THE EFFECT OF POTASSIUM FERTILIZATION ON PALES WEEVIL

by

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ABSTRACT

The objective of this study was to determine the effect of potassium fertilizer on pales weevil (*Hylobius pales*, Herbst.) feeding. To accomplish this goal two species of pine seedlings, loblolly pine (*Pinus taeda*, L.) and slash pine (*Pinus elliottii*, Engelm.), were treated with four different fertilizer solutions with potassium concentrations of 0 ppm, 325 ppm and 430 ppm. Four seedlings, one from each of the four fertilizer treatments, and eight weevils were included in each replication of the experiment. Seedlings were exposed to weevil feeding for a two week period followed by evaluation of feeding damage which was measured in two ways: (1) an estimation of phloem tissue damage and (2) a pressure bomb determination of seedling stress. Also, the potassium content of the seedlings was determined by atomic absorption spectrophotometry. Foliar analysis revealed significant differences in potassium content did exist between treatments, but only small decreases in phloem tissue damage occurred with increased potassium content. Results from the pressure bomb measurement were highly variable and of little value.

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INTRODUCTION

Pales weevil, (*Hylobius pales*, Herbst.) has become a serious insect pest of pine seedlings on regeneration sites in the South. The increased demand for forest products has brought about shorter crop rotations, and planting of high value, genetically improved seedlings has created a need for an effective pest management plan.

The purpose of this study was to determine whether potassium fertilizer, in the form of potassium chloride, could serve as a deterrent to pales weevil feeding and increase seedling survival, thus making application of potassium at planting a possible part of a pest management plan.

This thesis was written in the format and style of *Forest Science*.

LITERATURE REVIEW

Pales Weevil

Life History

The life history of pales weevil has been studied extensively throughout its range, which covers the eastern half of North America from Texas to Canada (Speers, 1958). Pierson (1921) did the first in-depth studies on pales weevil life history, and found that the adult weevils overwintered in the soil and emerged from hibernation in April. Finnegan (1959) later found that a secondary population existed, which overwintered as fifth and sixth instar larvae, and that up to thirty percent of the total population on a given area may overwinter in this form. This secondary population lags behind the major population since adults only emerge in late June or early July. Subsequent studies showed the same results throughout the range of pales weevil and suggested that having populations overwintering in two developmental stages was a possible survival mechanism insuring perpetuation of the species should one overwintering stage be destroyed (Bliss and Kearby, 1970).

Following emergence, which varies approximately one month from the northern to the southern portion of their range (Bullard and Fox, 1969), pales weevils enter into a short feeding period followed by mating and egg laying.

Feeding usually occurs in the same area as hibernation and lasts approximately two to three weeks. The weevils leave the feeding area and move to more recently harvested areas for mating and laying eggs. Bullard and Fox (1969) showed weevils traveled approximately two miles to reach breeding areas, but were capable of traveling much greater distances.

Upon arrival at recently cut or disturbed pine areas weevils mate, and the females lay their eggs in the inner bark of the roots of fresh pine stumps. The larvae hatch from late May to early July and begin feeding on the phloem tissue of the dead pine stumps. Pupation begins in mid July or early August and the adults begin emerging in early to mid August (Bliss and Kearby, 1970).

The secondary population which overwinter as larvae, begins emerging as adults in late June or early July. This second emergence seems to have no effect on the population size, suggesting that the weevils survive approximately nine months in the field (Bullard and Fox, 1969).

Feeding Habits and Host Species

Adult pales weevils feed on the phloem tissue of seedling stems and on the lateral branches of more mature pines. Thomas and White (1972) found that the sucrose component of loblolly pine (*Pinus taeda*, L.) was preferred by the weevils over glucose and fructose, and that the total lipid extract of loblolly phloem also produced significant feeding when compared to fractions of it. Further study of this lipid extract showed that a group of compounds within the neutral lipids of loblolly pine phloem also produced significant feeding responses (Thomas, 1972).

Feeding activity peaks at two periods during the year; first in the spring of the year following emergence from hibernation, and second in the fall before hibernation. The heaviest and most concentrated feeding is in the spring, when newly planted pine seedlings are destroyed. The weevils are almost omnivorous in respect to conifers, being able to feed on most coniferous species throughout their range. Taylor and Franklin (1970) showed the weevils exhibited a preference for loblolly pine, with shortleaf pine (*Pinus echinata*, Mill.) being the second most preferred species of the southern pines. Of the northern species Eastern white pine (*Pinus strobus*, L.) was most preferred by the weevils, but the greatest damage occurred on Christmas tree plantations of scotch pine (*Pinus sylvestris*, L.).

Overall, the damage done by pales weevils is most severe when breeding material, fresh stumps and underground slash, is near newly planted pine sites. Christmas tree plantations often suffer severe damage because each year trees are removed and new seedlings planted nearby. In the South the southern pine beetle (*Dendroctonus frontalis*, Zimm) kills large areas of older loblolly pine stands which provides areas for weevil breeding. Damage to seedlings, which occupy the openings provided by the beetle, occurs when the weevils emerge and start feeding (Beal and McClintock, 1945). Hill and Fox (1972) showed that this relationship also held for trees attacked by the black turpentine beetle (Dedroctonus terebrans, Oliv.).

Control Methods

Several possibilities exist for the control of pales weevil by stand manipulation. The most widely practiced control is to allow clearcut areas to remain unplanted for eighteen to twenty-four months or until the weevils have completed a life cycle and leave the areas. The biggest problem with this method is competing vegetation. By allowing the stand to remain unplanted for a long period of time hardwoods and other vegetation on the site gain a competitive advantage. Not only does this slow growth when the pine seedlings are planted, but an added loss in tree growth, due to delayed planting, is also incurred (Walstad, Hart and Cade, 1973).

A second possibility is the use of natural regeneration. By cutting during a good seed year or thinning to stimulate seed production a large number of seedlings can be established, so weevils can destroy some seedlings and still enough survive for regeneration of the stand (Speers, 1958).

At present, there seems to be some conflict about the third method, that of burning logging debris to remove the breeding sites. Speers (1958) reported that burning cutover areas has no effect on reducing their attractiveness to pales weevils, while Fox and Hill (1973) reported that burning reduced attractiveness to pales weevil but it also increased an area's attractiveness to the pitch eating weevil, Pachylobius picivorus (German).

Efforts in the area of biological control of pales weevil have centered around two species of fungi, the white muscardine fungus (Beaveria bassiana) and the green muscudine fungus (Metarrhizium anisopliae). Both occur naturally in weevil populations, where under normal conditions they infect about fifteen percent of the population (Taylor and Franklin, 1973). Walstad and Anderson (1971) found that the fungi were one hundred percent effective in killing field-caged weevils at a concentration equivalent to eighty pounds of spore per acre, but concluded that this method is not economically feasible at present due to the high cost of spore production.

At present Carbofuran is the most widely used insecticide against pales weevils. Walstad, et. al. (1973) reported that the use of Carbofuran, a systemic insecticide, in a kerosene and clay root dip mixture protected seedlings for five weeks after planting. They reported the method was also good for protecting the workers who handled the seedlings, but that the low persistance allowed weevils to do a great deal of damage in their fall feeding period.

Thomas and Bradley (1975) recently conducted a study on twenty-eight compounds as possible feeding deterrents to pales weevil. They suggested that results on carbanyl and two other carbamates, banomyl and mexacarbate, warranted field testing. No fertilizers were tested for their effect on the weevils.

Potassium's Effect on Forest Insects

The use of fertilizers to reduce insect damage on trees has received a great deal of attention over the past decade. Most research has dealt with nitrogen fertilizer effects on insect populations, because of its known effect on tree growth. Generally, these studies have shown that nitrogen reduces insect damage in addition to increasing tree growth (Stark, 1965), but exceptions do exist.

Aphids have been found to increase in population with the addition of nitrogen. According to Mitchell and Paul (1974) fertilization with nitrogen compounds at rates of fifty and two hundred pounds per acre increased the fecundity of Cooley spruce gall aphids (*Adleges cooleyi*, Gillete) by eleven to forty-two percent over untreated trees. Two years following fertilization aphid populations on treated and untreated Douglas fir trees (*Psuedotsuga menziesii*, Franco) were essentially the same.

The effects of potassium fertilizers on insects have only been studied a small amount in the past because they generally do not influence tree volume growth. Several studies have shown that insect populations are affected by the addition of potassium to the host tree.

Brüning (1967) found that the addition of potassium along with other fertilizers significantly reduced scale (Eulecanium corni, Bch.) infestations on black locust trees (Robinia psuedoacacia, L.). The birch leaf miner (Fenusa pusilla, Lep.) is affected by application of nitrogen, phosphorus and potassium (Juillet, 1967). First generation larval populations increased on treated trees after the initial fertilizer applications, but second and third generation populations decreased, and the decrease was proportional to increases in fertilizer rates.

Other work by Nef (1967) and later by Prichett and Smith (1972) has shown that fertilization with potassium reduced pine tip moth (Rhyconia spp.) damage in young pine plantations.

METHODS AND MATERIALS

Location

The study was conducted in a partially shaded, well ventilated greenhouse on two species of pine seedlings, slash pine (*Pinus elliottii*, Engelm) and loblolly pine. Greenhouse temperature and humidity varied throughout the study period, although heating was provided during the winter months. The study extended over a 24 week period beginning October 22, 1977 and ending March 25, 1978.

Seedling Growth and Fertilizer Treatment

Seedlings were six months old when acquired for the study, and had been grown in styrofoam blocks, having holes 3.8 cm in diameter and 15 cm deep, in a mixture of peat and vermiculite. Water was added as needed.

Fifty seedlings of each species were transplanted from the blocks to pots, 20.3 cm in diameter, containing a 3:1 mixture by volume of sand to perlite. Five hundred milliliters of distilled water were added to each pot directly after transplanting and once each week for three weeks prior to the first fertilizer application.

Four fertilizer treatments were used containing different concentrations of nitrogen applied in the form of ammonium nitrate, phosphorus in the form of superphosphate, and potassium in the form of potassium chloride. The treatment concentrations were as follows:

a) Treatment I contained 70 ppm nitrogen, 70 ppm phosphorus and no potassium,

b) Treatment II contained 320 ppm nitrogen, 320 ppm phosphorus and no potassium,

c) Treatment III contained the same concentration of nitrogen and phosphorus as Treatment II, and 325 ppm potassium, and

d) Treatment IV contained 320 ppm nitrogen and phosphorus, and 430 ppm potassium.

Also, the minor nutrients magnesium (20 ppm), calcium (50 ppm) and iron (20 ppm) were added to each seedling for a five week period starting the tenth week of the study. A summary of the fertilizer treatments and period of application can be found in Table 1 (pg. 11).

Fertilizers were applied in solution at a rate of 50 ml per week for twenty weeks. During the first ten weeks of this period 500 ml of distilled water were added to each pot approximately one half hour before the fertilizer solution was added. During the second ten weeks another 500 ml of water were added three days after the first.

Fertilizer treatments were replicated twelve times for each species. Of these twelve replications six were randomly chosen for testing with pales weevils.

Table 1. A summary of fertilizer treatments by element, concentration, and period of application.

Element Applied	Concentration (ppm)	Treatment				Period Applied
		I	II	III	IV	
K	0	X	X			October 22 to March 5
	325			X		
	430				X	
N	70	X				
	320		X	X	X	
P	70	X				
	320		X	X	X	
Mg	20	X	X	X	X	December 25 to January 22
Ca	50	X	X	X	X	
Fe	20	X	X	X	X	

Foliar Analysis for Potassium

The foilage of each seedling was analyzed by atomic absorption spectrophotometry to determine the effectiveness of fertilizer treatments. To prepare the samples for analysis the foilage was removed from each seedling and oven dried for a period of 48 hours. Afterwards the samples were ground and placed in the oven for twelve more hours. Following the second drying period 0.5 g of each sample were mixed with 20 ml of 1:1 nitric to perchloric acid solution, and boiled at 120^{o}C until all organic material and nitric acid was removed. The remaining perchloric acid and foilage minerals were diluted with 25 ml of deionized water and filtered into 100 ml volumetric flasks. The flasks were brought to an equal volume (100 ml) with deionized water. Finally, 1 ml was removed from the flask and diluted with 10 ml of .554% strontium solution. Readings were taken from this solution with an atomic absorption spectrophotometer (Perkins-Elmer, 1968).

Weevil Collection and Testing

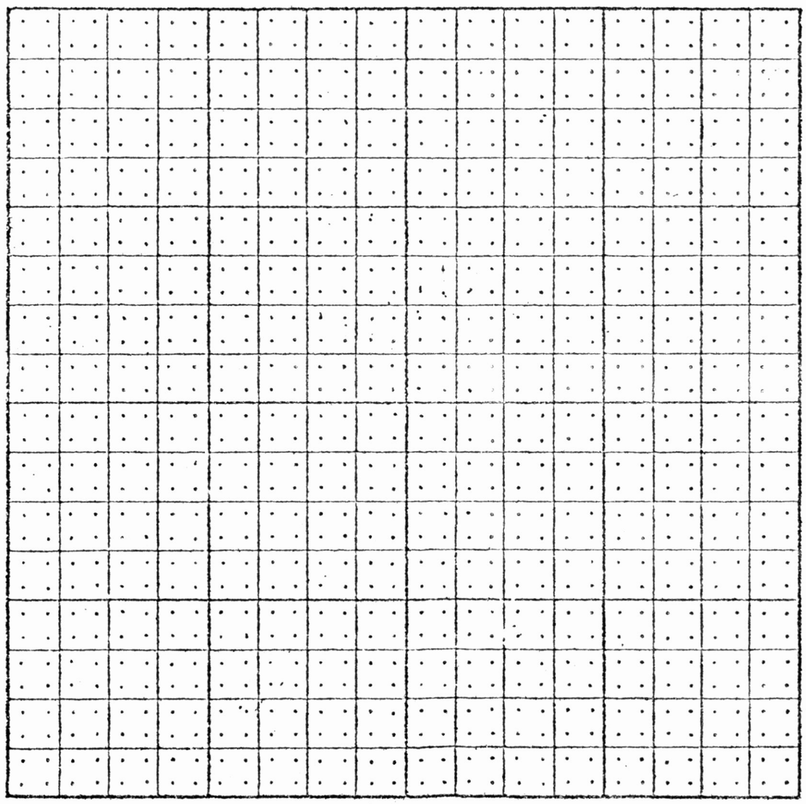
The weevils used in the experiment were collected March 12, 1978 on a clearcut area near Alto, Texas. Collections were made using freshly cut pine disks laid on bare mineral soil throughout the clearcut area (Ciesla and Franklin, 1965). Following collection the weevils were placed in cages, each containing four seedlings. A total of twelve cages were constructed of fine wire screen 76 cm wide. Each cage consisted of a 1.5 m piece of screen made into a cylinder 45.7 cm in diameter with the seam stapled to a thin strip of plywood. Circular pieces of screen were cut and stapled to the cylinders to form the top. The bottoms were stapled to a 1.2 m by 2.4 m sheet of plywood after the weevils were placed in the cages.

Each cage contained four seedlings, one from each of the four fertilizer treatments, and eight weevils. A total of twelve cages were constructed to enclose six replicates of the experiment for each species of pine seedling. Weevil feeding extended over a two week period starting March 12 and ending March 26.

Two methods were used to evaluate weevil feeding and its effect on plant vigor. First, a Scholander pressure bomb (Scholander et. al., 1965) was used to measure the effect of weevil feeding on seedling water relations, and second, a percentage estimation was made of the amount of bark and phloem tissue removed from seedlings by the weevils.

To measure the effect of weevil feeding on tree vigor two pressure readings were taken on each seedling with a Scholander pressure bomb. The first measurements were made in the morning two days after watering and four days prior to the start of the two week weevil feeding period. Measurements were made by cutting a needle from a seedling and securing it in the pressure bomb with the cut end up. Pressurized nitrogen gas was used to increase the bomb pressure until a bubble was formed on the cut end of the needle by nitrogen gas and needle sap. At this point a pressure reading was taken. This procedure was followed twice for each seedling and an average of the two was used as the first reading. The second measurements were made in the same way, in the morning three days after the weevils were removed from the cages and two days after watering. The differences between before and after measurements were used as an indication of a change in tree water relations with a large increase in pressure denoting a decrease in tree vigor.

The second measurement of weevil feeding was an estimate of the amount of bark removed from the seedlings. Typically, pales weevils feed by removing small patches of bark from the stem of a seedling and consume the phloem tissue beneath it. To estimate the feeding damage an acreage dot grid (see Figure 1, pg. 15) designed for measuring map areas, was laid over the seedlings and a count was made of the total number of dots falling on the stem, and of those dots falling only on feeding damage. A feeding damage percent was calculated by dividing the damage area count by the total count. Two counts were



MODIFIED ACREAGE GRID

(64 dots per square inch.)

To be used for acreage determinations on maps of any scale.

Place grid over area to be measured; count dots, multiply by converting factor to compute total acreage. When dots fall on area boundary count alternate dots.

Figure 1. A copy of a modified acreage dot grid (real grid is transparent).

made for each seedling by turning the stem 180^{o} following the first count. The average of the two was used as the total feeding percent for a seedling.

RESULTS AND DISCUSSION

Statistical analysis of the data was done with Duncan's multiple range test (α = .05). Those means which were found statistically significant by Duncan's method were compared further by analysis of variance for a one way classification (α = .05). The results of this procedure are summarized in Table 2 (pg. 18) for loblolly pine and Table 3 (pg. 19) for slash pine.

Fertilization with potassium chloride did have a significant effect on the foliar potassium content of both species. Significant differences for loblolly pine occurred between the mean foliar potassium content of Treatments II (no potassium added) and III (325 ppm potassium), and between Treatments II and IV (430 ppm potassium). For slash pine statistical differences only occurred between Treatments II and IV. Seedlings of both species exhibited a relatively high potassium content probably due to the initial six month growing period in peat and vermiculite, which generally contains a much higher level of potassium than most forest soils.

The amount of weevil feeding estimated by use of an acreage dot grid, was not significantly reduced by the addition of potassium chloride to the seedling. Loblolly pine, and to a smaller extent slash pine, did exhibit a general decrease in mean feeding damage with

Table 2. A comparison of means for foliar potassium content, feeding damage, seedling stress change, and seedling height for loblolly pine. Numbers in parentheses are standard deviations.

	TREATMENT			
	I	II	III	IV
Foliar K[1] Content (Mg/g)	5332.7 (1396.2)	4245.6[a,b] (2132.3)	6506.8[a] (1219.7)	6207.0[b] (574.7)
Feeding Damage (%)	19.1 (19.9)	19.4 (11.3)	13.3 (12.4)	12.3 (7.1)
Seedling[2] Stress Change (Atm.)	3.06 (3.03)	1.19 (1.17)	1.00 (0.80)	0.17 (1.96)
Final Seedling Height (cm)	23.7 (4.23)	25.8 (6.65)	28.5 (2.39)	26.75 (4.86)

[1]Means with the same letter are significantly different using Duncan's multiple range test (α = .05) and analysis of variance for a one way classification (α = .05).

[2]As measured with a pressure bomb. Numbers represent mean pressure change between first and second readings.

Table 3. A comparison of means for foliar potassium content, feeding damage, seedling stress change, and seedling height for slash pine. Numbers in parentheses are standard deviations.

	TREATMENT			
	I	II	III	IV
Foliar K[1] Content (mg/g)	6486.8 (814.8)	5607.5[a] (1597.0)	6866.5 (2505.8)	8585.3[a] (1833.8)
Feeding Damage (%)	25.3 (18.4)	23.6 (8.9)	23.4 (16.8)	20.4 (9.8)
Seedling[2] Stress Change (Atm.)	1.24 (2.33)	1.02 (0.96)	0.00 (1.82)	1.36 (1.47)
Final Seedling Height (cm)	29.3 (1.99)	27.7 (1.37)	28.4 (3.37)	29.8 (3.42)

[1]Means with the same letter are significantly different using Duncan's multiple range test ($\alpha = .05$) and analysis of variance for a one way classification ($\alpha = .05$).

[2]As measured with a pressure bomb. Numbers represent mean pressure change between first and second readings.

increasing potassium content of the foilage (see Figure 2, pg. 21). Also, no relationship was noticed between the size of the seedlings and the amount of feeding damage that occurred.

Use of the pressure bomb as an evaluation of tree stress due to weevil feeding was not effective, possibly due to the small sample size, and the amount of time between pressure measurements. A larger sample size and an extra two to three weeks between measurements might have reduced some of the variation within treatments.

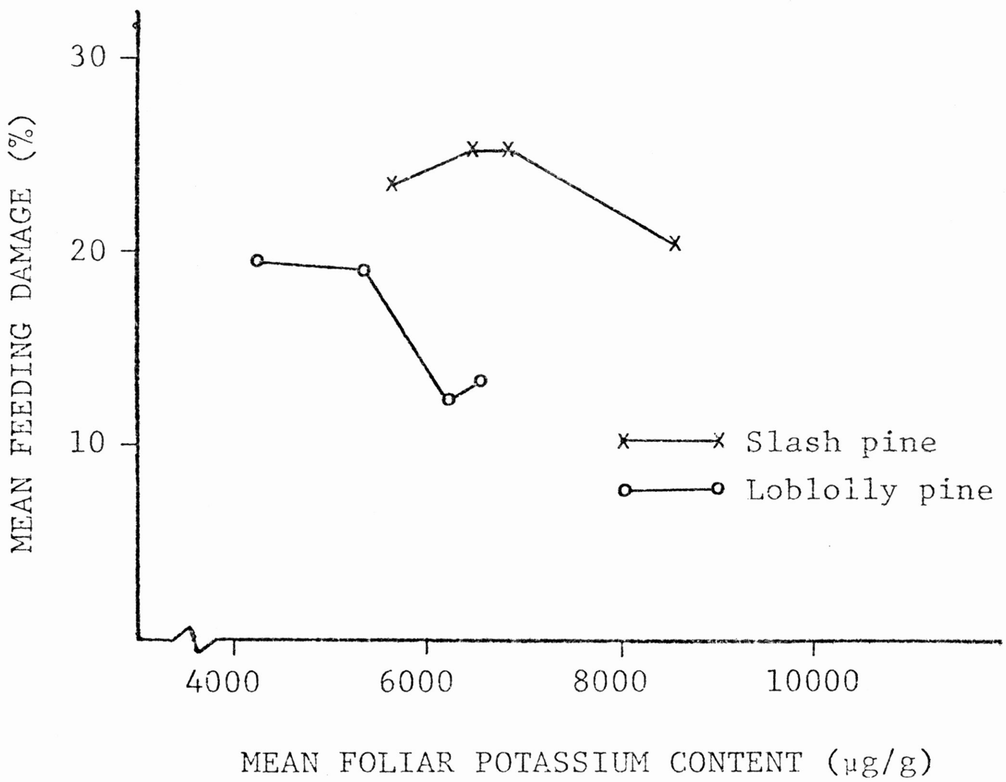


Figure 2. A graph showing the reduction in feeding damage that occurred with increasing potassium content of the seedlings.

CONCLUSION

Potassium content of the seedlings did influence the amount of feeding damage done by pales weevils as shown in Figure 2 (pg. 21). This decrease in feeding may have been caused by a general increase in plant vigor with the addition of potassium, although potassium apparently had no effect on the height of either loblolly (Table 2, pg. 18) or slash pine (Table 3, pg. 19). This later observation is consistent with those made by Prichett and Smith (1972) where they found potassium had no effect on height growth of young pine trees. The addition of potassium also may have had some effect on the chemical composition and nutritional value of the phloem sap, making it less desirable to the weevils than those seedlings which did not receive potassium fertilization.

Use of the Scholander pressure bomb to evaluate the effect of weevil feeding on tree vigor produced highly variable results and was of little use for this purpose. Variability might have been reduced by increasing the sample size, and by allowing a greater period of time between the first and second readings. Extending the period following insect feeding by several weeks would have given the seedlings more time to react to weevil feeding and may have revealed greater differences between treatments.

The fact that small reductions in weevil feeding did occur, and other studies have shown similar results with other forest insect pests, suggests that further investigation in this area is needed.

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