Figure 3). Recapture at a different disc generally took three to six days (insects marked A, B, C, and D), however, one female marked E moved about seven m to another disc in one night (Figure 3).

Seasonal Population Changes

The discs used in this study dried out in about seven days. The adult capture data showed the discs were most attractive on the third and fourth days after placement (Figure 4). The data used to examine adult population was taken at the peak time of disc attractiveness which was the third and fourth day after the discs were placed in a plot (Figure 5).

The pales weevil adult population levels varied between the two counties with the average number of adults per disc higher in Tuscola County (W and K plots) than they were in Genesee County (R and F) (Figure 5). Plots W-1 and W-2 had the most adults of the four plantations. The low adult counts of plots F-2 and F-3 probably resulted from a mid-May application of Lindane[R] by the owner for European pine sawfly (*Neodiprion sertifer* (Geoff.)).

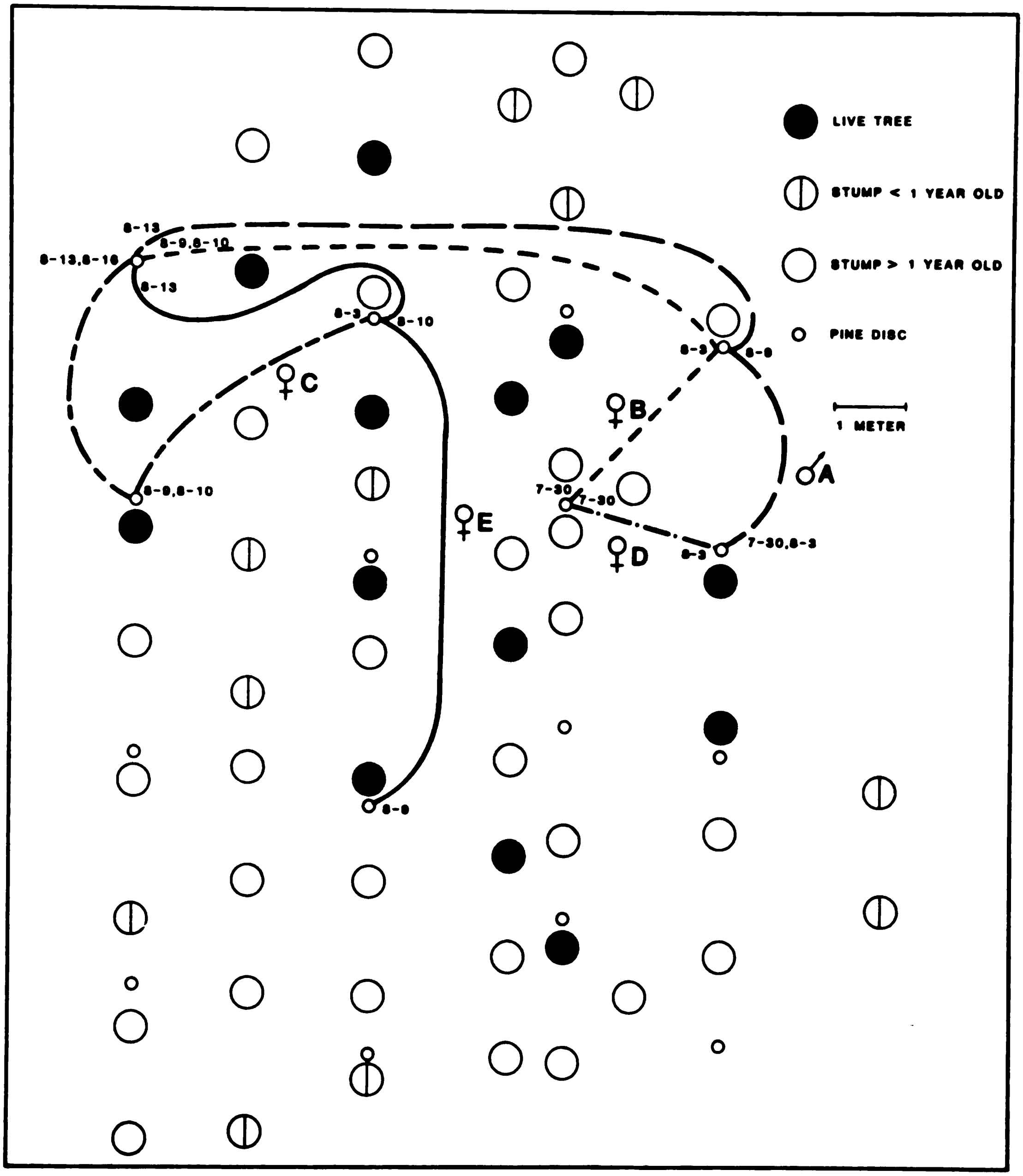

Figure 3. Dates, Capture Points, and Pathways of Five Adults in Plot W-1 During 1979. Pine Discs were Replaced Weekly

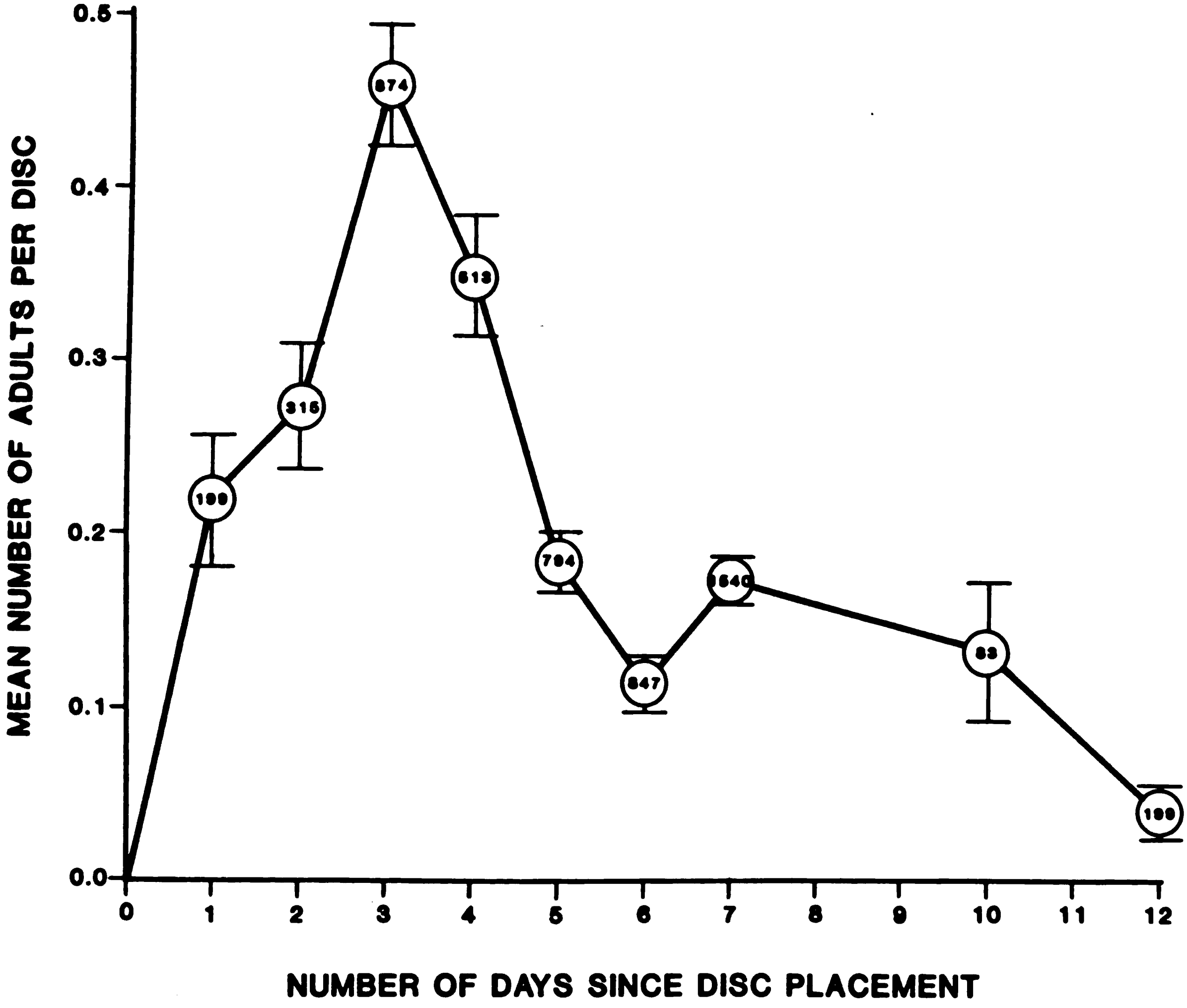

Figure 4. Mean Number of Adults per Disc by the Number of Days Since the Discs were Placed in the Plots. Vertical Bars are One Standard Error Above and Below the Mean. The Number of Discs Used to Determine the Means Varies from 83 to 1540.

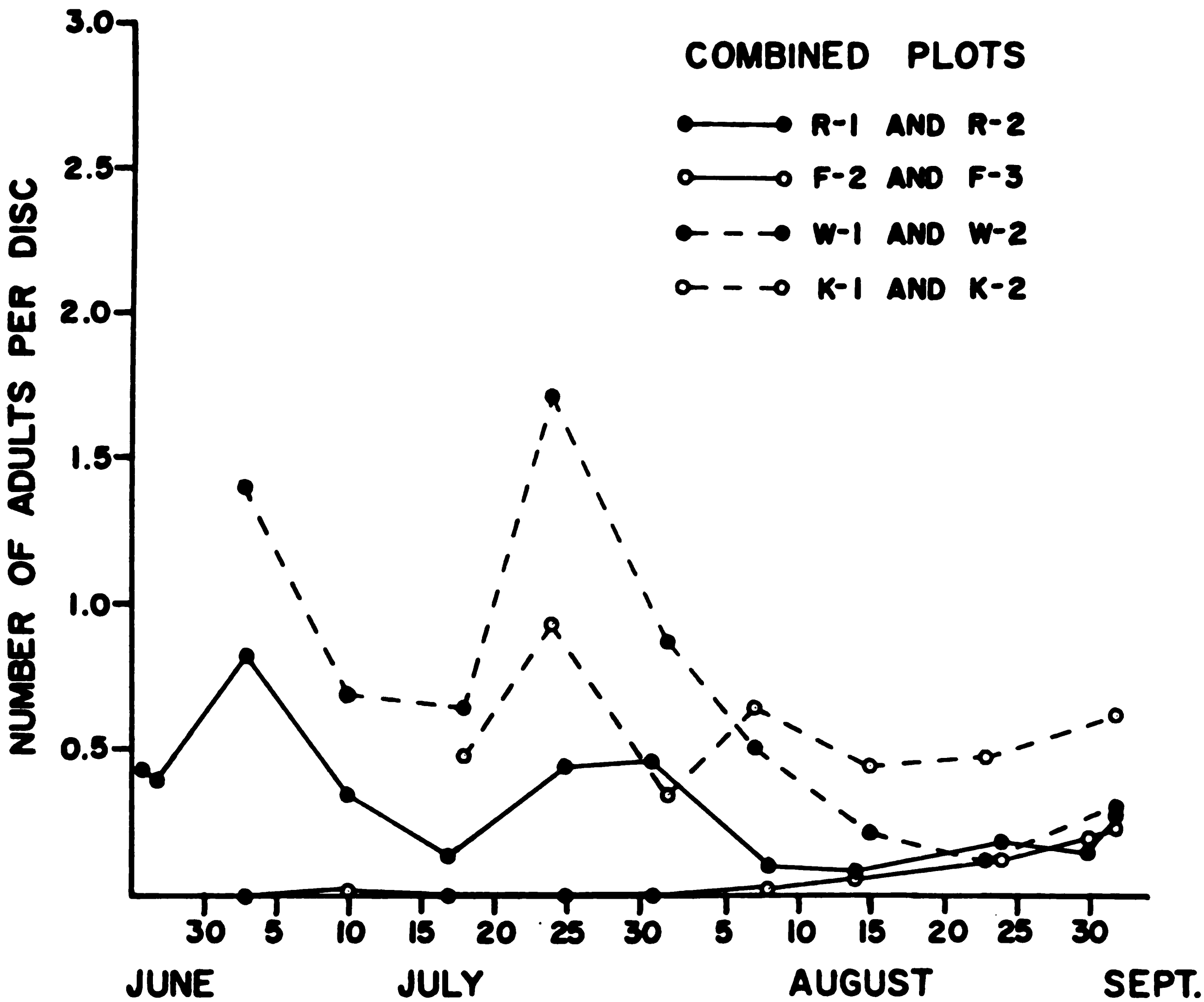

Figure 5. Combined Plot Average Number of Adults Caught Per Disc for Each Plantation During the Summer of 1978

In general, populations were high in early and late July (Figure 5). In the R- and W-plots the average number of adults per disc was high in the first week of July and again in late July. In the W-plots the peak population values on July 3 and July 24 were significantly different (0.01 level) from all other dates except for July 10, 18 and August 1 (Table 3), using Tukey's method of multiple comparisons (Neter and Wasserman, 1974). Likewise, in R-plots the peak in the number of adults per disc on July 3 was significantly different from all other values except for June 26, 27, July 10, 25 and 31. In K-plots data points were not significantly different, but followed a similar trend. The F-plots did not show any peaks, but numbers rose in August.

The number of adults on the trees at night increased exponentially from June until mid-September of 1980, when sampling was stopped (Figure 6A). When temperature at 2200 hours EST was compared to the number of adults captured on the trees there appeared to be a temperature threshold between 15° and 17°C (Figure 6B). At or above the threshold the number of adults per tree varied from 4.4 to 29.0. Below the threshold there was a linear relationship ($y = -4.028 + .458\,x$). The population was highest on September 6 when the temperature was 23.3°C--an exceptionally warm evening.

Discussion

Pales weevil adults, attracted to a Christmas tree plantation, tend to remain in one area throughout that year as long as there are fresh-cut stumps and live trees. Adults are attracted to the volatile oils or resins released by the stumps or freshly cut stem or branches of pine. This olfactory response brings adults to new stumps in the spring where

Table 3. Average Number of Adults per Disc in 1978 for Rumbold, Kimmel and Walk Plantations on the Third or Fourth Day After New Disc Placement

Date		Rumbold	Kimmel	Walk
June	26	0.44 ab *	-	-
	27	0.38 ab	-	-
July	3	0.82 b	-	1.50 ab
	10	0.31 a	-	0.69 cd
	17	0.16 a	-	-
	18	-	0.49 a	0.73 a
	24	-	0.89 a	1.68 bc
	25	0.40 ab	-	-
	31	0.42 ab	-	-
August	1	-	0.40 a	0.88 a
	7	-	0.57 a	0.52 d
	8	0.11 a	-	-
	14	0.08 a	-	-
	15	-	0.51 a	0.23 d
	23	-	0.49 a	0.17 d
	24	0.19 a	-	-
	30	0.16 a	-	-
September	1	0.29 a	0.63 a	0.31 d

*Averages of a plantation followed by the same letter are not significantly different at the .01 level.

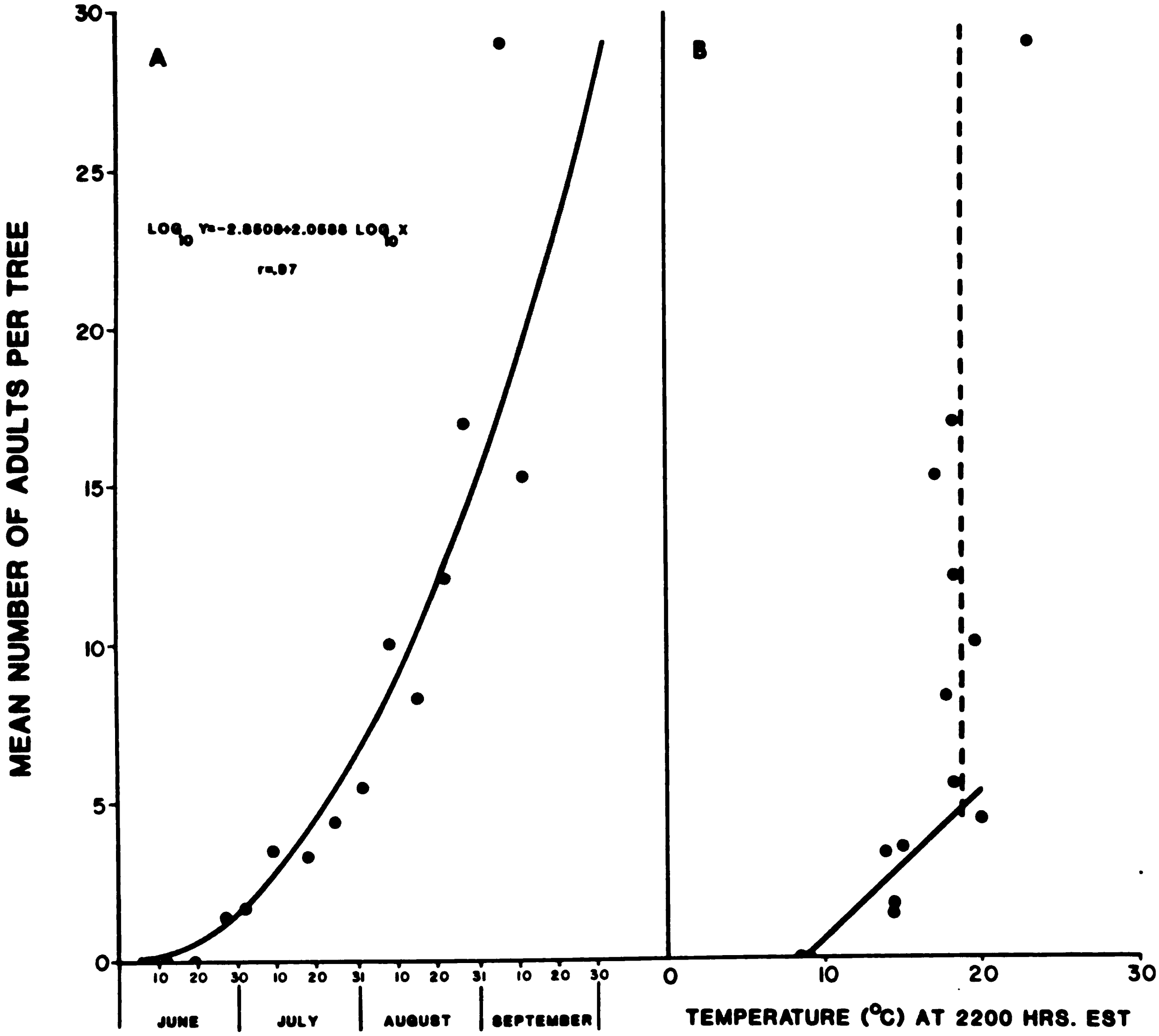

Figure 6. Mean Number of Adults per Tree at Night by Date and Temperature (°C) at 2200 hours EST. Samples were Taken in 1980 at Plot K-1.

they mate and the females oviposit. In June the chemicals diminish and adults are not found around the stumps. If a fresh-cut section of pine, such as a stem disc, is placed on the ground, adults will be attracted to it until it dries out (see Figures 4 and 5). The major problem associated with using pine discs to study adult movements is the influence of the discs on adult behavior. For example, adult females oviposit in the discs for some time after oviposition in the stumps normally ceases. Also, both males and females, attracted to the discs, sometimes remain at a particular site for days or weeks.

The data from adult trapping and marking indicate a fluctuating activity of the population, especially when the data is taken more than four days after the discs were placed. Because of changes in attractiveness even when the adult counts are considered only at the peak of disc attraction, the populations showed a significant (0.01 level) rise in early and late July. Comparison with temperature and precipitation did not show any relationship between these and population changes. This was verified by a meteorologist.[2] The fluctuations could not be accounted for by adult emergence or migration. Adult emergence occurred in the first of August as shown by plots F-2 and F-3 (see Figure 5). All adults found in these plots were callows.

The tree counts, on the other hand, reflected the seasonal change in adult behavior in Christmas tree plantations. As stump attractiveness wears off, the adults move beneath the trees where they remain during

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[2]Donald Haines, Meteorologist, USDA, NCFES, Stephen S. Nisbet Building, 1407 South Harrison Road, East Lansing, Michigan 48824.

the day. On warm evenings, especially when the temperature is above 15°C, they climb the trees to feed on the branches. The exponential population increase throughout the seasons occurs because adults move from the stumps to the trees and are joined by new adults emerging from the stumps.

A practical use of population changes is in the timing of pesticide applications for the control of the pales weevil. In the spring when olfactory response is greatest, pesticides can be applied to the area around the stumps. In the fall, when the number of adults on the trees at night is the highest, pesticides can be applied on the trees by mist blower or hydraulic sprayer. An evening application when temperature is above 17°C would increase control effectiveness, because more adults would be on the trees.

IMPACT OF ADULT FEEDING ON THE MARKETABILITY OF CHRISTMAS TREES

Adult pales weevil feeding can cause unsightly trees with shoot flagging, branch mortality, branch and stem feeding scars and tree-face deformity (Rennels and DeBarr, 1965). This feeding damage is mostly cosmetic and thus reduces the grade of a Christmas tree which lowers its value (Rennels and DeBarr, 1965; Baker, 1972). This study was made to determine the impact of the pales weevil adults on the grade and marketability of Christmas trees.

Methods and Materials

Christmas trees in each permanent plot were graded using the USDA Christmas tree grading scale (USDA, 1975). A Christmas tree was graded as either: 1) premium, the best; 2) choice, second best; 3) standard, third best; or 4) cull, the worst. A tree is graded by the number of good faces, taper and crown density.

A face of a tree is one vertical quarter of a tree's crown. A "good face" is one that is free of defects of any kind, "bad face" has a hole or space in the crown or one or more flagged shoots. A premium tree has to have four good faces, a choice has three good faces, and a standard has any two adjacent good faces. All worse trees are culls. The taper, the width of the crown at the tree base which is expressed as a percent of the height of the crown, is also used in grading. A premium and choice tree has a taper between 40 and 90 percent and a standard has a taper below 40 percent or greater than 90 percent. Crown density varies among tree species and is also used in grading. A medium density crown of one tree species may be more or less dense than a medium density crown of another species. A premium or choice tree has a medium or heavier crown density; standards have less.

Each tree in all plots were graded twice. Trees were graded first as if there was no weevil injury and then again with injury. The feeding impact of the adults was assessed by counting the number of flagged shoots caused by the pales weevil on each tree. Trees were grouped having 0, 1-4, 5-9, 10-19, 20-29, 30-39, 40-49, or 50+ flags.

Results

Tree Grades Excluding Adult Injury

In general, there were few changes in tree grades from spring to fall of 1979 for each plantation (Table 4). The most grade changes occurred in the Rumbold plantation where the percentage of premium trees fell from 23.8 in the spring to 5.4 in the fall. Leniency during initial use of the grading system was the major reason for the high percentage of premium trees in plot R-1. It was the first plot graded in the spring. The other plantations showed a slight increase in the percentage of choice and premium trees from spring to fall of 1979. Trees in the Fras and Kimmel plantations changed the least, whereas trees in the Walk plantation changed the most. Most trees in these plantations were in the same grade category in the fall that they were in the spring (see Appendix Table 8).

Trees left unharvested in the fall of 1979 changed somewhat by the spring of 1980 (Table 4). Trees in the Kimmel and Walk plantations changed the most. The percentage of culls improved by a factor of two, for example, in the W-plots the percentage of cull trees changed from

Table 4. Percent of Total Trees in Each Grade Category When Pales Weevil Adult Injury is Excluded in Grade Determination for Spring and Fall of 1979 and Spring of 1980

	Plantation Plots	Rumbold R-1 %	Fras F-1,2,3 %	Kimmel K-1,2 %	Walk W-1,2 %	All Plots %
Spring 1979	n	168	215	179	83	645
	Cull	13.1	26.1	27.4	22.9	22.6
	Standard	25.6	48.8	44.1	36.1	39.8
	Choice	37.5	18.6	26.8	37.3	28.2
	Premium	23.8	6.5	1.7	3.6	9.3
Fall 1979	n	165	201	179	46	591
	Cull	15.2	25.9	24.6	28.3	22.7
	Standard	46.1	47.3	43.6	26.2	44.2
	Choice	33.3	19.4	28.5	41.3	27.8
	Premium	5.4	7.5	3.3	4.3	5.4
Fall 1979 Trees Unharvested	n	71	153	71	17	312
	Cull	25.4	32.7	43.7	70.6	35.6
	Standard	62.0	51.0	28.2	17.6	46.5
	Choice	11.3	11.8	26.8	11.8	15.1
	Premium	1.4	4.6	1.4	0.0	2.9
Spring 1980	n	71	153	71	17	312
	Cull	26.8	28.3	23.6	35.3	27.2
	Standard	63.4	48.7	50.0	52.9	52.6
	Choice	8.5	18.4	22.2	11.8	16.7
	Premium	1.4	4.6	4.2	0.0	3.5

70.6 in the fall of 1979 to 35.3 in the spring of 1980. This improvement in grades was due to the disappearance of injury from agents other than the pales weevil (i.e., Eucosma sp., frost injury, etc.).

Tree Grades Including Adult Injury

The change in tree grades when injury was included was related to a change in the number of flagged shoots. The percentage of trees having 0 and 1-4 flags was higher and the percentage of trees having more than four flags was lower in the fall of 1979 than in the spring of 1979 (Figure 7). The major exception was in the K-plots where the percentage of trees having more than four flags was higher in the fall than in the previous spring.

Unharvested trees had more flagged shoots in the spring of 1980 than they did in the fall of 1979 (Figure 7). In the spring of 1979 and the spring of 1980, all trees in the W-plots had one or more flags.

In the spring of 1979 the percentage of eastern white pine, Scots pine and Douglas-fir trees without shoot-flags in plots R-1, F-2 and F-3 was 35.5 percent, 59.4 percent and 45.0 percent, respectively (Figure 8). By the fall of 1979 the percentage of flagged eastern white pine decreased more than the other species. After harvest the percentage of trees in each flag-group remained nearly the same. By the spring of 1980 flagging increased from adult feeding the previous fall. Blue spruce which was in plots F-2 and F-3, did not flag during this study.

In the fall of 1979 in all plots except the K-plots, some standard and cull trees from the spring became choice and premium trees (see Appendix Table 9). In the K-plots there were more cull trees and less choice trees in spring. In all plots, there were more premium trees in the fall. The grades of unharvested trees in the F- and R-plots changed

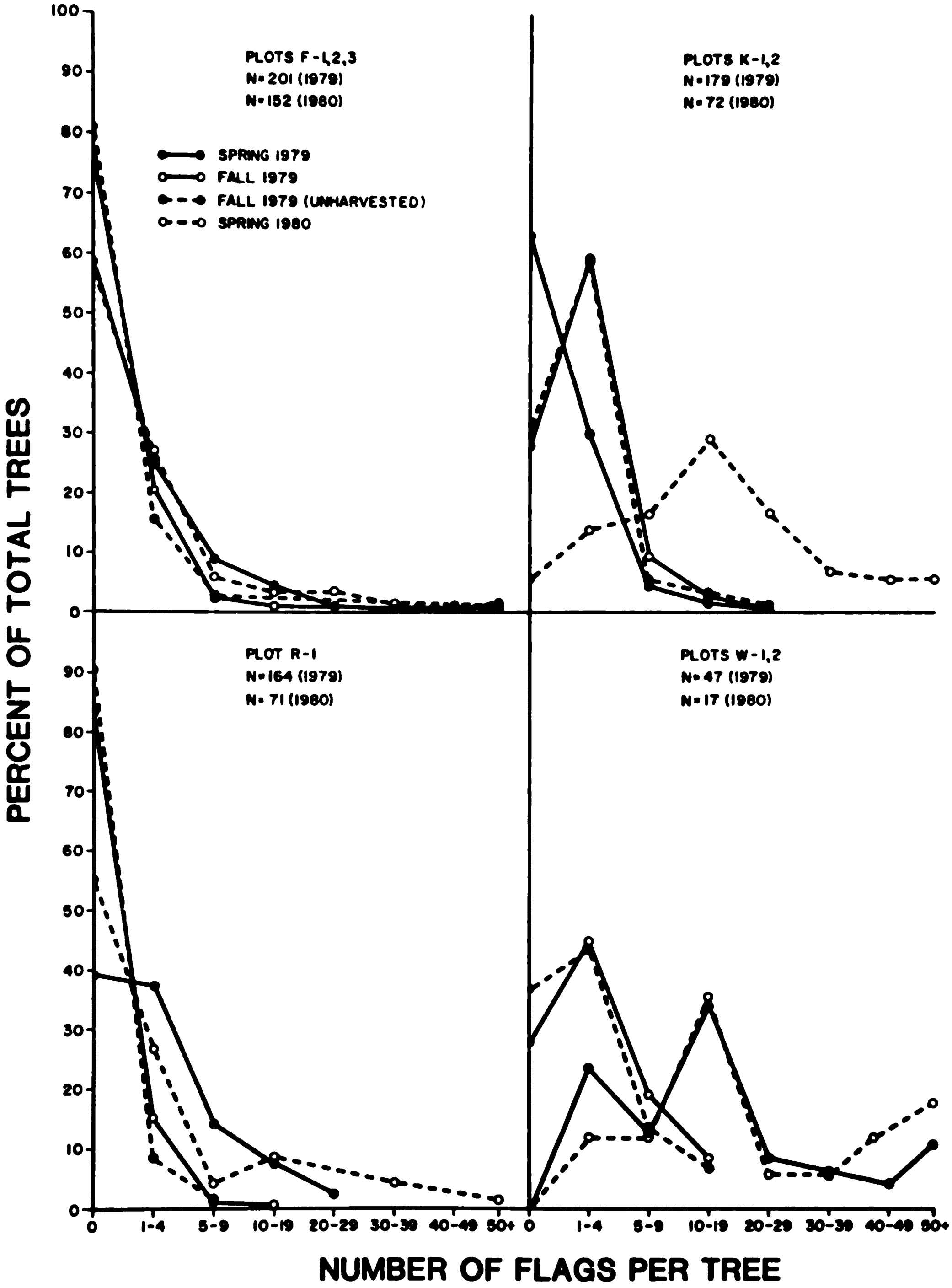

Figure 7. Percent of Trees Within Ranges of Flags per Tree for Each Plantation

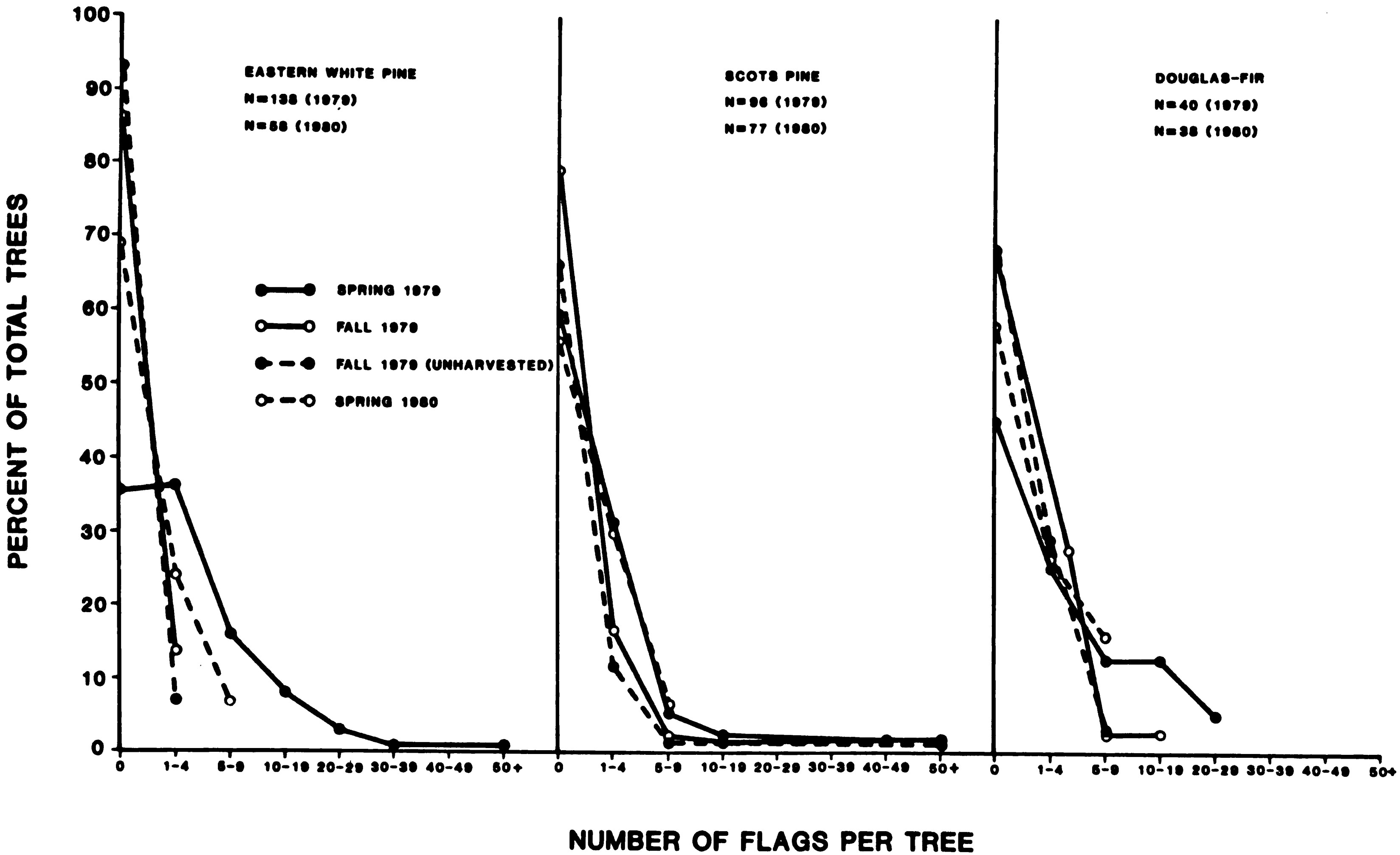

Figure 8. Percent of Eastern White Pine, Scots Pine and Douglas-Fir Trees in Plots R-1, F-2 and F-3 and the Number of Flags per Tree in the Spring and Fall of 1979 and Spring of 1980

Table 5. Percent of Total Trees in Each Grade Category When Pales Weevil Adult Injury is Included in Grade Determination for Spring and Fall of 1979 and Spring of 1980

	Plantation Plots	Rumbold R-1 %	Fras F-1,2,3 %	Kimmel K-1,2 %	Walk W-1,2 %	All Plots %
Spring 1979	n	168	215	179	83	645
	Cull	51.8	42.3	43.0	77.1	49.5
	Standard	32.7	43.7	37.4	19.3	36.0
	Choice	13.1	9.8	19.0	3.6	12.4
	Premium	2.4	4.2	0.6	0.0	2.2
Fall 1979	n	165	201	179	46	591
	Cull	31.5	35.3	53.6	56.5	41.5
	Standard	41.8	42.8	33.5	13.0	37.4
	Choice	22.4	16.4	11.7	28.3	17.6
	Premium	4.2	5.5	1.1	2.2	3.5
Fall 1979 Trees Unharvested	n	71	153	71	17	312
	Cull	46.5	41.2	70.4	88.2	51.6
	Standard	49.3	44.4	16.9	0.0	36.9
	Choice	4.2	10.5	12.7	11.8	9.6
	Premium	0.0	3.9	0.0	0.0	1.9
Spring 1980	n	71	153	71	17	312
	Cull	45.1	50.7	87.5	100.0	60.6
	Standard	45.1	35.5	11.1	0.0	30.1
	Choice	8.5	11.2	1.4	0.0	7.7
	Premium	1.4	2.6	0.0	0.0	1.6

only slightly after winter. The culls increased in all plots, especially in the K- and W-plots. The W-plots had all the trees as cull in the spring of 1980.

Plots R-1, F-2 and F-3, which contained a mixture of tree species, showed differential effects that the pales weevil had on different tree species. In general, eastern white pine exhibited more injury from adult feeding in the spring of 1979 than did Scots pine or Douglas-fir (see Appendix Table 10). By the fall, however, eastern white pine improved in grades more than did the others. Blue spruce in plots F-2 and F-3 was not injured by the weevil. Douglas-fir showed some injury from adult feeding but was injured more by frost.

Grade Comparison

Adult injury reduced the grades of trees in all categories (Table 6). Premium, choice and standard trees decreased with some becoming cull trees. The effect of adult injury on grades was greater for certain plots at certain times than in others. For example, in the W-plots cull trees increased by a differential of 54.2 percent in the spring of 1979 when injury was included. On the other hand, the percentage of culls in the K-plots increased by 15.6. By the fall, the effect of adult feeding decreased in all plots except the K-plots where the difference between culls that excluded and included injury was higher than in the spring.

The effect on the grades of unharvested trees was less than in the spring of 1980 (Table 6). For example, in the W-plots the increase in cull trees when injury was included was 17.6 in the fall of 1979 and 65.7 in the spring of 1980. Again, this increase in cull trees included trees from all of the three other grade categories.

Table 6. Differences in Grade Percentages Between Grades Excluding Adult Injury and Including Adult Injury for Spring and Fall of 1979 and Spring of 1980

	Plantation Plots	Rumbold R-1 %	Fras F-1,2,3 %	Kimmel K-1,2 %	Walk W-1,2 %	All Plots %
Spring 1979	n	168	215	179	83	645
	Cull	+38.7	+16.2	+15.6	+54.2	+26.9
	Standard	+9.1	-5.1	-6.7	-16.8	-3.8
	Choice	-34.4	-8.8	-7.8	-33.7	-15.8
	Premium	-21.4	-2.3	-1.1	-3.6	-7.1
Fall 1979	n	165	201	179	46	591
	Cull	+16.3	+9.4	+29.0	+28.2	+18.8
	Standard	-4.3	-4.5	-10.1	-13.2	-6.8
	Choice	-10.9	-3.0	-16.8	-13.0	-10.2
	Premium	-1.2	-2.0	-2.2	-2.1	-1.9
Fall 1979 Trees Unharvested	n	71	153	71	17	312
	Cull	+21.1	+8.5	+26.7	+17.6	+16.0
	Standard	-12.7	-6.6	-11.3	-17.6	-9.6
	Choice	-7.1	-1.3	-14.1	0.0	-5.5
	Premium	-1.4	-0.7	-1.4	0.0	-1.0
Spring 1980	n	71	153	71	17	312
	Cull	+18.3	+22.4	+63.9	+64.7	+33.4
	Standard	-18.3	-13.2	-38.9	-52.9	-22.5
	Choice	0.0	-7.2	-20.8	-11.8	-9.0
	Premium	0.0	-2.0	-4.2	0.0	-1.9

Harvested versus Unharvested

In most plots the percentage of choice and premium trees that were harvested in 1979 was higher than for the trees unharvested (Table 7). Also, the percentage of cull trees harvested was lower than those that were not. The most culls were harvested from the Kimmel and Walk plantations and the most choice trees were harvested from the Rumbold and Walk plantations. In plot R-1, 46.9 percent of the trees harvested were standard and choice eastern white pines (see Appendix Table 11). The smallest percentage of trees was harvested from the Fras plantation (Table 7).

Discussion

The impact of the pales weevil on the marketability of Christmas trees, as measured by the changes in tree grades and the differences between trees harvested and unharvested, depended upon the time of year, tree species, weevil population and method of harvest.

Tree grades and the impact of the pales weevil varied depending on the time of year that the trees were graded. In the spring and summer, when flagged-shoots form from the previous year's adult feeding, the percent of cull and standard trees was higher. As fall and harvest approached, the flagged needles tended to fall and lessened the impact. For example, there was an increase in cull trees from spring to fall of 1979 in the K-plots while in the other plots there was a decrease in cull trees. Because trees are harvested from the Kimmel plantation and shipped to some of the southern states, they must be harvested in October and early November. The other plantations served mostly a local market and trees were harvested later. This means that the trees in the K-plots had to be graded a month or more before the other plots, and as this was before

Table 7. Percent of Total Trees Harvested and Unharvested for Each Plantation by the Fall of 1979 Tree Grades Including Adult Injury

Plantation (Number of Trees)	Fras (201)		Kimmel (179)		Rumbold (165)		Walk (46)	
	H %	U %	H %	U %	H %	U %	H %	U %
Cull	4.0	31.3	25.7	27.9	11.5	20.0	23.9	32.6
Standard	9.0	33.8	26.8	6.7	20.6	21.2	13.0	4.4
Choice	8.5	8.0	6.7	5.0	20.6	1.8	23.9	0.0
Premium	2.5	3.0	1.1	0.0	4.2	0.0	2.2	0.0
Total	24.0	76.1	60.3	39.6	56.9	43.0	63.0	37.0

H = Harvested

U = Unharvested

many of the brown needles had started to drop, there were more flagged trees than in the other plots (Figure 7). Because of this early harvest, more standard trees were selected than what might have been if harvested later (Table 7).

After harvest in 1979, impact of the pales weevil increased in the spring of 1980. This is a result of new flags forming from adult injury in 1979. Plot R-1 did not show an increase in cull trees over unharvested trees in the fall of 1979. This was due mainly to the high percentage of eastern white pines that were harvested that contributed to the higher impact of the adults in 1979.

The pales weevil had more impact on some tree species than on others. This not only depended on the susceptibility of a tree species to attack, but also on the ability of a tree species to recover before harvest. Of the tree species in this study, blue spruce was the only one that did not show signs of adult feeding. It was planted among species that were more susceptible in plots F-2 and F-3 and perhaps this contributed to the lack of any injury. Among the tree species attacked, eastern white pine improved the most before harvest for it did not retain the dead needles on flagged shoots as long as Scots pine or Douglas-fir. Thus, both in R-1 and in plots F-2 and F-3, the percentage of choice and premium white pine trees available for harvest was higher than Scots pine or Douglas-fir (see Appendix Table 11).

Feeding injury caused by the adults in the fall appeared as flagged shoots the next spring (Corneil and Wilson, 1980). Because of this, the weevil population of the previous year has more impact on the trees than the present year's population. In 1978 the Walk plantation had the highest adult population and also had the highest amount of injury. As would be expected, the impact of the pales weevil was greater in this plantation than in the others. The trees had more flags and there were more culls than in the others, both in 1979 and 1980.

The Kimmel plantation had the second highest population and, except for the spring of 1979, was second in the severity of injury by the adults. A factor that may have reduced the impact of the adults in the spring of 1979 was that harvesting had just begun the previous year in plot K-2 so the amount of injury was less than in plot K-1.

The Rumbold plantation had the third highest population in 1978 but the injury caused by the adults was close to both the Kimmel and Walk plantations. The main reason for this was the mixture of the more susceptible eastern white pine with Scots pine in plot R-1, whereas, the K- and W-plots contained only Scots pine.

In the Fras plantation where the adults were effectively reduced for most of 1978, the impact of the adults was the least of the four plantations. Also, the mixture of eastern white pine, Scots pine, Douglas-fir and blue spruce in plots F-2 and F-3 reduced the impact of the pales weevil on the tree grades to some extent.

There were two different harvest methods among the plantations used in this study. Trees in the Rumbold plantation were selected for harvest by the public, while trees in the other plantations were selected by the owners. In the Fras, Kimmel and Walk plantations a higher percentage of cull and standard trees were harvested. This was especially true in the Kimmel plantation because trees were harvested earlier than in the others. In the Rumbold plantation, most of the trees harvested were standard and choice. Because trees were selected by the public instead of the owner, there appeared to be more selectivity in choosing a tree than when a grower selected them. Therefore, the impact of the pales weevil on the Christmas trees would be greater in plantations using the "choose and cut" harvest method than when grower selected.

The impact of the pales weevil adults on the marketability of Christmas trees varied among the four plantations used in this study. There was a general decrease in injury in the fall in all plantations, however, with early harvest, as in the Kimmel plantation, the impact was greater than when harvest was later. The impact of the adult was also affected by the mixture of tree species. It was lessened when eastern white pine or blue spruce were planted along with Scots pine and increased when Scots pine was planted alone.

The harvest method also affected the impact on the marketability. The "choose and cut" method, as in the Rumbold plantation, tended to increase the impact, whereas, selection by the owner, as in the Fras, Kimmel and Walk plantations allowed the harvest of trees in lower grade categories.

BREEDING PREVENTION TEST

The major source of breeding material for the pales weevil is pine stumps (Peirson, 1921; Finnegan, 1959), although live trees have been reported infested by the weevil in Wisconsin (Goyer, et al., 1971). During the initial stages of this study it was observed that stumps with a few live branches still attached were not used for breeding by the pales weevil. Therefore, this test was done to determine whether or not stumps with live branches intact were resistant to infestation by the pales weevil.

Methods and Materials

In July of 1980, 60 stumps were tagged in the Rumbold plantation, 30 eastern white pine and 30 Scots pine. Half of these stumps had live branches attached, the other half did not. In September, 14 stumps of each species and treatment were removed and taken to the laboratory for dissection. In the lab, the bark was removed from each stump and the number of pales weevil larvae, pupae, adults and empty pupal cells were counted.

In July of 1979, 30 Scots pine stumps were tagged in the Kimmel plantation, again half with live branches. In September the stumps were removed and dissected in the lab. Care was taken to note any signs of oviposition and larval development in stumps with live branches.

Results

Stumps that had live branches at the time of removal did not contain any pales weevils. If the branches died or were never present, heavy infestations of the pales weevil occurred. During the dissection of stumps with live branches, no visible sign of oviposition of larval development was found. One stump without branches was heavily rotted and attacked only by the northern northern pine weevil, Pissodes approximatus Hopkins. Data collected in 1979 from the Kimmel plantation resembled that of the Scots pine in the Rumbold plantation. Close examination of the stumps with live branches did not reveal any signs of oviposition or larval tunneling in the bark.

Number of Insects Found in Seven Stumps with and Seven Without Branches in the Rumbold Plantation from Eastern White Pine and Scots Pine Christmas Trees

With Branches		Without Branches	
White Pine	Scotch Pine	White Pine	Scotch Pine
0	74*	31	9
0	0	21	77
14*	0	32	38
0	0	19	29
0	0	33	0**
0	0	22	50
0	0	8	6

*Branches were dead at the time of removal.
**Stump heavily rotted, with Pissodes approximatus heavy in the upper stump area.

Discussion

As long as branches left on eastern white pine and Scots pine stumps remained alive the pales weevil will not use the stump for breeding. If the branches died or were never left on the stump, then large numbers of insects were found in the stumps. It could not be determined whether or not females oviposited in the stumps with live branches. If they did then apparently the live tissue of the stump possibly prevented egg or larval development in the cambial region. Another possibility is a more rapid "glazing" over of the cut surface, thus reducing the release of attracting chemicals. Immature development was not observed in stumps with live branches or in living trees as reported in Wisconsin (Goyer, et al., 1971).

These findings were supported by the observations of some of the Christmas tree growers that soon after the method of tree reestablishment, called "stump culture," where lower whorl branches were shaped into new trees, was ended, problems with the pales weevil occurred. The reason behind the recommendation against the use of this method was based on the danger of infestation and development of other problems such as Lophodermium needlecast (*Lophodermium pinastri* (Schard. ex Fr.)) and the pine needle scale (*Phenacaspis pinifoliae* (Fitch)) which are heaviest on the lower whorl branches.

CONCLUSIONS AND RECOMMENDATIONS

The survival behavior responses of the pales weevil adults and the seasonal changes in attraction to freshly-cut stumps in Christmas tree plantations in southeastern lower Michigan affect the adult movements within a plantation and the adult population. In the spring when olfactory attraction to the stumps is the strongest, few adults are found on the trees at night. As the attractiveness of the stumps wears off in June, survival behavior responses, similar to those of the pine root collar weevil, become more dominant, and the adults aggregate beneath the trees during the day. During the night, especially when temperature is above 17°C, adults climb the trees in large numbers and feed on the stem, branches and buds of the trees. These seasonal changes in adult locations can be used in the location and timing of pesticide applications. In the spring when adults are immediately around the stumps, pesticides can be applied to the area around the stumps. In the fall, when adults have moved to the trees, pesticides can be applied on the trees by mist blower or hydraulic sprayer. Making evening applications when temperature is above 17°C would increase control effectiveness.

Control of the pales weevil is not always necessary because the impact of the adult on the marketability of Christmas trees varied depending on the time of year, tree species, adult population and method of harvest. Near harvest many of the needles drop off flagged shoots, especially on eastern white pine, reducing the impact of injury on the tree grades. In plantations where the owner selects trees for harvest, the impact of adult injury is also reduced, especially if trees are harvested in November and December. The impact on marketability is greater when trees are harvested by the "choose and cut" method, because of the greater selectivity of the public in choosing a tree for harvest.

Depending on the type of harvest method, the decision for control of the pales weevil should be based on tree appearance in the fall, rather than in the spring or summer. If the value of the trees is still low in the fall, then plans for the removal of or pesticide application to the new stumps should be made for the next spring. If severe damage appears in the summer from the previous year's adult injury, similar injury the next year can be reduced by an evening pesticide application to the trees in the fall. Leaving live branches on the stumps to prevent their use as breeding material can only be recommended if other pest problems that develop on these branches are not present. The live branches can then be used as "tip-ups" to produce new trees, or the stumps can be mechanically destroyed after harvest in the area is completed.

APPENDIX

RESULTS OF TREE GRADING

Table 8. Percent of Trees in Grade Categories Excluding Adult Injury in the Spring and Fall of 1979

Spring 1979 Grades Excluding Adult Injury	Fall 1979 Grades Excluding Adult Injury									
	Plots F-1,2,3 n=201					Plots K-1,2 n=179				
	Cull %	Standard %	Choice %	Premium %	Total %	Cull %	Standard %	Choice %	Premium %	Total %
Cull	21.4	3.5	0.0	0.0	24.9	14.5	8.4	3.9	0.6	27.4
Standard	4.5	40.8	4.0	0.5	49.8	8.4	27.4	8.4	0.0	44.1
Choice	0.0	3.0	14.9	1.5	19.4	1.7	7.8	15.1	2.2	26.8
Premium	0.0	0.0	0.5	5.5	6.0	0.0	0.0	1.1	0.6	1.7
Total	25.9	47.3	19.4	7.4	100.0	24.6	43.6	28.5	3.3	100.0
	Plot R-1 n=164					Plots W-1,2 n=47				
	Cull	Standard	Choice	Premium	Total	Cull	Standard	Choice	Premium	Total
Cull	8.5	4.9	0.0	0.0	13.4	21.3	6.4	2.1	0.0	29.8
Standard	4.3	20.1	1.2	0.6	26.2	6.4	14.9	4.3	0.0	25.5
Choice	2.4	15.2	18.9	0.6	37.2	2.1	4.3	34.0	0.0	40.4
Premium	0.0	6.1	12.8	4.3	23.2	0.0	0.0	0.0	4.3	4.3
Total	15.2	46.3	32.9	5.5	100.0	29.8	25.5	40.4	4.3	100.0

Table 9. Percent of Trees in Grade Categories Including Adult Injury in the Spring and Fall of 1979

Spring 1979 Grades Including Adult Injury	Fall 1979 Grades Including Adult Injury									
	Plots F-1,2,3 n=201					Plots K-1,2 n=179				
	Cull %	Standard %	Choice %	Premium %	Total %	Cull %	Standard %	Choice %	Premium %	Total %
Cull	31.3	7.0	3.0	0.5	41.8	31.8	9.0	2.2	0.0	43.0
Standard	4.0	33.3	6.0	1.0	44.3	16.8	17.3	2.8	0.6	37.4
Choice	0.0	2.5	7.5	0.5	10.5	5.0	7.3	6.1	0.6	19.0
Premium	0.0	0.0	0.0	3.5	3.5	0.0	0.0	0.6	0.0	0.6
Total	35.3	42.8	16.4	5.5	100.0	53.6	33.5	11.7	1.2	100.0
	Plot R-1 n=164					Plots W-1,2 n=46				
	Cull	Standard	Choice	Premium	Total	Cull	Standard	Choice	Premium	Total
Cull	24.4	16.5	11.0	0.6	52.4	56.5	8.7	10.9	2.2	78.3
Standard	4.9	21.3	4.9	1.2	32.3	0.0	4.4	13.0	0.0	17.4
Choice	2.4	3.1	5.5	1.8	12.8	0.0	0.0	4.4	0.0	4.4
Premium	0.0	0.0	1.8	0.6	2.4	0.0	0.0	0.0	0.0	0.0
Total	31.7	40.9	23.2	4.3	100.0	56.5	13.0	28.3	2.2	100.0

Table 10. Percent of Total Trees for Plots R-1, F-2 and F-3 of Each Tree Species in Grade Categories Excluding and Including Adult Injury by Season and Year Graded

Plot		R-1				F-2 and F-3							
Tree Species		E. White Pine		Scots Pine		E. White Pine		Scots Pine		Blue Spruce		Douglas-Fir	
Grade		E	I	E	I	E	I	E	I	E	I	E	I
Spring 1979	Number of Trees	134		34		8		72		17		42	
	Cull	9.0	53.0	29.4	47.1	25.0	87.5	20.8	36.1	29.4	29.4	52.4	69.0
	Standard	20.1	29.9	47.1	44.1	37.5	12.5	59.7	55.6	41.2	41.2	42.9	31.0
	Choice	41.0	14.2	23.5	8.8	25.1	0.0	15.3	6.9	17.6	17.6	2.4	0.0
	Premium	29.9	3.0	0.0	0.0	12.5	0.0	4.2	2.8	11.8	11.8	2.4	0.0
Fall 1979	Number of Trees	130		34		8		62		15		40	
	Cull	15.4	33.1	14.7	26.5	25.0	50.0	24.2	32.3	26.7	26.7	60.0	67.5
	Standard	40.0	36.2	67.6	61.8	37.5	25.0	58.0	54.8	33.3	33.3	37.5	32.5
	Choice	38.5	26.2	14.7	8.8	25.0	12.5	16.1	11.3	20.0	20.0	2.5	0.0
	Premium	6.2	4.6	2.9	2.9	12.5	12.5	1.6	1.6	20.0	20.0	0.0	0.0
Fall 1979 (Trees Unharvested)	Number of Trees	53		18		5		59		13		38	
	Cull	28.3	54.7	16.7	22.2	40.0	60.0	23.7	30.5	30.8	30.8	61.5	66.7
	Standard	56.6	41.5	77.8	72.2	60.0	40.0	57.5	55.9	30.8	30.8	38.5	33.3
	Choice	13.2	3.8	5.6	5.6	0.0	0.0	16.9	11.9	15.4	15.4	0.0	0.0
	Premium	1.9	0.0	0.0	0.0	0.0	0.0	1.7	1.7	23.1	23.1	0.0	0.0
Spring 1980	Number of Trees	53		18		5		59		13		38	
	Cull	26.4	37.7	27.8	66.7	40.0	40.0	20.3	35.6	23.1	23.1	55.3	73.7
	Standard	60.4	49.1	72.2	33.3	60.0	60.0	52.5	45.8	30.8	30.8	44.7	26.3
	Choice	11.3	11.3	0.0	0.0	0.0	0.0	25.4	18.6	23.1	23.1	0.0	0.0
	Premium	1.9	1.9	0.0	0.0	0.0	0.0	1.7	0.0	23.1	23.1	0.0	0.0

E = grades excluding adult injury

I = grades including adult injury

Table 11. Percent of Total Trees Harvested and Unharvested for Plots R-1, F-2 and F-3 by Tree Species and Grade Excluding and Including Adult Injury in the Fall of 1979

	Plot	R-1				F-2 and F-3							
	Tree Species	E. White Pine		Scots Pine		E. White Pine		Scots Pine		Blue Spruce		Douglas-Fir	
		H	U	H	U	H	U	H	U	H	U	H	U
Grades Excluding Adult Injury	Number of Trees	130		34		8		62		15		40	
	Cull	3.8	11.5	5.9	8.8	0.0	25.0	1.6	22.6	0.0	26.7	0.0	60.0
	Standard	16.9	23.1	26.5	41.2	0.0	37.5	3.2	54.8	6.7	26.7	0.0	37.5
	Choice	33.1	5.4	11.8	2.9	25.0	0.0	0.0	16.1	6.7	13.2	2.5	0.0
	Premium	5.4	0.8	2.9	0.0	12.5	0.0	0.0	1.6	0.0	20.0	0.0	0.0
	Total	59.2	40.8	47.1	52.9	37.5	62.5	4.8	95.2	13.4	86.6	2.5	97.5
Grades Including Adult Injury	Number of Trees	130		34		8		62		15		40	
	Cull	10.8	22.3	14.7	11.8	12.5	37.5	3.2	29.0	0.0	26.7	2.5	65.0
	Standard	19.2	16.9	23.5	38.2	0.0	25.0	1.6	53.2	6.7	26.7	0.0	32.5
	Choice	24.6	1.5	5.9	2.9	12.5	0.0	0.0	11.3	6.7	13.2	0.0	0.0
	Premium	4.6	0.0	2.9	0.0	12.5	0.0	0.0	1.6	0.0	20.0	0.0	0.0
	Total	59.2	40.8	47.1	52.9	37.4	62.5	4.8	95.2	13.4	86.6	2.5	97.5

H = Harvested

U = Unharvested

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