PROCEEDINGS

of the Fifteenth Annual

WESTERN FOREST INSECT WORK CONFERENCE

Banff, Alberta

March 9-11, 1964

<u>Not for Publication</u>

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EXECUTIVE COMMITTEE (Fifteenth Conference)

K. H. Wright, Portland - Chairman
B.H. Wilford, Fort Collins - Immediate Past Chairman
P.W. Orr, Portland - Secretary-Treasurer
N.E. Johnson, Centralia - Councilor (1961)
R.F. Shepherd, Calgary - Councilor (1962)
J.A. Schenk, Moscow - Councilor (1963)

R.F. Shepherd, Calgary - Program Chairman

EXECUTIVE COMMITTEE ELECT

J.M. Kinghorn, Victoria - Chairman
K.H. Wright, Portland - Immediate Past Chairman
A.F. Hedlin, Victoria - Secretary Treasurer
R.F. Shepherd, Calgary - Councilor (1962)
J.A. Schenk, Moscow - Councilor (1963)
F.M. Yasinski, Albuquerque - Councilor (1964)

N.D. Wygant, Fort Collins - 1965 Program Chairman

Prepared by the Secretary-Treasurer, A.F. Hedlin, from summaries submitted by Discussion Leaders. Stenographic services and duplication processing provided by the Forest Entomology and Pathology Branch of the Department of Forestry, Victoria, B.C.

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FIFTEENTH ANNUAL WESTERN FOREST INSECT WORK CONFERENCE

March 9-11, 1964

The Fifteenth Annual Western Forest Insect Work Conference convened at 9:00 a.m. in the Solarium, Cascade Hotel, Banff, Alberta.

Mr. G.H.L. Dempster, Superintendent, Banff National Park, and Dr. G.P. Thomas, Officer-in-Charge, Forest Entomology and Pathology Laboratory at Calgary, welcomed the Conference members.

Dr. Brian Hocking, Head, Entomology Department, University of Alberta, delivered the keynote speech, "Tongues in Trees," dealing with some of his entomological experiences in Asia and east Africa.

The following visitors and new participants of the Conference were introduced:

Dr. Brian Hocking, Edmonton, Alta.
Dr. Jock Clark, Fredericton, N.B.
Dr. Bud McGinnis, Lethbridge, Alta.
Dr. Lorne Ebell, Victoria, B.C.
Dr. H. Brix, Victoria, B.C.
Dr. Ed Clark, Durham, N.C.
Dr. Frank Webb, Winnipeg, Man.
Dr. G.W.K. Stehr, Sault Ste. Marie, Ont.
Dr. John Simeone, Syracuse, N.Y.
Dick Goyer, Moscow, Ida.
Jack Robins, Calgary, Alta.
Gerry Lanier, Berkeley, Calif.
Dr. B.M. McGugan, Ottawa, Ont.
J.M. Whiteside, Washington, D.C.
W. Dean McClanahan, Washington, D.C.
L.F. Pettinger, Portland, Ore.
Bruce Roettgering, Juneau, Alas.
Richard Brenton, Edmonton, Alta.

MINUTES OF THE INITIAL BUSINESS MEETING

March 9, 1964

The Chairman called the initial business meeting to order at 11:00 a.m., March 9, 1964, in the Solarium, Cascade Hotel, Banff, Alberta.

Minutes of the final business meeting of the Fourteenth Annual Western Forest Insect Work Conference at Portland, Oregon were approved as printed in the Proceedings.

The Treasurer's report was approved as read. The balance on hand, as of March 1, 1964, was $292.01.

The Secretary-Treasurer outlined the recommendations agreed upon at the Executive Committee meeting held March 8, 1964. Actions and recommendations arising from this meeting were as follows:

1. The registration fee was set at $3.00 for members. Students free.

2. A Nominating Committee consisting of N. E. Johnson, Chairman, John Chapman and Walter Cole was appointed to nominate candidates for Chairman, Secretary-Treasurer, and Councilor to replace N. E. Johnson.

3. Meeting sites for 1965, 1966, and 1967 were suggested as follows:
   1965 - Denver, Colorado
   1966 - Victoria, B.C.
   1967 - Salt Lake City - Ogden, Utah areas.

4. Two suggested themes for the 1965 meeting are "Pesticide Hazards to Wildlife and Other Forest Organisms" and "Economics of Direct Control". The Executive feels the use of workshops is desirable.

5. A joint meeting with the Central International Forest Insect Work Conference has been set for the Denver meeting in 1965, persuant to members wishes. The Executive recommends that the 1965 Program Committee work with the CIFIWC in formulating the program.

6. The Executive recommends that the possibilities of a joint meeting with pathologists of the Western Forest Disease Work Conference at Victoria in 1966 be explored.

7. The Executive recommends that the Unpublished Reports Committee be dissolved with thanks to its Chairman, R. E. Shepherd, for a job well done.

8. The Executive feels that survey and control subjects have been and will continue to be adequately covered. No revision in Conference format is necessary.

9. The Executive announced the appintment of a committee to study the impact of the revision of the genus <u>Dendroctonus</u> with instructions to report to the members at the final business meeting. The committee appointed consisted of Calvin Massey, Chairman, George Hopping and Phil Johnson, members.

10. The Executive recommends that the need for a clearinghouse of foreign translations be determined.

Chairman Ken Wright then discussed the Executive Committee recommendations with the Conferees.

Don Schmiege, Juneau, Alaska, extended an invitation to the Conference to hold a future meeting at Juneau.

R.W. Stark suggested that the proposed theme for the 1965 meeting be broadened to "Economics of Control". Walter Cole suggests that fluctuation of insect populations be discussed concurrently with the economic aspects of control.

R.W. Stark and others suggested that the 1965 joint meetings with the Western International Forest Insect and Disease Work Conference be a full four days to allow for full coverage of mutual-interest subjects.

The program topics should be of a general nature dealing with material problems and broad principles.

P.C. Johnson moved and N.E. Johnson seconded that the Western Forest Insect Work Conference meet jointly with the Western Forest Disease Work Conference at Victoria, B.C. in 1966. Carried.

Galen Trostle moved and C.L. Massey seconded that the Unpublished Reports Committee be dissolved with thanks to Roy Shepherd for a good job. Carried.

H.J. Heikkenen moved and R.W. Stark seconded the appointment of a committee to explore the need for establishing a clearinghouse for foreign translations. Carried.

A standing committee will be appointed if the need and desirability is established.

The following are reports submitted by the standing committees:

Common Names Committee

P.C. Johnson, Chairman, read the following report:

Minutes of the Committee's 1963 annual meeting at Portland, Oregon on March 4, 1963 were read and approved at the final business meeting of the 14th Conference on March 6, 1963 at the Portland-Sheraton Hotel, Portland.

Several Committee actions were taken as directed by the Conference Executive Committee:

1. From experience as a member of the Common Names Committee of the Entomological Society of America during the past year, the Chairman of the Conference Common Names Committee recommends that:

   "The Conference Executive Committee, and not this Committee should initiate with the Executive Board of ESA whatever action is deemed necessary to (a) assure a permanent position on the ESA Common Names Committee of a forest entomologist from one of the several forest insect work conferences throughout the United States, (b) recommend a makeup of the ESA Committee which would assure systematic representation from the several branches of economic entomology, and (c) revise rules for approval of common name proposals by the ESA Committee and by the ESA membership-at-large".

2. The Chairman of this Committee has within recent weeks contacted the chairmen of the Northeastern Forest Pest Council (Mr. E.B. Walker, Forest Advisory Services, Pennsylvania State Department of Forests and Waters, P.O. Box 1467, Harrisburg, Pa.) and of the Southern Forest Insect Work Conference (Dr. Lloyd O. Warren, Department of Entomology, University of Arkansas, Fayetteville, Ark.) concerning the desirability of joining with this Conference in (a) giving greater backing to common name proposals for forest insects, (b) gaining a permanent place for a forest entomologist on the ESA Common Names Committee, and (c) exploring possible changes in the procedures of the ESA Committee in approving common name proposals. Replies are awaited as of this date.

The Committee's form for proposing common names of western forest insects was revised and multilithed. Supplies of these were sent on February 11, 1964 to 19 locations in the western United States and Canada representing governmental agencies, universities, and private corporations engaged in forest insect research, surveys, and control activities. A copy of the revised form is attached.

A new form was approved by the Committee to facilitate records of common name proposals. A copy of this form, currently stocked at Missoula, is attached.

Several Committee members are currently engaged in restating the justification of common names proposed for the following forest insects:

<u>Barbara</u> <u>colfaxiana</u>	Douglas-fir cone moth
<u>Zelleria</u> <u>haimbachi</u>	Pine needle-sheath miner
<u>Ergates</u> <u>spiculatus</u>	Giant softwood borer
<u>Pseudohylesinus</u> <u>grandis</u>	Silver fir beetle
<u>Pseudohylesinus</u> <u>granulatus</u>	Fir root beetle
<u>Platypus</u> <u>wilsoni</u>	Wilson ambrosia beetle

The above proposals, rejected early in 1963 by the ESA Committee, will be resubmitted shortly.

One common name proposal was received during the year, but it was subsequently withdrawn by the proposer.

The annual meeting of the Common Names Committee will be held at 5:00 p.m., March 9, 1964, Cascade Hotel, Banff, Alberta.

N.E. Johnson moved and David McComb seconded that the Common Names Committee report be accepted as read. Carried.

Education Committee

Chairman R.W. Stark reported that Committee activities during the year consisted of his review of Dana and Johnson's book "Forestry Education in America - Today and Tomorrow". Stark then read his review. The Education Committee agreed to consider Stark's review at their annual meeting at 9:00 p.m., March 9, 1964. Their findings will be reported to the final business meeting.

Unpublished Reports Committee

The main work of indexing reports which have accumulated in files previous to 1957 has been completed. Two stations, Portland and Berkeley, have not been able to index these old reports and have indicated that, with their present resources, this is not feasible. All stations have been indexing current reports and these are completed from 1958 to 1962.

	Index	Supplements
North. Forest Exp. Sta.	up to 1957	1958-60, 61-62
Int. For. Expt. Sta. Missoula	up to 1958	subsequent reports included with Ogden.
Int. For. Expt. Sta. & Forest Pest Control, Ogden	up to 1959	1960-62
Pac. N.W. Exp. Sta. Portland	none	1959-60, 61, 62, 63
Forest Pest Control Portland		1961-62
Rocky Mtn. Exp. Sta.		
Albuquerque	up to 1958	1959-60, 61-62
Fort Collins	1935-1953	1954-62
Forest Pest Control Denver		1961-62
Pac. S.W. Expt. Sta. Berkeley	none	
Forest Pest Control San Francisco		1961-62
Forest Ent. and Path. Lab.		
Victoria	up to 1957	1958-62
Vernon	up to 1956	1957-62
Calgary	up to 1957	1958, 59, 60, 61, 62

In 1962 indexes were obtained from the Forest Pest Control Group in the Division of Timber Management but it was realized that their reports were of limited value to the membership and are only to report on new techniques and developments in the future (14th Proceedings: 2-#8).

Ethical Practices Committee

W.E. Cole and R.W. Stark were appointed to work with Tom Silver in finding a suitable candidate for 1965. This august Committee will function throughout the Conference. W.E. Cole pointed out that this Committee is promising something really, really big for its 10th anniversary celebration in 1965.

The Forest Entomologist Directory was discussed. H.J. Heikkenen asked for the Conference endorsement of the project. It was suggested that members consider this project for decision at the final business meeting.

R.L. Furniss reminded the Conference that the Annual Meeting of the Entomological Society of America will be held in Portland, Oregon in 1966. Conference members are encouraged to participate to the fullest.

The retirement in 1964 of charter members George Hopping and Ralph Hall was announced.

Charlie Eaton's serious illness was mentioned.

Meeting adjourned 1:50 p.m.

TONGUES IN TREES - SUMMARY OF KEYNOTE ADDRESS

by

B. Hocking
Entomology Department
University of Alberta
Edmonton, Alberta

"And this our life, exempt from public haunt,
Finds tongues in trees, books in the running brooks
Sermons in stones, and good in everything".

A number of examples of hypopharyngeal "tongues" in a variety of forest crops was given. Firstly, a problem in the bamboo crop in India during wartime conditions was discussed. This involved the activities of a number of species of Bostrychid beetles in bamboos both during seasoning, in storage and in use and the dependence of these insects on the carbohydrate content of the bamboo. Some discussion of an experimental evaluation of a number of preventive procedures followed which indicated that under normal peace-time conditions the standard native practices of seasonal activity in harvesting and storing the bamboo crop would in itself prevent the problem from ever arising.

A brief picture was then given of the numerous insect associations with several species of Acacia in East Africa extending from the ants of the genus Crematogaster inhabiting the gall-like swellings at the base of the stipular thorns of this plant to butterflies and various beetles and bugs which mimic the ants and even a preying mantid which mimics the galls themselves. All of these were abundantly found in association with these trees. A brief discussion of the significance of these associations to the growth and development of the tree was given.

An illustration of circumstances in which termites, normally considered to be pests of trees and forests, proved to be essential to the very existence of trees was presented.

The talk concluded with a few illustrations of extremes of growth of trees and of forest types and a reference to the importance of bearing in mind the hazard of two-legged forest pests.

PANELS

INFLUENCE OF INSECT ATTACK UPON FOREST TREES

A. Defoliators Panel Chairman, V.M. Carolin, Jr.)

Defoliators and Defoliation

by

J. Clark, Guest Panelist

Neither estimates of insect populations nor of total defoliation are enough in themselves to explain the interactions of a complex of factors affecting damage. The insect-tree relationship is of prime importance and it is essential to investigate all the physiological processes involved, both in the insect and in the tree. Tree physiological processes disturbed by defoliation include loss of photosynthesizing tissue, upset of water relations within the tree, and with young leaves, at least, temporary disturbance of endogenous growth regulating substances.

In the case of conifers, where there are probably significant physiological differences with age of leaves, it is necessary to know how these age groups are distributed in the tree crown. In white spruce and balsam fir, there is no difference in retention time of needles. However, spruce has a greater percent of foliage in the 'A' crown sector (upper crown quarter), much of it new needles; fir has more foliage in its 'C' crown-sector, largely made up of 2-7 year old shade needles. A specific pattern of foliage distribution appears to exist in mature balsam fir, and a similar pattern has been found by Silver for Douglas-fir. In all three species, the five youngest needle ages make up 87-91 percent of the total foliage, and new and 1-year old needles constitute 50 percent or more of the foliage.

The photosynthetic efficiency of leaves in relation to their age and position in the crown is of the utmost importance. Changes in light or temperature or moisture result in rather large differences in the rate of apparent photosynthesis. Except during the early growth of new needles, there is a general decrease of photosynthetic activity with needle age. When photosynthetic rates and foliage distribution data are combined, it is possible to estimate the contribution made by each age of foliage to the total photosynthetic capacity of the tree. Early in the season the new growth contributes little or nothing; foliage older than six years contributes practically nothing to the net assimilate. If the tree's respiratory requirements are considered (estimated as 10 percent of the total assimilate), even the six-year and five-year-old leaves do not contribute toward the surplus carbohydrates necessary for growth and for food storage. In spruce the 4 to 9 year inclusive needles, and in fir the 5 to 9 year needles, synthesize scarcely enough carbohydrates to maintain life in the tree.

Defoliating insects, when at high population levels, do not feed exclusively on one age of foliage before tackling another. Natural preferences for new or old foliage are subordinated by population pressures, thus causing scarcity of the preferred food, with the result that defoliation then progresses through the crown, sector by sector, more or less. Heavy infestations of the spruce budworm tend to defoliate balsam fir from sector A (upper crown) towards D (lower crown). For each crown sector, combining the photosynthetic rate for each age of foliage with the percentage quantity of each age of foliage shows approximate contributions by crown sectors to the total photosynthetic capacity of the tree. These estimates, after adjustment for light intensity variations, show that the less shade tolerant spruce contributes more from the upper half of the crown. In the shade tolerant fir, not only do the upper and lower halves contribute equally, but so also do the A and D sectors.

This approach is believed to be useful for dealing with severe and widespread outbreaks of defoliators that call for damage estimates or recovery predictions in the stand or over a large area. Loss of photosynthetic capacity is no doubt one of the most important effects of defoliation, but not the only one. Artificial defoliation experiments have provided indirect evidence that internal moisture and growth hormone relations are probably disturbed too.

Matched, fully-crowned spruce and fir trees were artificially defoliated by sectors, removing whole branches. Trees were prepared for dial gauge dendrometer measurements at breast height the previous winter. Radial growth measurements were made during three successive growing seasons, 1959-61. Curves from pruning trees in sectors A and D are quite similar and agree with estimated photosynthetic contributions; growth rate is not reduced much below that of control trees. However, when about 50 percent of the photosynthetic capacity is lost, the effects on radial growth become significant and the severity of damage depends on <u>where in the crown the defoliation took place</u>. It is clear that the upper half of the crown is of much greater importance to the tree's continued growth. Indeed it appears to be the upper quarter of the crown that spells the difference between death and life, and the eventual recovery of previous radial growth.

To get the overall picture of total growth, these trees were felled in November 1961 and annual ring measurements made at various heights from the stump to nearly the top of the main stem. Total growth corresponds rather well with growth rates shown for breast height. Again, the A sector of the crown is conspicuously necessary for the growth and recovery of the tree. These results cannot be explained entirely on the basis of lost photosynthetic capacity; water uptake and hormone balance are undoubtedly affected as well. Indirect evidence indicates that effects may be extremely localized. For instance, defoliation of the penultimate twig of fir during the winter has no effect on the next year's shoot growth. Removal of a similar amount of foliage from the ultimate twig, however, has a pronounced effect on the growth of the new shoot.

Evidence in regard to moisture relations was obtained by comparing defoliated and transplanted spruce. The effects---short shoots and short needles---are identical, and presumably the causes are too. The only difference is in the manner in which moisture relations were disturbed. Another example of this sort of relationship is shown in the grafting of conifers. A scion that is not overtopped by foliated shoots on the stock plant will, in most cases, not 'take', while a side-grafted scion will in most cases become a successful graft. This suggests water, rather than hormonal, relationships are at work.

Probably indirect evidence for the action of growth hormones alone is seen in flowering balsam fir. In nature, heavy flower production is followed by reduced shoot growth. A possible reason is that the millions of pollen grains are each supplied with a hormone for the growth of the pollen tube. With the shedding of pollen, a large fraction of the existing supply of growth hormone in the twigs is lost at a time of year when replenishment cannot be quickly overcome. That this probably does happen can be demonstrated by artificial methods. If needles are carefully taken off the flowering branch in December and January, leaving the male flowers, practically no shoot growth takes place in May and June. If male flowers are carefully removed in December or January, the shoot growth in May and June is better than in the ordinary flower-and-foliage-bearing control branch.

Artificial defoliation of trembling aspen and beech had some interesting results. Groups of trees 6-10 feet in height were completely defoliated once a year for three consecutive years. The defoliation of different groups was done at intervals, two weeks apart, on or about the same dates each year. All aspen withstood the three-year's defoliation remarkably well; except for those defoliated in August, all of them refoliated each year. Radial growth was, however, greatly reduced. Leaves on the refoliated crown were of quite different shape from those removed earlier in the season.

About half the beech suffered heavily from the repeated defoliation and in a rather peculiar seasonal pattern. All trees defoliated before mid-July bore a second set of leaves before the end of the season. Two or three of the trees defoliated in the third week of July produced a few small leaves often on epicormic shoots before the end of the summer, but in most the buds took on the characteristic spindle shape of dormant beech buds. Trees defoliated in August never showed any inclination to refoliate or to develop epicormic shoots and the buds were scarcely different from normal dormant buds.

A hypothesis is proposed, to show that the young leaves are a heavy drain on the stored food, contributing little to the total photosynthate, and that early season defoliation removes the leaves before repayment to the stored food is made. Production of even a sparse second crop of leaves taxes the already depleted reserves to the limit. Defoliation later in the season gives the leaves time first to re-pay, in part at least, the reserve food used for their production. No further drastic withdrawal is required from the reserves because refoliation does not occur. Therefore, the photosynthetic period has merely been shortened <u>after</u> the food reserves have been partly replenished.

In conclusion, the assessment of damage by defoliating insects is not simple because the nature and severity of the damage depend on many interacting factors concerned with the insect, the tree, and the season. To begin to understand these interrelationships, a great deal more knowledge of tree physiology is necessary. I trust that the examples given will provide food for future thought.

Feeding Patterns of Defoliators

by

R.E. Stevens

Defoliators operate in many ways, producing many different kinds of effects on their host trees. Let us review their feeding patterns---how and when the insects feed and how their action varies under different conditions. With these patterns in mind, we might consider some of the problems involved in relating studies on foliage complement and artificial defoliation to what happens in the real world.

According to feeding habits, defoliators can be lumped into the following classes: (1) "open feeders" or "clear feeders", (2) needle miners, (3) bud miners, and (4) "wasteful feeders". Open feeders include defoliators, such as the Douglas-fir tussock moth, Hemerocampa psuedotsugata, which feed readily on new and old foliage alike and others that feed wholly or mainly on the old needle growth. Needle miners, such as Recurvaria milleri and R. Starki, feed within the needles, hollowing them out. Bud miners, such as the spruce budworm and black-headed budworm, often show diversity in habits. Larvae characteristically enter the new vegetative buds and feed within them; as the foliage expands they feed between the new needles. As development continues, older foliage may be eaten. The wasteful feeders are insects that chop off or destroy much more live material than they use for food. The pine needle-sheath miner, Zelleria haimbachi, is an outstanding example. The Zelleria larva chews its way through the needle sheath into a bundle of newly developing needles, and feeds on the tender growing point within. In effect, the entire bundle of needles is destroyed.

How defoliation occurs within the tree is of considerable importance. We can visualize species that tend to operate first and most severely in the upper part of the crown. A greater proportion of the foliage on the upper crown is new growth. This is probably the commonest situation encountered with defoliators, and the one in which top-killing is an early manifestation of damage. Spruce budworm, Douglas-fir tussock moth, and the silver-spotted halisidota, Halisidota argentata, are examples.

On the other hand, populations of the white-fir sawfly are concentrated in the lower portions of crowns when it occurs in dominant and codominant trees. This, coupled with the species' preference for older foliage, results in it not being particularly destructive with respect to growth reduction and tree mortality.

Variation in habits at different stages of the life cycle should also be considered. The spruce budworm commonly acts as a needle miner in the earliest feeding stage and sometimes as a pollen feeder, in addition to being a bud miner, then an open-feeder. The pine needle-sheath miner spends two and a half of its five larval instars as a true needle miner; however the mine is so small that it is considered to be of no consequence so far as tree damage is concerned.

Variation in feeding patterns also occurs with increased population density. The pine butterfly is a good example; ordinarily the larvae feed only on the older needles, but under outbreak conditions they eat old and new needles alike.

When defoliation occurs---time of attack---is important. Defoliation in May, for instance, can be expected to have a different effect than the same amount and kind of defoliation in August. Among the array of defoliators we find species that feed early and late. Some extend their feeding over long periods.

To show the problems in relating artificial defoliation studies to natural conditions, I would like to briefly consider one example. The lodgepole pine needle miner in California has a two-year life cycle. During the first feeding season larvae commonly mine old needles, starting in mid-July, and by October have moved to and mined four new ones. Then in the flight year an additional needle, sometimes more, is destroyed before the larvae pupate. While some of the mined needles remain on the tree, an abscission layer is formed in many of them, and these needles fall to the ground.

This illustrates that defoliation is a complicated process. The experimenter must take into account the progressive nature of the feeding; a simple removal of needles in the case of the pine needle miner would hardly be sufficient. The pattern of defoliation within the tree---top to bottom---would have to be dealt with. So would the condition of tree---whether the infestation was a recent one or one of several years' standing. The observer has to recognize all these things and deal with them if he is going to attempt to simulate the insects' effects.

Defoliation and Host Tree Reactions

by

V.M. Carolin

Tree host reactions to defoliator attack or damage may have a direct or indirect bearing on the course of further damage. In some cases the reaction is in response to injury; in other cases the reaction is coincidental. Host reactions usually appear to be of advantage to the host; however, the opposite may apply and in some cases the reaction may have no real bearing on tree survival. The important question to foresters is whether, with a particular insect on a particular host, the course of damage can be reversed.

Kinds of reactions include refoliation from normal vegetative buds, production of adventitious buds, shedding of leaves, resin production, and peculiarities in flowering habit. Reactions vary primarily with the species of host tree, but the feeding pattern of a defoliator may qualify the intensity of the reaction. Some tree species are 'weak sisters', while others are moderately or well qualified genetically to cope with defoliator damage.

Refoliation from normal vegetative buds occurs every spring with deciduous trees, including larch. These trees, compared with those having persistent leaves, have an obvious advantage in coping with defoliator populations. A second crop of leaves during the season that damage occurs may have considerable significance, since some immediate benefit in food reserves may accrue. The timing of refoliation is important; Dr. Clark has already cited a case where refoliation depletes the food reserves. Larch refoliates early in the season following damage from spring feeding by the larch casebearer, Coleophora laricella. Production of this second crop of needles is tied in with intensity of spring damage, and numbers of needles are half that of the first crop. After five or six years, the length of needles of both the first and second crop of needles is much reduced. Trees continue to survive and it is problematical how many years they can withstand such heavy defoliation, without a respite to build up food reserves. (Data from R.E. Denton, U.S.F.S.)

Some interesting results of defoliation of larch, under severe attack by the larch sawfly, have been shown by Lejeune (1951). After three to four consecutive years of severe infestation, trees produce so little foliage that few larvae can be supported. Simultaneously the number and length of terminal shoots decreases. Because sawfly adults lay their eggs only on new shoots, populations cannot be maintained in their absence.

Production of adventitious buds is usually stimulated by the loss of vegetative buds and shoots, caused by feeding of bud-miners such as spruce budworm. The result is to maintain the capacity of the tree to put on new growth the following spring. The ability of Douglas-fir to produce adventitious buds under severe defoliation by the spruce budworm appears much greater than that of white fir. Although production of adventitious buds has been recorded for ponderosa pine, larch, and western hemlock, the ability of western tree species to sustain adventitious bud production over a period of time is not well-known.

Shedding of partially consumed leaves often occurs as a reaction to damage. Sometimes the shedding takes place while insects are feeding, and is beneficial to the tree. For instance, some of the mined needles of firs attacked by the spruce budworm contain living larvae when needles are shed. Shedding of damaged new growth of conifers at the end of the feeding period seems to have little significance. However, shedding of old growth needles only partially damaged by feeding appears disadvantageous to the tree. In the case of hemlock looper on western hemlock, many needles are only lightly fed upon, but are shed along with more seriously damaged needles. This results in maximum loss of foliage for the amount of needle tissue devoured.

Resin production of conifers---amount and time of production---may have a significant bearing on damage caused by leaf-miners and bud-miners. Bennett (1954) found that pines with large numbers of resin canals in the needles were scarcely acceptable to larvae of a pine needle miner, _Exoteleia pinifoliella_. In studies of the European pine shoot moth, Harris (1960) demonstrated that success of initial larval attack on buds of pines varied with stage of development of resin canals in the buds, and with differences in resin production between tree species.

In summary, host tree reactions must be carefully considered in damage studies. Since it is not usually known whether tree reactions will affect the course or amount of damage, defoliation estimates should be obtained both before and after the host reacts. Amount of refoliation and acceptability of this food to the defoliator must be considered. Indirect effects of defoliation, such as discovered by Lejeune for the larch sawfly, should not be overlooked.

Defoliation and Tree Mortality

by

B. E. Wickman

The following comments on defoliation and subsequent tree mortality will be limited to several of the currently important western forest insects attacking conifers; namely the lodgepole needle miner, spruce budworm, western hemlock looper, Douglas-fir tussock moth, white fir sawfly, pine butterfly, and pandora moth. The objective is to indicate, for the different insect species listed, the amount of defoliation necessary to kill a host tree and the type of trees most susceptible to this mortality.

There are many complicating factors involved. Usually the concentration of large numbers of weakened trees attracts and breeds tremendous numbers of bark beetles and other cambium-mining insects. These insects attack trees which might have died from defoliation alone, or kill trees which might have survived defoliation quite easily. Consequently, some of the mortality figures included here should be considered as at least partially beetle caused.

Any defoliator, even those considered of minor consequence, has the potential by sheer numbers or an extended feeding period to overcome even the healthiest tree. Luckily for entomologists, though, most important defoliators have attack and feeding habits which can be correlated with host reaction, allowing us to make at least educated guesses concerning the amount of damage likely to occur. The feeding habits reported by Bob Stevens are a most important factor in making predictions of subsequent tree mortality.

The spruce budworm, a feeder on new foliage, has probably caused more tree mortality in Canada than in the western United States. Some of this may be due to a difference of hosts. As a rule Douglas-fir and true firs, defoliated of only new foliage, take 4 or 5 years of repeated feeding before the needle complement is reduced enough to cause tree mortality. Large firs with slightly over 25 percent total foliage reduction usually have tops killed and can be classified as dying, even though actual death might take up to 5 years. Similar damage to Douglas-fir results in no mortality, with 50 percent or more defoliation being necessary to kill small trees. Here we definitely see a difference in host reaction.

Second to be considered are three insects which concentrate their feeding on old foliage. The white fir sawfly during its 1951-54 outbreak in northern California killed only 1 percent of 1,000 trees examined. Mortality was confined to suppressed and intermediate trees, and none was caused by bark beetles. The pandora moth has caused devastating mortality of ponderosa, Jeffrey, and lodgepole pines, but effects of defoliation have been masked by subsequent bark beetle outbreaks. The insect has a 2-year life cycle and usually terminal buds are spared, so it usually takes 4 years before serious tree mortality occurs. Mature and overmature trees seem to be more susceptible to feeding and subsequent mortality. The lodgepole needle miner, which has a 2-year life cycle, is a tree killer in California. In the 1909-17 outbreak, Patterson ascribed none of the mortality to defoliation alone, but rather to a subsequent outbreak of mountain pine beetle. In the present outbreak, studied by Struble, after six years of heavy feeding entire stands of lodgepole pine were being killed by defoliation, in some cases without any aid from bark beetles. The first trees to die were usually the overmature. After 10 years Struble found in one area that 19 percent of the trees over 10 inches d.b.h. and 14 percent of the trees under 10 inches had been killed by defoliation.

Finally, we can examine mortality caused by defoliators which feed on old and new growth throughout the crown. The pine butterfly has caused serious amounts of mortality in Washington and Idaho. Evenden reported 26 percent of the stand on 27,000 acres was killed, 12 percent by defoliation alone, in the 1922-23 outbreak. The insect can cause almost complete defoliation in one generation, with mortality of mostly overmature trees occurring by the second year. The Douglas-fir tussock moth, with help from bark beetles, has caused spectacular losses in white fir in the Sierra Nevada by the second year of feeding. In the 1934-37 outbreak, at least 12 percent was attributed directly to feeding. In the 1955-56 outbreak, only 0.5 percent of the timber loss could be attributed to defoliation alone. However, defoliation did cause 34 percent of the trees under 6 inches d.b.h. to be killed. Mortality increased with amount of defoliation and most mortality occurred in trees over 70 percent defoliated. Trees under the 10-inch d.b.h. class, or the suppressed and intermediates, were most susceptible to death by defoliation alone. The hemlock looper has caused extensive damage in coastal forests. Kinghorn found that the first year after collapse of the outbreak tree mortality was light, and only totally defoliated trees died. During the second and third years after the outbreak, mortality increased considerably, but by the fifth year had declined. In hemlock, fir, and spruce, larger trees suffered a higher mortality percent for all defoliated classes than smaller trees. Mortality increased with percent defoliation. In Douglas-fir, mortality was higher in smaller trees.

Expected tree mortality after defoliation by these principal insect pests has been summarized in table form for purposes of this talk. As foresters aim toward more intensive forest management, they will expect more sophisticated predictions of tree mortality after insect defoliation. We are unable to do this now for many insect-host combinations.

Damage Symptoms as Related to Growth

by

C. B. Williams Jr.

The purpose of this paper is to show the close relationship between the various external damage symptoms exhibited by spruce budworm attacked trees and the concomitant reductions in tree growth.

A total of 101 dominant and codominant grand fir, Engelmann spruce and Douglas-fir trees, whose d.b.h.'s ranged from 8.0 to 16.0 inches, were selected for study from forest stands recently attacked by the spruce budworm. The trees were first classified on the basis of the number of damage symptoms they exhibited and their d.b.h.'s measured, then the trees were felled and sectioned. Disks obtained from these sections provided material for annual radial and volume increment analyses. Total height, annual height increment (1941-1958), and length of dead top was measured on each felled tree. The impact of budworm feeding on radial, height, and volume increment was shown by a comparison of tree growth during the 1946-1956 outbreak (damage period) and a predamage period of equal length in years (1935-1945).

Radial increment illustrated the annual and cumulative effects of budworm feeding more clearly than height and volume increment. This was determined through graphical examinations, covariance, and multiple range tests. Generally, reduction in radial increment between damage ratings was significant at the .05 level. Spruce budworm feeding affected height growth more than radial or volume growth. Top-killing occurred frequently among moderately damaged trees, particularly grand fir.

Analyses repeatedly showed that the various damage symptoms exhibited by trees attacked by the spruce budworm are closely related to reductions in the increment. These external damage symptoms can be grouped into several damage classes and used in damage surveys of budworm-attacked forest stands.

ABSTRACT

Effects of artificial defoliation of pine on subsequent shoot and needle growth

by

H.M. Kulman

(Read by G.T. Silver)

Red pine, Pinus resinosa Ait., trees in a five-year-old plantation were artificially defoliated in July, 1959. In order to simulate insect defoliation, the needles were clipped off at the distal end of the facicle. The treatments consisted of the removal of the 1959, 1958, 1957, 1959 + 1958, 1959+ 1957, and 1958 + 1957 needles. Subsequent measurements of needle and shoot-length growth were made in the fall of 1962. Three of the 6 treatments resulted in a significant reduction in shoot-length growth of 10 to 40 per cent in the first growing season after defoliation. Treatments involving the removal of current (1959) needles resulted in a significant reduction in shoot-length growth of 38 to 63 per cent in the second season after defoliation. Treatments in which the current year's needles were removed resulted in a significant reduction of 19 to 32 per cent in the length of needles produced in the following season. All three treatments in which the current year's needles were removed resulted in the production of significantly longer (9 to 42 per cent) needles in the second season after defoliation. Significant shoot and needle-length reductions were also obtained in smaller studies using Scotch pine, Pinus sylvestris L. The shoot reductions are discussed in relation to the effects of defoliation on the availability of needles as storage organs and producers of photosynthate for the following season's shoot elongation. Needle length changes are discussed in relation to the effects of defoliation on the availability of needles to produce photosynthate at the time of needle primordia formation and needle elongation.

B. Gall Forming and Sucking Insects and Mites.

Panel Chairman, N.E. Johnson

Growth Regulating Substances in Trees

by

Dr. J. Clark

Some ten years ago I became interested in the balsam woolly aphid, Adelges piceae, because of the nature of damage caused to the trees. Certain responses to the insect's feeding such as drooping of shoot tips, suppression of bud development, swellings or 'gout' due to cortical hypertrophy and hyperplasia, and formation of wide rings of compression-like xylem 'rotholz', strongly resemble growth abnormalities that have been produced experimentally in other plant species by the application of synthetic growth regulating substances and herbicides. At that time I was occupied with other work and could indulge my interest in the physiological aspects of the aphid problem, only by carrying out simple field experiments and observations. These strengthened my conviction that the symptoms of aphid attack were somehow related to unbalanced growth hormones in the tree, but it was only three years ago that I finally found the time and the opportunity to embark on full-scale research into the problem.

I soon became aware that, in general, there was really very little known about growth hormones in trees per se, and practically nothing was known about those in coniferous trees in particular. It was obvious that investigation of normal healthy fir trees would first be necessary to determine the nature of growth substances and the mechanisms of growth regulation in Gymnosperms. Only then would investigations of the abnormal condition, the aphid infested trees, become meaningful. It is mainly the first stage, the studies of healthy trees, that I wish to describe today. However, I would like to tell you also about preliminary work I have done with infested trees if, for no other reason, but to open up avenues for discussion at this Conference.

I do not intend to subject you to the plethora of technological details inherent in studies of plant growth hormones. However, a very brief outline of the combined use of chromatography and growth bioassay techniques will help to clarify the significance of the graphs and tables on slides that follow.

Ether extracts of the plant tissues were purified, concentrated, and applied quantitatively on the start line of chromatographs. Two types of chromatographs were prepared; (1) Twenty-inch sheet on which a large amount of extract was applied as a uniform dense start line; from these, pieces of any appropriate width were later cut out for use in the bioassay; (2) Slotted sheet on which accurate serial dilutions of extract were applied as starting spots; from these, pieces the entire width of the strip were cut out for bioassay. The two types of chromatographs were related quantitatively; 10 inches of starting line in (1) contained exactly the same amount of extract as the undiluted starting spot in (2). The papers were equilibrated in the vapours of, and irrigated in a solution of, isopropanol-ammonia-water (8:1:1 V/V) until the front of the partitioning solvent reached a previously marked distance (usually 10 inches) from the start. While these operations progressed over a 72-hour period, oat seeds were germinated and grown in the dark for use in a growth bioassay; in this case the 'Avena first internode straight growth bioassay', which is one of the many standard procedures for assaying plant growth substances. To each culture tube was added 1 ml. of buffered nutrient solution, 10 Avena internode sections, and a piece of the dried chromatograph which had been divided into equal sections of the Rf scale. Certain sections would thus contain auxins, others inhibitors (if present) and the remainder various unknown inactive substances extracted from the tissue. Control tubes contained clean paper. The tubes were rotated in the dark for 18 hours at 25°C. then the Avena sections were measured. The average length of internode sections in a tube indicated the presence of an auxin if the length was significantly greater than that of controls, or the presence of a growth inhibitor if the length was less than that of controls. This outline gives a deceptively simple account because all these operations must be carried along on a strictly timed schedule; a slip-up in any one upsets the entire sequence and complete repetition becomes necessary.

From the literature it appeared that plant growth hormones are produced by the buds, and therefore the best place to start my investigations would surely be in the buds early in spring. I did exactly this, despite certain observations I had made earlier, while studying defoliation of fir, which suggested that there were possibly other sites of hormone production. Anyway, unopened buds, year old needles, and twigs, were used at first then, after buds opened, the current shoots were included too. Extracts from all these tissues showed some growth stimulation at one time or another but the results were inconsistent, due I believe, to great quantities of gums, pigments, and resins that were not removed entirely by the purification procedures and their residues then interfered with the flow of the partitioning solvent in the chromatographs. These less than successful analyses were carried on for about two months, by which time shoot elongation was completed yet new buds were still poorly developed. At this point, about late June, I decided to take from the trunk a sample of the inner bark and cambial zone because, I argued, radial growth rate should be just about its peak then and auxins ought to be there. This was immediately successful, not only did the bioassay results show clearly defined zones of growth promotion and inhibition but there was a suggestion of a chromogenic reaction when these chromatographs were sprayed with Salkowski's reagent for indolic compounds. The extracts of inner bark were much freer of gummy impurities than those of buds, twigs, and needles. Fortunately too, from the aspect of the aphid studies, the activity of the cambial meristem was probably of greater importance than that of the terminal meristem. From that time on, all samples were from the inner bark half way up the trunks of mature trees. All results that follow pertain to analyses of trunk bark.

Now that the existence of growth regulating substances was known, qualitative and quantitative studies on a seasonal basis were necessary. Various experiments, each designed to furnish a specific kind of information about these growth substances, were repeated as often as possible throughout the year. The collective results indicated that both the auxin (1AA) and the inhibitor (which is probably inhibitor B complex) were present in the bark in <u>all seasons</u> and essentially in the <u>same quantities</u>. This was indeed a surprising development because, as I already mentioned, auxins were supposed to appear in the buds in spring, move basipetally initiating cambial activity as they went, then disappear in the fall of the year! As a check, the seasonal analyses were continued for another full year. In addition, advantage was taken of the bark-peeling season to look for possible changes in the location of auxin within the bark (and here I use 'bark' in the sense of everything external to the xylem). Previously unsuspected lateral movement of auxin was actually found.

It has been suggested (Wort) that the tissues adjoining the dormant cambium contain a reserve of auxin and an increase in temperature triggers the liberation of free auxin from these stores of inactive hormones.

Our results lend support to this hypothesis. This might explain too why trees occasionally commence radial growth <u>before</u> the buds swell and burst.

Coming back to the seasonal analyses of 'bark' (middle, inner, cambial zone, and cambium inclusive):- we note that auxin and inhibitor are present every month. The results above are for 2" wide strips of chromatograph, in most instances these provide over-optimal amounts of auxin in the bioassay media as can be seen from the increased activity in the results below for $\frac{1}{2}$" wide papers, i.e., 1/4 the concentrations above. Inhibition was more pronounced with the 2"-wide papers. The apparent downward trend in auxin activity from February to December is not real but, as we now know, is due to changing response of Avena to 1AA with the season.

If large seasonal changes in the auxin were taking place, the peaks in these activity curves would shift to the right or to the left depending on where the optimal concentration for growth happened to be at that time.

It is apparent that when these substances are bioassayed separately, one promotes, the other inhibits, growth of oat internodes. But in nature they do not exist separately; therefore, it was necessary to investigate their combined effects on growth. Early experiments were purely qualitative but clearly showed that the inhibitor had a pronounced effect on growth whether or not the auxin was present. Substituting authentic IAA for natural auxin gave similar results. These semi-quantitative experiments suggested that growth responded more to variations in concentration of inhibitor in the mixture than to variations in the IAA concentration. In addition, extremely low concentration of inhibitor in combination with optimal IAA, enhanced the growth response beyond that due to IAA alone--in other words there was a synergistic effect. Combining the natural auxin and inhibitor in various mixtures brought out an interesting feature.

Here one unit of inhibitor suppressed growth just as much in the presence as in the absence of auxin, whereas .1 units seemed to be just about critical; neither inhibition nor promotion occurred. However the dilution series here was too coarse to detect what really went on, so refined inhibitor dilutions close to the critical point were combined with wide dilutions of IAA. But first let us see the relationship of these dilutions to the activity curves for authentic IAA, natural auxin and inhibitor when bioassayed separately.

Note that peak IAA and auxin activity occur at the same place in the dilution series as the 'critical point' of inhibitor. Now, instead of the wide range of inhibitor dilutions, a very narrow range about the critical point are combined with the wide range of IAA dilutions--this is what happens.

Here the extremely sensitive control of the inhibitor over the IAA-induced growth shows up clearly. It almost appears as if the auxin plays a passive role. This raises an interesting point. If the amounts of auxin and inhibitor remain relatively constant in the bark throughout the year, then the controlling factor becomes a question of dilutions, and of course the quantity of solvent, water, would be of paramount importance. There is scarcely any change in the auxin-induced growth over this narrow range of near optimal concentrations whereas consentrations of inhibitor over the same range, completely suppress auxin induced growth at one end and allow its free expression at the other. This concept, that moisture content of the inner bark might play some part in controlling cambial activity, is not entirely new, it has been suggested before (Priestley 1930, Zahner 1963). I do not consider it to be the only controlling factor, undoubtedly there are others. However, we do know that bark moisture varies greatly during the year and moisture, rather than temperature, etc., seems to be closely correlated with certain well-known features of radial growth in trees, for example:

1. The spring commencement and autumn cessation of cambial activity. (Dilution concentration respectively of the growth inhibitor).
2. Narrow growth rings during dry years. (Again concentration of inhibitor).
3. False or double rings during a good growing season that has been interrupted by a brief but intense drought, or by defoliation. (Again concentration, followed by dilution, of the inhibitor!)

One might add to these such abnormalities as, short tufted shoots due to defoliation or root damage through transplantation (reduced water causing concentrated inhibitor solution), the succulent luxurious growth of sucker, laminas and coppice shoots supplied with water from a fully developed root system suddenly deprived of its large crown by disease or mechanical injury (here is the opposite effect--extreme dilution which possibly allows not only optimal growth, but even the synergistic effect already mentioned, to take place).

Growth regulators in other tree species

Up to this point I have dealt only with balsam fir, but reference to your program will show that I am supposed to cover "hormone relationships in unattacked trees and plants". Well, out of curiosity, I actually did a few analyses of other species, using exactly the same techniques as already described for fir.

The same pattern as for balsam fir occurs here again almost exactly, and probably the same growth regulators are involved. Strangely enough, aspen, the only broad-leafed species tested, gave results like the conifers.

Interesting experiments were carried out recently (by Westing 1960) with red pine. He staked young trees over sideways then, as the leaders began to bend upwards, he bioassayed the 'upper' and 'lower' halves of the curvatures for auxin and found greater activity in the 'lower' portions. Though he failed to identify the active substance, its characteristics agreed in almost every respect with the auxin found in balsam fir and tentatively identified as indole-3-acetic acid.

The Woolly Aphid and Growth Hormones in Fir

Studies of the aphid itself and of aphid-infested trees have so far been of an exploratory nature because, first, I have been almost fully occupied investigating the normal situation in healthy trees and, secondly, heavy infestations of the aphid are becoming quite hard to find in the vicinity of Fredericton and this means travelling considerable distances to collect material. Therefore the results that I give here today should be considered as purely preliminary, entirely open to question and criticism, and will probably require extensive revision in the light of future investigations.

A few extractions were made of aphid eggs, crawlers, adults and wool (mixed) and bioassayed for possible plant growth regulating substances.

Collections from Chipman and Campobello Island showed good auxin activity near the Rf of authentic IAA, and probably another active substance at RF .85. No growth inhibition occurred. Though these samples consisted of materials of insect origin, it is possible that the activity was due to the presence of bark auxin either inside the feeding adults or in their woolly secretions. Another attempt, using crawlers only, gave absolutely no growth promotion; however, this sample was extremely small--fewer than 50 crawlers crushed directly on the start spot of a chromatogram.

Another line of investigation was to bioassay the bark extractions from gouty twigs and heavily infested stems and compare these with the normal pattern for healthy tissues.

This was not done quantitatively--the bark from twig nodes was stripped off until about the same fresh weights of gouty and healthy material were obtained. However, the results suggested that a change had taken place in gouty tissue, inhibition seemed to be stronger and this led to similar, but quantitative, analyses of stem bark.

In the upper graphs there appears to be much greater growth inhibition by infested than by healthy bark but part of this inhibition (Rf .1-.5) could be due to greatly over-optimal concentration of IAA (if present). In the lower graphs dilution of healthy bark extract enhances auxin activity but similar dilution does not show growth promotion in the extract of infested bark. Therefore, it seems that the pattern for infested bark was different from that of healthy bark in several ways: (1) the usual B-complex inhibition was stronger and more extensive; (2) the auxin (IAA) was either missing entirely, or in such high concentration that even the diluted form was still over-optimal, (very unlikely) or the auxin activity was completely suppressed by a new 'inhibitor' (Rf .2-.5) that had never appeared before in analyses of healthy bark.

About that time my colleague, Dr. Bonga, was successfully culturing spruce bark in connection with his studies of dwarf mistletoe. We decided to try the same tissue culture technique with fir bark as a possible means of testing growth regulating substances on the same kind of tissues as they were originally extracted from. Small patches of bark were removed aseptically and grown in nutrient agar media to which were added (or omitted) authentic lAA, fir bark auxin (lAA), and fir bark inhibitor (inhibitor B-complex). Addition of authentic lAA in physiologically suitable concentrations did not affect the growth or success of the cultures, indicating that the necessary amounts of auxin required for growth were contained in the bark patches or produced by them from precursors. But addition of inhibitor, especially in very high concentrations, did affect the growth and in a most interesting manner.

This slide will help to refresh your memories on what the general anatomy of normal healthy bark looks like, as well as the relation and juxta position of one tissue to another. The labels identify various tissues or elements as follows:

(a) xylem
(b) cambium
(c) sieve tubes
(d) phloem parenchyma cell
(e) phloem ray cell
(f) resin duct
(g) cortical cell
(h) phloem parenchyma

Note particularly the orderly arrangement of the phloem elements. When high concentrations of inhibitor were added to the nutrient agar, the culture blocks became obviously different from the controls; (1) the amount and extent of normal callus (proliferation of cambial and end ray cells) was less and (2) a swelling developed just above the agar surface. Sectioning of the blocks showed these swellings were of internal origin caused by hypertrophy of phloem parenchyma and phloem ray cells (p and q) which distorted and displaced the sieve tubes (r).

Here you can see part of the swollen region and, in higher magnification, the hypertrophied parenchyma cells and distorted sieve tubes. Note normal and hypertrophied phloem parenchyma cells at d and p respectively.

The effects of the inhibitor are evident in these sections of bark cultured over lengthening periods:

A. Normal orderly arrangement of phloem during first few days.
B. Hypertrophy well advanced at 2-3 weeks.
C. Extreme hypertrophy of phloem parenchyma and phloem ray cells at 5-6 weeks.

Since these are all at a magnification of X100 the over-all result is quite apparent; in B, the diarrangement of the sieve tubes c into isolated bundles has commenced and the phloem sclerenchyma h has been pushed to the left; in C, complete disorganization of sieve tubes has left only a few small bundles within the field, the remainder, as well as the phloem sclerenchyma, have been pushed far to the left beyond the limits of the photomicrograph. By measurements on both transverse and longitudinal sections it was calculated that enlargement of cells due to hypertrophy must be in the order of 40 to 60 times, all of which took place in about 6 weeks. This hypertrophic growth produced in the phloem of fir bark cultures by massive doses of the inhibitor appears very similar anatomically to localized swellings, described by Balch (1952) and more recently by Oechssler (1962), that develops in the phloem of various species of *Abies* fed on by *Adelges* spp.

This raises a question and suggests a word of caution. Can this substance rightly be called a *growth inhibitor* (as I have done today) solely due to its effects on the elongation of oat segments, when it behaves also as a *hypertrophic stimulant* in balsam fir bark cultures? It is rash indeed to make generalizations about the growth regulatory properties of a particular substance on the basis of any *one* biological test.

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It is the rule rather than the exception in biological research that new leads come from accidental findings and these leads, when followed, channel the investigation into a new direction. Our fortuitous discovery of the hypotrophic properties of this substance might well be the lead that will help to unravel some of the intricate mechanisms involved in the woolly aphid-balsam fir relationship. On the other hand it might well lead up a blind alley.

Influence of Balsam Woolly Aphid Upon Hormone Relationships, Tree Growth, and Mortality

by

Dr. R.G. Mitchell

An attack by the balsam woolly aphid is a double-barreled one which is hard to separate in terms of which causes the most damage. In one, the aphid attacks the main stem, influencing the xylem, which carries water to the crown; the phloem, which contains sieve cells for transportation of elaborated foods; and the phloem parenchyma, which functions vitally in food storage. In the second type of attack, the aphid infests the tree crown and prevents new growth by inhibiting bud development.

Stem Infestations

Aphid infestations on the main stem of North American Abies cause the trees to produce annual rings with abnormally large amounts of dark, reddish wood. This aspect of damage was studied cooperatively by the U.S. Forest Service and Oregon State College.

Anatomical investigations of the xylem tissue of grand, subalpine, and Pacific silver fir revealed that in abnormal wood the cells were circular rather than rectangular in cross-section; secondary cell walls were abundantly marked with microscopic checks; the proportion of thick-walled, summerwood-like tissue was greatly increased; and there were an unusual proliferation of traumatic resin canals. Other distinguishing characteristics of the abnormal wood were: Cell walls in the springwood were about 50 percent thicker than normal; tracheids were some 40 percent shorter; fibril angle was two to three times greater; and the number of rays per unit area was nearly doubled.

These effects of woolly aphid attack occur in all three species and in about equal proportions, suggesting the reaction between aphid and host as being fundamental in nature and independent of tree species. The initial site of reaction in the tree is not readily apparent, nor is it clear whether the initiating agent functions as an inhibitor or stimulant. Some characteristics suggest that host reaction may occur in the cell differentiation stage rather than in the cambium; other characteristics indicate the vascular cambium as being the primary site of action.

It is possible that the abnormal, aphid-affected rings affect water-conduction. Some symptoms in aphid-infested trees, such as drooping leaders and positive sap pressures in mid-summer, suggest some kind of stress in the functional part of the xylem. Other observations on the transport of dye in infested trees also suggest that the patterns of water transport in the main stem differ somewhat from normal.

Effect of the Aphid on the Crown of Grand Fir

Grand fir may survive balsam woolly aphid infestations as long as 15 years. The tree is therefore a good species for determining the effect of infestations on normal needle complement. The U.S. Forest Service and Weyerhaeuser Company worked cooperatively on this aspect of aphid damage, as well as the factor of growth reduction.

The first signs of crown deterioration appear after 4 to 6 years of stem infestation, but only the new growth is affected, and this mostly at the bottom of the crown. After 6 years of infestation there is no detectable reduction in the amount of old needles but a 55% reduction in the number of new needles. As the period of infestation increases, the number of new needles drops precipitously. A loss of 10 percent of the old needles and 85 percent of the new needles can be expected after 10 years of infestation. Then the number of old needles drops sharply. After 14 years of infestation, the needle loss measures about 80 percent for the old and 95 percent for the new. At this stage, the remaining foliage is concentrated largely in the upper third of the crown.

Effect of Infestations on Growth of Grand Fir

Height Growth: The first indication of loss of height growth appears after 3 to 7 years of stem infestation. Once the tree begins to react to the infestation, the loss in height growth is usually precipitous: First year, 20-60%; second year, 40-70%; third year, 60-80%; fourth year 65-80%; and a gradual loss each year thereafter until the eighth or ninth year when height growth is nil. Also, in about half the infested grand fir, the top snaps out after 3 to 7 years of infestation. A lateral limb does not take over to replace the lost leader.

Diameter Growth: The first effect of balsam woolly aphid infestation on radial growth is acceleration of growth in the immediate area of the infestation. On grand fir this begins at the bottom of the bole and moves gradually upward. Within 3 to 4 years after an infestation begins, its effects can be detected by a decrease in radial growth in the upper part of the stem. Decreased growth is most noticeable in fast-growing trees: 50-55% in the first year, 65-80% in the second year, 90-95% in the third year, and 95-99% thereafter, until the tree dies. Because of the accelerated growth in the lower stem and simultaneous decreased growth above, the form class (in this case diameter at 4-1/2 feet divided into diameter at 20 feet) of the afflicted trees differs markedly from normal trees, ranging from 0.80 in non-infested trees to 0.35 in trees infested 14 years.

Mortality

Amount of mortality due to the balsam woolly aphid can be severe in all three tree species, but is generally most spectacular in subalpine fir. It is least noticeable in grand fir. For Pacific silver fir it was found that the better the site, the more stem infestations there are; and the more stem infestations there are, the greater the mortality. The relationship between heavy mortality and good growing site is also apparent with subalpine fir but is not too evident with grand fir. However, for all three species, in any stand, it is the large-diametered trees which are first attacked and killed by the balsam woolly aphid. The reason for the the relationship between susceptibility and thriftiness of stands and individual trees is a mystery.

THE EFFECT OF APHIDS ON THE HOST PLANT

by

Norman E. Johnson

Aphids are known for their effect on the growth and form of many plants. Leaf curling, rolling, crumpling, chlorosis and galling are common effects of aphid feeding. Atrophy as well as hypertrophy is involved. Internally, marked histological abnormalities accompany such symptoms. Carter (1962) says that the severity of the symptoms depends on (1) the severity of the infestation, (2) duration of feeding activity and (3) specific plant reaction to the stimulus of the insect secretion. Aphids may affect their host by sucking too much plant sap and thus devitalizing the host, secretion of a toxic or growth stimulating or retarding substance into the plant, introduction of virus or more generally a combination of these. In most cases the tissue abnormality is limited to a localized area of feeding. In other cases the toxic secretion may actually be systemic and symptoms develop at sites removed from the area of feeding.

The associations of insects with galls has been known for centuries. Aphids are among the many groups of insects capable of causing galls. The galls may or may not seriously affect the host plant. Little is known about the physiological and chemical factors associated with gall formation in the case of true aphids. With Phylloxera and Adelges, it appears that the gall may be initiated by indoleacetic acid.

The amount of plant sap that aphids remove from the host can be considerable. Through their stylets having food canals of 0.5u the aphid may be able to extract 1ul per hour. Thus a million aphids would extract a liter of plant sap per hour. Many small Douglas-fir trees will have a thousand aphids on their stem. Three year old Douglas-fir have a total displaced volume of only about 250 cc. Only a small portion of this will be phloem sap. A thousand aphids would remove 1ml. per hour.

What is the effect of aphid feeding on forest trees? There are many virus diseases of broadleaved trees that are undoubtedly insect transmitted. Phloem necrosis of elm may be one of these according to Baker. Virus diseases of walnut ash, locust, birches and so forth may well be transmitted by insects including aphids. There is only one record of suspected virus disease on a conifer. This was reported by Smolak in 1948 on Picea excelsa. Aphids feeding on the infected tree were suspected of transmitting the virus. Blattny (1956) was able to transmit the suspected malady experimentally with aphids.

Among the aphids infesting conifers, the spruce aphid, is probably one of the most serious. This insect has killed millions of board feet of Sitka spruce along the tidelands of the Oregon and Washington coast (Keen, 1952). This insect is also destructive to spruce stands in Europe.

The spruce aphid, through its feeding activity, causes chlorotic spots on the needles, which later turn entirely yellow then brown or violet just prior to the death of the needle which soon falls from the stem. The aphid, according to Kloft and Ehrhardt (1959) inserts its stylet bundles through the stomata on the under or upper side of the needle, intercellularly or intracellularly through the mesophyll tissue--the area where assimilation of food takes place, through the endodermis and then through the transfusion tissue and sucks in the lumen of the phloem cells near the heart of the needle. Even before there is noticable change of color of the needle, the aphid causes a destruction of the choloroplasts, apparently from some material injected into the cell by the aphid. There is considerable increase in respiration and decrease in assimilation in needles affected by the aphid.

Nearly every species of conifer is infested by a species of the genus Cinara. Graham (1939) states that when aphid infestation on young trees is heavy, the resulting damage can be great--usually in the form of reduced growth.

REDUCED GROWTH OF DOUGLAS-FIR SEEDLINGS ASSOCIATED WITH INFESTATIONS OF CINARA SPECIES (HOMOPTERA: APHIDAE)

By Norman E. Johnson

Abstract

Aphids of the genus Cinara are capable of causing serious growth reduction of Douglas-fir seedlings. Growth of infested seedlings may be only one-fourth to one-half that of uninfested seedlings. The aphids are easily controlled by injecting demeton around the base of the seedling. The presence of ants to clean up excessive honeydew is shown to be beneficial for the aphids.

MEALYBUG INFESTATIONS ON FOREST TREES

By

R.J. Washburn

I dare say most of you have never encountered widespread epidemic populations of a mealybug in your coniferous forests. Some of you may question that mealybugs can become an economic forest pest.

The fact is, after a rather exhaustive review of text and references commonly used by forest entomology students, it must be concluded mealybugs have not been considered a significant forest pest. An equally exhaustive review of technical papers and references on mealybugs for the most part reveals little more than some mealybugs have as their host forest trees.

Actually at least 25 known species in 11 genera feed upon forest trees in North America north of Mexico. Hosts for these mealybugs include nearly all of the western conifers as well as a good many of our decidious trees.

The only recent published record of damaging mealybug infestations on forest trees I could find was by H.E. Milliron in the August 1958 Journal of Entomology. In this paper he discusses an infestation of _Dysmicoccus_ _obesus_ damaging fifteen year old loblolly pine in Delaware.

Dr. Ross recently sent me a copy of an article to appear in the Canadian Bi-Monthly Progress Report on a _Puto_ _cupressi_ outbreak discovered last fall near Princeton, British Columbia. This is a first record of mealybug damage in interior British Columbia. The same species, however, has been recorded on Douglas-fir in Alberta. In fact the collection was made about 30 miles from Banff.

It is, of course, possible some of you may know of mealybug infestations or published reports that I am not aware of. If so, I would certainly appreciate hearing from you before this conference adjourns.

The purpose of this paper is to discuss the mealybug infestations we have in the Intermountain Region, to bring out their mode of attack, damage symptoms, extent of damage, and damage impact. In addition, I hope my little discussion will stimulate your awareness to the potential damage that can be caused by some mealybugs.

We have been plagued with serious infestations of a species of _Puto_ in high altitude Engelmann spruce stands in southern Utah for a good many years. We have recently completed the description of this species and have given it the name, _Puto_ _sandini_. The manuscript has been submitted to the Entomological Society for publication in the Annals.

Epidemic infestations of this pest were first discovered on the Fishlake National Forest in 1939, and had obviously been epidemic for several years prior to its discovery. The infestation has persisted and now covers about 10,000 acres which is the total acreage of spruce on the mountain.

A second, and much larger infestation, was discovered in 1953 on the Aquarius Plateau of the Dixie National Forest. This infestation covers over 50,000 acres. Both infestations occur between 10,000 and 11,200 feet elevations.

Briefly, the life history is as follows: Puto sandini has a four-year life cycle with progeny being produced ovoviviparously by mature females under the bark flakes on the bole of Engelmann spruce trees. Young are born in late August or early September.

Production of young appears to be tied to daily accumulation of temperature above 42° F. Progeny do not appear before the accumulated temperature reaches approximately 650°, but may not appear until daily accumulated temperature reaches 800°. The females die after progeny production is completed. Young remain under bark flakes until late September when they migrate to the base of the tree where they overwinter in the duff.

The young crawlers migrate from the duff sometime in May long before the winter's snow has melted. They move up the bole of the tree and onto the branches to feed on the needles. Feeding continues until about mid-July when the crawlers start to migrate back to the bole of the tree. Crawlers on seedlings migrate to the duff. Sometime in September the crawlers migrate back to the needles and feed. However, during this period feeding is intermittent and some crawlers can be found on the bole under bark flakes. In the latter part of September they again migrate down to the duff where they overwinter.

The next year, feeding, migration, and overwintering pattern is identical to the previous year.

Migration in May from the duff to the foliage is repeated the third year. However, feeding is discontinued the latter part of June. Females migrate to the bole of the tree and form a transparent pupae case that is not fastened to the bark. The females emerge about July 1, nearly 30 days earlier than the males. Male pupation occurs near the first of July. The pupae case is a conspicuous white cottony elliptical pod open at the posterior end. Pupae occur singly or in masses and can be found under bark flakes, along dead branches, and near the fascicle of older green needles. Males remain as pupae for approximately 30 days. Several days prior to emergence, wing tips and wax tails protrude from the open end of the pupae case. Winged males emerge near the first of August, seek out females, mate, and die.

By the first of September many of the females migrate to the needles and feed. The latter part of September they migrate to the duff, overwinter, and the following May crawl from the duff, migrate to the needles, and feed. In mid-June the gravid females migrate to the bole of trees and rest under the bark flakes. The young are born sometime in late August or early September, thus completing the life cycle.

Migration back to the bole of the tree for three of the four years starts between the 12th and 17th of July and is completed in 15 days. This migration is not related to daily accumulated temperature, but may be related to length of daylight and intensity of sunlight and/or temperature. Temperature records show maximum summer temperatures occur in mid-July.

Several years of successive feeding by epidemic populations of mealybugs can cause tree mortality. In addition, growth loss, crooked terminals, and limb mortality may be widespread in epidemic infestations.

The first visible indication of feeding by the spruce mealybug is copious sap flow from the branches during the summer of the second year of feeding. ________ During the third year of feeding the needles turn yellow. ________ By the end of the third feeding season the trees become conspicuous due to the yellow needles scattered throughout the infested trees.

In persistent epidemics a majority of the limbs and twigs become black from the formation of black sooty mold. The mold does not seem to form on the needles.

Our efforts to assess the damage caused by this mealybug are somewhat sketchy. For example, we know that many thousands of trees less than four inches DBH have been killed but we do not have accurate counts of this loss. On the other hand, we can show a decided decrease in increment production has occurred as a result of the mealybugs feeding within the epidemic on the Dixie National Forest.

The normal healthy spruce stands on this forest at 10,000 feet altitude contain 8,640 bd. ft. per acre. Growth loss due to the mealybug feeding equals 1,570 bd. ft. per acre for the thirteen years we calculate the infestation has been epidemic. On the total area infested on the Dixie National Forest, growth loss equals 1.4 million bd. ft.

Growth loss per acre per year amounts to 121 bd. ft. This may not seem like much to you who come from real timber producing areas, but within the highest commercial forest in the western hemisphere this loss nearly equals the average annual growth per acre. In addition to the volume loss in saw-timber there is outright mortality of seedling and small trees plus the deformity of young, growing stock.

Unfortunately we do not have similar data from our Fishlake National Forest infestation. In this infestation, logging was started shortly after the discovery in 1939. While logging did utilize a lot of infested sawtimber, it resulted in a much greater concentration of mealybugs in the leave blocks and small trees, particularly the seedlings, since the mealybugs readily move from fresh fallen trees to nearby standing trees.

The following slide should give you some idea of how this loss through mealybug feeding is manifested. This slide shows the accumulated growth for the period 1950 through 1963 DBH classes. The green bar represents the check or noninfested area, and the red bar represents the infested area.

The next slide shows the difference in growth between infested and noninfested by years. As you can see the six to eight inch DBH trees are more seriously affected than the larger diameter trees. That is -- the difference in increment width between infested and noninfested was the greatest. The larger diameter classes were less affected and their curves are somewhat similar.

Our other major mealybug infestation occurs near McCall, Idaho in the northern portion of our Region. The mealybug here is Puto cupressi (Coleman). This is the same beast recently reported by Doug Ross to be infesting a mixed conifer stand near Princeton, British Columbia.

In our area, Puto cupressi has been epidemic since 1957. The preferred host is alpine fir; however, white bark pine, and to a lesser degree, Engelmann spruce and lodgepole pine are also attacked. The outbreaks have followed a pattern of developing in a drainage, persisting for two or more years, then almost dying out, only to reappear in an adjacent drainage. Whenever heavy mealybug populations have persisted for three or four consecutive years, some alpine fir trees have been killed. At present, slightly more than 14,000 acres are infested.

The life history and mode of attack of this mealybug is considerably different than for Puto sandini.

Unfortunately there is much we do not know about Puto cupressi, but we do know they lay eggs instead of giving birth to living young, and have one and possibly more generations per year. In August, eggs are deposited in small circular cottony masses and are generally attached at the junction of twigs or at the base of the needles. Damage is caused by direct feeding and by black sooty mold that forms on deposits of the liquid sugary discharge of the mealybugs. Sooty mold is a fungus that forms over the surfaces of the needles. The mold is not a true parasite since it does not penetrate the cells of the plant but lives entirely on the surface and derives its nourishment from the secreted "honey dew".

The combination of mealybug feeding and black sooty mold causes the following damage:

General loss of tree vigor.
Atrophy of leaders.
Deformity of branches or main stems of small trees.
Crown thinning - twig and branch mortality, and finally after several years of successive feeding by epidemic populations, outright tree mortality.

Most of the trees killed in our infestations have been alpine fir and mortality has been greatest in trees under eight inches DBH.

These last two slides illustrate that not all of our mealybug problems are on forest trees. This infestation is seriously affecting elephant ear cactus, an aesthetic attraction in Zion National Park.

I suppose the logical question that should arise at this point would be: What can be done to minimize the damage caused by mealybugs? First, of course, the outbreaks need to be discovered in their early stages and their potential to increase, spread and do damage determined by careful biological evaluations. The task may be relatively simple or it may involve an unknown species that might require considerable investigation.

What about control? For the spruce mealybug, we have felt all along the introduction of insect predators and parasites would be our best bet. First, I should state that to the present, we have not found any native insect predator or parasite of the spruce mealybug. There are several avion predators but their controlling influence against epidemic populations have been nil.

After considerable investigation and assistance from specialists dealing with mealybugs on citrus, we imported a small colony of <u>Brumus saturalis</u>, a coccinellid native to Pakistan and other countries of the Far East. They were released in a large cage encompassing an eight-foot infested spruce. They readily fed upon the mealybugs but did not make it through the winter. We have explored the transfer of local colonies of <u>Hippodamia convergens</u>, but their habits were so well established, they quickly moved off the mountain. Our efforts in this field were very limited and ended in failure. Nevertheless, I am convinced the introduction of entomophagous insects offer real promise. It has certainly proved its value against mealybugs infesting citrus and other fruit trees.

Speaking of the spruce mealybug, we considered the most promise in direct chemical control would be through the use of systemics. Presently, however, systemics tend to be too toxic and expensive to use on forest infestations.

We did conduct some limited tests with the systemic, Thimet, using two methods of applications: tree injection and surrounding the tree with a ring of the granules. Evaluation of the effectiveness of the material was confounded by the migration habits of the mealybugs. Nevertheless, there was a significant population decrease on the treated trees for two consecutive years after treatment. However, until less toxic systemics are developed and more effective means to apply these materials over forest areas are devised, the information has little more than academic value.

As mentioned in my discussion on the Fishlake infestation, some attempt has been made to reduce loss through logging. However, several hazards are connected with logging. The main ones are: Concentration of the mealybug infestation on the residue stand, especially the young growing stock, and the hazard of dissemination to uninfested stands. In fact, on the Dixie National Forest, sawlogs from the infested areas are not permitted to be moved through noninfested spruce stands. Unfortunately, when I transferred from Research to the Detection and Evaluation Section, research in mealybugs was terminated in our Region. Certainly much more needs to be done.

In summary, I would like to stress these points: Little is known about mealybug infestations in our forests. Some species can build to epidemic populations, persist and cause extensive damage. Damage is usually quite subtle, and for that reason, infestations and resultant damage can be easily overlooked.

Introduction of insect predators and parasites may be the best way to control these pests. Logging, thinning, or other culture approaches to control should be investigated to determine adverse side effects before being attempted. Control through the use of systemics holds promise, but several problems need to be overcome before they can be used as a suppressive measure over widespread forest areas.

Finally, I would be amiss if I did not proclaim the timeworn, but justifiable claim that much more research is needed.

INFLUENCE OF MITES ON FOREST TREES[1]

Dr. David G. Fellin

Introduction

There have been at least four outbreaks of the spruce spider mite in the Rocky Mountains in the last 40 years, and all of them have been associated with the use of insecticides to control some other forest pest, in one case a combination of a sawfly and the pine tube moth, once the Douglas-fir tussock moth, and twice the spruce budworm. In the first instance lead arsenate was used and in the latter three the insecticide used was DDT. An interesting spruce spider mite outbreak occurred in shortleaf and loblolly pine in southern Arkansas and northern Louisiana in 1959. The infested area covered 10 million acres and was not associated in any way with the use of insecticides.

Fortunately all known mite outbreaks in forest trees have been short-lived. The largest known outbreak in the Rocky Mountains, that in Montana in 1957, covered about 800,000 acres in 1957 and was already down to 170,000 acres the following year. The one in the southeast apparently lasted only a year or so.

The general outward appearance of the forest, the tree, and the needles by mite feeding.

At the onset of mite feeding, affected conifers acquire an overall unthrifty appearance due to the removal of material from the needles by the feeding mites. Foliage of infested evergreen, as well as other types of vegetation, loses its deep green lustre and turn a dingy yellow, gray, dull rusty brown, or russet or bronzed color. Foliage generally appears dessicated; twigs are often so dry they can be broken with little pressure.

Often, whole stands of both large and small trees take on a brown sickly color but most often, as with other insects, there is quite a difference between trees and especially between larger and smaller trees in the general appearance of the tree following mite feeding.

It is of interest that older needles are often the first to be attacked. Injury is often first noticeable on the lower branches of the tree and evidence of injury spreads progressively towards the top. Interestingly enough, the same is true in cotton. The lower leaves are attacked first and the infestation spreads upward. If not checked, the entire plant may be defoliated but if the progress of the pest is checked, the health of the foliage is frequently restored and only a few leaves may be shed.

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[1] This paper is essentially a literature review; only a very small part of it represents original work. In the interest of space a section on cited literature is not included. Nevertheless, numerous authors of both published and unpublished work must be acknowledged for the majority of the data herein.

Each insertion of the mite stylet causes a discoloration, yellowing or chlorosis of the needle in the immediate area of penetration. These chlorotic or bleached and discolored spots are often interspersed with the normally green needle surface and present a stippled appearance often referred to as salt and pepper mottling. With only scattered feeding punctures the needles will apparently recover. However, when mite populations are heavy and chlorotic spots become more numerous and many cells are killed the needles will usually dehydrate and drop off, leaving the twigs and branches bare. In the 1959 outbreak on pines in the southeast it was reported that many trees lost most or all of their foliage as a result of mite injury. However, needles on other trees turned various shades of grayish-brown but apparently didn't drop.

A few observations on 30 Douglas-fir, 10 each at 3 locations in Montana over a 3-year period (1957-1959), may illustrate the progressive change in needles as a result of mite feeding. Relatively heavy feeding in any one year seemed to set off a change in foliage color which often ended with the needles dropping from the tree:

1. Needles that were green in any one year were usually yellow to straw-colored the following year.

2. Needles that were yellow to yellow-orange to straw- or rust-colored in any one year were nearly always brown to red-brown or even absent the following year. Some persisted even another year but many had dropped off by the second year.

3. By 1959 needle drop was severe on many sample trees. It was almost like being in the rain to stand beneath some trees and vigorously shake the limbs overhead.

The general appearance of conifer needles as a result of mite feeding is more or less the same as the appearance of leaves of various other plants after mite feeding. Oligonychus bicolor feeding on the upper surfaces of red oaks in Nova Scotia caused leaves to develop a speckled grayish color due in part to molt skins and webs. On cotton, each incision by mite stylets eventually cause a blackish spot and after much feeding the leaf becomes highly spotted beneath. At first, the spots are yellowish then blood-red to crimson, and later, if heavy feeding continues, the entire leaf turns rusty red, then brown and dries up. On various ornamentals, light mite infestations appear as a stippled pattern on the leaf. Later, the individual spots run together, the leaf becomes grayish-green in color, then yellowish, finally turns brown and drops prematurely. Both adults and nymphs of a tetranychid feeding on the under surface of soybean leaves cause speckling, stippling, bronzing, and, finally, abscission.

The general effect, cytologically and histologically to the needles of coniferous trees by mite feeding

I have found no reference to studies on the internal damage to needles of forest trees by mites. Since the symptoms are very similar to mite damage on broad leaves, and the mites generally belong to the same family, Tetranychidae; perhaps one can assume that the internal damage is at least similar.

Mite injury to plant leaves generally is quite like that done by piercing insects. The spruce spider mite and other tetranychids, feed by inserting their stylet-like mouth parts into the epidermal, palisade and mesophyll cells of the needles or leaves and extract the chlorophyll and various cell material.

Most often, on broad leaves, the feeding is done from the underside of the leaf. The primary damage often occurs in the palisade layer, beneath the upper epidermis. These parenchyma cells are punctured and ruptured, the contents of the cells are partially or completely withdrawn and the cells become shrunken, distorted, and collapsed. Only the cell walls are left, which appear as a disorganized mass. One difference here between the generalized structure of a broadleaf and conifer needle must be mentioned. A generalized broadleaf contains essentially 4 layers--from top to bottom, an upper epidermis, a layer of palisade parenchyma, a layer of spongy mesophyll and a lower epidermis. Compare this, then, with the structure of a generalized conifer needle--from outside inward, an epidermis, a hypodermis (interpreted by some as a palisade layer), an area of spongy mesophyll, and a endodermis which encloses a mass of transfusion tissue and the vascular bundles.

We can only assume, then, that mites feeding on conifer needles puncture the epidermis and do most of their feeding in the spongy mesophyll. Whether they penetrate the endodermis and feed also on cells in the transfusion tissue is not known. Nor is it known whether or not they feed on phloem cells in the vascular bundle.

In some cases observed damage by the feeding mites is confined to cells actually penetrated by the stylets, there being no loss of turgor in cells adjacent to those which had their entire contents withdrawn. In other cases, however, cells near the puncture are also affected.

In some tetranychids, the pharynx acts as a pump and is provided with muscles the contraction of which form a vacuum which results in the inflow of plant cellular contents. Under the scope, the appearance of these mites feeding is a discontinuous green stream of protoplasm moving up through the leaf tissue into the pharynx. This sucking action by the mite is probably aided by the turgor pressure of the cells which would cause an exudation of cell contents at the point of puncture. A tetranychid feeding on bean leaves can puncture and suck the contents from 18-22 cells per minute but this is apparently influenced by age of leaves and temperature.

The average area of bean leaf surface punctured by one mite in 24 hours was as follows:

	Young leaves	Old leaves
24°C	0.50mm^2	0.33mm^2
26°C	0.66mm^2	0.41mm^2
32°C	0.85mm^2	0.74mm^2

The chlorosis (or reduction of green color) can probably be essentially attributed to the destruction of chloroplasts, minute bodies (4-6 microns in diameter), often shaped like biconvex lenses. These chloroplasts are found especially in the cell cytoplasm of the assimilation and photosynthetic palisade parenchyma but also and most characteristically in the principal photosynthetic tissue, the mesophyll of leaves. They also occur in other green parts of the plant.

These chloroplasts contain the chlorophyll pigment, much protein and 30-40 percent of the leaf nitrogen. Hence, the needle suffers a loss of chlorophyll and a concomitant reduction of pigmentation, reduction of protein and a nitrogen deficiency, through the destruction and removal of the chloroplasts.

These factors, plus a certain amount of mechanical damage in turn affect the physiological functions of the needle. On bean leaves infested with Tetranychus telarius, injured areas often showed increased transparency, transpiration was greatly accelerated in comparison with water intake, dissimilation was increased and photosynthesis to a greater or lesser extent, inhibited. Respiration is often increased as well.

Needle chlorosis caused by the feeding of some sucking insects, notably aphids, is often attributable to the secretion of saliva and its injection into the needle. This probably complements the removal of material from the needle resulting in the chlorosis. Only one reference was found which reported that, through the use of radioactive tracers, a species of tetranychid mite was found to inject material into the plant tissue during feeding.

Do spider mites on forest trees, confine their feeding to the needles? Some adelgids, for example, feed largely on parenchyma tissue but they do apparently tap some phloem elements in young growing shoots. Whether this occurs with mites on forest trees is not known.

Stomatal entry has been reported for at least two aphids on conifer needles though aphids apparently rarely use this pathway. The pattern of damage and chlorosis, at least on Douglas-fir, indicates mites probably also only rarely use this as a means of entry to the needle mesophyll.

In general, then, what happens to coniferous trees following damage by spider mites as just discussed? Partial foliage loss no doubt causes a reduction in growth. In Montana in 1957 and 1958 the tree volume lost as a result of the mite outbreak was probably far more important than actual outright tree killing although some tree mortality may have occurred as a result of combined mite and budworm damage. Older trees may be able to withstand more feeding than younger ones. In instances of severe attack older trees may become severely injured and unsightly but may live for several years before deterioration is complete and the plant dies. Young trees or new transplants may be killed in a single season if the attack by the mites is severe enough. Right here in Alberta, for example, C.E. Brown reported the spruce spider mite caused serious damage to seedlings in nurseries in the late 1950's. In seed and transplant beds, heavy mite infestations so reduced the vigor of seedlings that they had to be left additional years in the beds to prevent high mortality once transplanted.

WORKSHOPS ON SPECIFIC FOREST INSECT PROBLEMS

Workshop No. 1

SEED AND CONE INSECTS

Chairman: J.A. Schenk

The 1964 cone and seed workshop began with a short discussion of the bi-annual cone and seed newsletter. It was generally agreed that the newsletter did serve a useful function and should be continued. In the opening discussion of sampling procedures, it was suggested that researchers should continually check their work areas in order to locate any "bad spots" that might influence sampling data. Population fluctuations of Conophthorus monticolae, Eucosma rescissoriana, and seed midges (Contarinia sp.) were very briefly mentioned also. It was generally agreed that physical factors such as temperature extremes were quite effective in insect control and that work with potentiometers, e.g. the "Rubicon" potentiometer made by Minneapolis-Honeywell Co., be encouraged.

In discussion of current studies and new species and ecological observations, the presence of Choristoneura fumiferana on cones of lodgepole pine was mentioned by Lorne Ebell. It was also noted by J.A. Schenk that Conophthorus monticolae enters at the base of the first group of cone scales and then continues up the cone axis rather than entering the base of the petiole as other species of Conophthorus.

Increased feasibility of systemic insecticides was discussed along with the general concensus that dye studies had very limited use in cone and seed insect studies. The concluding discussion centered on the benefits derived from ladder trucks and other apparatus in speeding up cone collecting.

Workshop No. 2

BARK BEETLES

Chairman: W.E. Cole

Cole opened the workshop urging the participants not to review projects as such but to brainstorm the theories, philosophies, and problems in their approaches and procedures. Rob Reid was then called on to lead off with his work on the biology of the mountain pine beetle.

Les McMullen brought out that the Douglas-fir beetle in his region is probably going through a 2-year generation. R.I. Washburn reiterated his experience in the same situation in southern Utah. In the latter case, the infestation collapsed during the second winter.

The longest discussion centered on predisposition factors of the Host Relations Section. Many entered in, each with his study and assurance of host attraction. In this Chairman's opinion, and in light of Stark's work, seasonal, and in particular daily, oleoresin pressures fluctuate so greatly that the theory of random fluctuations of cycles seems more fitting than host selections. In this theory oscillations determining population size (or attack density) need only be about as regular as would be expected of a random variable. Thus, the chance of any one tree being attacked is purely a matter of chance--that is, all factors occur coincidentally.

Nutrition was a short-lived but interesting discussion. Ed Clark's technique for rearing southern pine beetle was discussed--a lower humidity seemed to be the important factor. Nutritional requirements for minimum, optimum, and maximum brood development were suggested but little light could be shed. However, nutrition was believed to be of importance in the intra-specific competition for food and/or space.

J.M. Powell's bioclimatic study was discussed. The results might effect population dynamics and epidemiology. However, in Powell's absence no conclusions could be reached.

Bill Nagel's work with predators--especially evaluating the effectiveness, was brought out. This work is not far enough along for a full discussion.

Wygant presented Knight's work on woodpeckers--estimates of numbers and as a controlling factor.

Discussions on evaluations were short but lively. Washburn presented sampling by stages or months to develop life tables and when and how much mortality has taken place--Wygant favored a single sampling time. Roy Shepherd and Cole presented their respective sampling plans.

Workshop No. 3

DEFOLIATORS

Chairman: G.T. Silver

The informal workshop on defoliators was attended by about 15 persons including J. Clark and H. Brix. The presence of two tree physiologists presented an excellent opportunity to discuss the physiological aspects of defoliation. As few notes were taken during the workshop, the comments were summarized from memory.

The relationship between foliage complement and photosynthetic activity of different ages of foliage raised the possibility of evaluating defoliator outbreaks by the relative value of foliage lost rather than per cent defoliation. In this way the loss, expressed as a decrease of photosynthetic capacity, would theoretically be more closely related to the effect on the tree. J. Clark agreed that this would be an ideal method, but believed that it was too early to put into effect until more work had been done on the numerous factors involved, especially foliage distribution in crowns by species. It is obvious that a species such as red pine with a complement of three years' needles would have a completely different distributional pattern than say balsam or Douglas fir with eight or more years needles. Another problem is estimating the per cent loss of foliage; ocular estimates currently in use are a good indication of defoliation which has occurred, but such estimates could be crude if applied to photosynthetic activity by age of needles. Crown levels must also be considered; Sector A (the top 1/4 of the crown) is more important than the other sectors for recovery. Trees often recover rapidly even if Sectors B, C, and D are severely defoliated so long as Sector A is not seriously affected. Conversely, defoliation of the upper half of the crown has an immediate effect on radial growth and a rather lasting effect on tree vigour. Persistent defoliation of this kind generally kills the tree. It appears that several factors, other than the loss of photosynthetic capacity, are involved here. Clark believes that water uptake is badly disturbed which leads to partial drying out at the apex of the crown. Also, he feels that growth hormone production and distribution is severely affected by this type of defoliation. In general, growth substances seem to move downwards, seldom or at best very slowly upwards. Hence the defoliated apex receives less than its share of growth hormones.

The pattern of defoliation which apparently has a considerable effect on tree mortality and recovery is therefore related to the feeding pattern of the insect involved. Some species, such as the spruce budworm and the black-headed budworm normally cause severe top defoliation which results in heavy damage. An insect such as the saddle-backed looper, which feeds from the bottom up in such a pattern that there is complete defoliation in the lower crown sectors but the top sector is only lightly defoliated, could be helpful to tree recovery and the loss of 80 - 90% of the foliage less serious than if the feeding pattern was from the top down. The time of defoliation, e.g., early or late in the growing season, and the duration of defoliation, one year or five years for example, are also important factors, but the effect on tree survival varies between tree species.

H. Brix presented the theory that severe defoliation resulted in serious root damage, and this was indeed found so in studies carried out on spruce budworm defoliated trees in New Brunswick. Brix suggested that the degree of defoliation or damage to tree might be determined by root examination, the theory being that the number of root hairs and small absorbing rootlets would be appreciably reduced on heavily defoliated trees.

The physiologists presented a logical theory for delayed tree mortality. When a tree is severely defoliated there is usually a large reduction in radial increment as well as deterioration of the root system. Reduced radial growth and root damage may continue for several years. After the defoliator outbreak subsides the trees attempt to recover by refoliating, often putting out large crops of new leaves for several consecutive years. The sudden increased amount of leaf surface with subsequent transpiration and other requirements are too great for the damaged root system to supply. If the inbalance between crown and roots becomes too great, tree mortality occurs. The role of increment loss which reduces the amount of conductive wood in the tree is not thoroughly understood, but could be a factor. Another important factor is weather conditons; hot dry summers increase the amount of transpiration, and if the amount of water lost is greater than what can be absorbed by the damaged roots, death will occur.

In summary it was agreed that much could be gained by entomologists and tree physiologists working more closely together on common problems. If the physiologists know more about the field entomologist's problems, some of the answers could be obtained by small changes in existing projects. A starting point could be studies of the photosynthetic value of foliage of different ages for different tree species, and the effect of defoliation on root systems. Entomologists could assist by obtaining basic information such as the relative proportion of foliage by age for the different tree species, and by carrying out more intensive and extensive post infestation studies to obtain accurate data on tree recovery and mortality. There is no doubt that some of the problems in evaluating defoliator outbreaks can only be solved by understanding more about the tree itself.

Workshops Nos. 4 & 5

DAMAGE APPRAISALS AND APPLIED CONTROL

Chairmen: G.C. Trostle
R.E. Stevens

The workshop panels concerning "damage appraisals" and "applied control" were combined. There were about fifteen members in attendance. The following topics were discussed:

PERSON	DISCUSSION
Terrell	Methods of measuring damage by casebearer and spruce budworm.
Ross	Damage appraisals of Engelmann spruce beetle and Douglas-fir beetle. The use of Thiodan to control Contrarinia on Christmas trees.
Scott	Use of Malathion for control of spruce budworm. Use of "Micronair" (small amount of concentrated insecticide) for insect control.
Robbins	Problem of extensive surveys in areas of widespread damage--5,000 to 10,000 square miles of needleminer damage. Control of needleminer with Dimethoate.
Roettgering	Control of black-headed budworm with one-quarter pound DDT. Effects of DDT on aquatic insects. Use of recorder during aerial observations.
Wickman	Damage to Douglas-fir by other insects following defoliation by tussock moth.
Stevens	Use of Lindane in control of bark beetles in Ponderosa pine.
Lauterbach	Use of color photos for aerial photo plots for determining damage. Both current and over an extended period.
Trostle	Use of BHC to prevent attacks in heavy use areas.

Several other topics were discussed which added to the general knowledge of specific problems in local areas and the solutions which have been applied.

INFLUENCE OF FOOD QUALITY AND QUANTITY UPON INSECTS

Panel Chairman: J.A. Chapman

Insect Nutrition

by

A.J. McGinnis

There is little doubt that knowledge of human nutrition has benefitted mankind. Should it not be possible, therefore, to use knowledge of the nutrition of pest species to the detriment of the insects? As the problems associated with insecticide usage increase, the need for natural forms of resistance to insect pests becomes more pressing. Some forms of resistance may be detectable through nutritional and biochemical investigations. While such forms of resistance individually may not be adequate, by combining these factors in new varieties higher levels of resistance should be obtained.

Dr. R.H. Painter at Kansas State University, a pioneer in the field of plant resistance to insect attack, has classified the phenomenon under three main headings, tolerance, preference, and antibiosis. We are concerned primarily with antibiosis which he defines as "the adverse effect suffered by insects because of feeding on particular host plants".

What factors are involved in antibiosis? In our work three interrelated factors have been considered, deficiency, toxins, and balance. Deficiency is the absence or insufficient supply of a dietary component that is required by the insect. Toxins are natural components in the plant tissues that adversely affect the insect parasite (this type of resistance is best illustrated by the work of S.D. Beck and co-workers on the corn borer at the University of Wisconsin). The third factor, balance, is less easily defined. For both humans and farm animals, the importance of the proper balance between protein and carbohydrate has been well documented. More recently the importance of more specific balances such as those existing among amino acids in the diet has been demonstrated. Indeed, we have shown that by adding an excess of the essential amino acid leucine to an otherwise satisfactory diet, cutworm development was inhibited and mortality was high.

The problems of studying insect nutrition are numerous. Indeed rearing a new insect under laboratory conditions often constitutes a major challenge. Once the insect can be reared for even part of its growth period in the laboratory, nutritional investigations become practical. We have found the following three techniques extremely useful in our investigations.

1) Plant tissues that have been lyophilized and ground form the basis of good diets for some insects. Diets prepared from lyophilized tissues have the advantage of year-round availability, day-to-day uniformity, and offer the opportunity for altering the diet by either supplementation or extraction.

2) Most pest species cannot be reared on chemically defined diets, which is a prerequisite for determining the essentiality of dietary components by the classical deletion procedure. An alternative method employing a radioactive substrate such as glucose-U-C^{14} has been successfully employed with several insect species and has provided information on their needs for both amino acids and fatty acids.

3) It is frequently difficult to determine whether lack of growth and development results from too little food being consumed or from a nutritional defect in the diet. A procedure adapted from studies with large animals offers an indirect means of measuring utilization with insects such as cutworms and grasshoppers. The method employs an inert index compound such as Cr_2O_3, which is uniformly distributed in the diet at a concentration of about 4 percent. Consumption and utilization can be determined by measuring the concentrations of Cr_2O_3 in the food and excreta and making some simple calculations. This indirect method has been compared with the classical gravimetric procedure and offers a number of advantages.

There is little doubt that both quality and quantity of food have a definite effect upon insect development. While this paper has concentrated on nutrition of insects of agricultural importance, most studies of insect nutrition have certain problems in common regardless of the species under investigation. Perhaps some of the methods used and results from studies with agricultural pests can be of value in nutritional studies with forest insects.

Nutrition of Defoliators

by

F.H. Schmidt

Insect nutrition is a broad subject, which, in its broadest sense, includes factors which lead to the selection of suitable food material by insects, factors which determine whether or not a particular food or a portion of it can or will be utilized by them, factors which determine the minimum nutritional requirements for insect growth, development, reproduction and other special needs, and factors which determine the efficient utilization of available nutrients, or the degree of successfulness of an insect on a given food containing at least all of the minimum nutritional requirements. This breakdown applies to the nutrition of defoliators, or leaf-feeding insects, as well as to the nutrition of any other group of insects. Since a consideration of all aspects of the nutrition of defoliators would be too vast an undertaking in the time and space available on the panel, I have decided to restrict my remarks to the nutrition of defoliators as viewed from the aspect of host selection or specificity, and to make a few suggestions on how a forest entomologist can contribute not only to a solution of the cause of the host specificity of defoliators but to the utilization of this information in research on stand resistance to them.

Defoliators can be conveniently subdivided into three feeding groups, depending on whether they are more or less discriminating in their selection of host plants. Some, such as the hemlock and larch sawflies, will attack comparatively few host species, and may, therefore, be regarded as monophagous. Others, such as the spruce budworm and the lodgepole needle miner, will attack several but not a great number of species of hosts, and may be regarded as oligophagous. Still others, such as the hemlock looper and several species of tent caterpillars will attack a wide selection of different host species, and may be regarded as polyphagous. It is generally agreed that the cause of monophagy, oligophagy, and polyphagy - or host specificity - is largely due to chemical substances inherent to plants, which cause them to be either accepted or rejected by feeding insects. The result is that the insects are more or less restricted to the hosts on which they are usually found.

There are presently two extreme schools of thought on the basis of host specificity among phytophagous insects. Both of these agree that host specificity has, for the most part, a chemical basis. The point of divergence of the two hypotheses occurs when considering whether the fundamental basis of the specificity is attributable to primary plant substances or attributable to secondary plant substances. Primary substances are those found in large quantity (e.g. various sugars, proteins, "free" amino acids, vitamins etc.), are relatively few in number, have little smell or taste, and appear to be present in all leaves. Secondary substances are those found in small quantities (e.g. alkaloids, essential oils, specific glycosides, tannins, organic acids, etc.) are very numerous (thought to be in excess of 50,000) with a wide variety of chemical structures, have a distinct odor or taste usually, and are not present in all plants but are, rather, characteristic of plants of a certain genus, family or group.

One extreme school, that of Kennedy and his associates in England, believes, essentially, that host selection is based strictly on the presence of adequate primary substances within a plant. The factor determining which individual host is selected is the existence of a critical ratio of one primary substance to another, given other suitable conditions.

The other extreme school, that of Fraenkel and his associates in Illinois, believes that host selection is based strictly on the presence or absence of secondary substances within a plant. These are regarded as either "attractant" or repellent principles, but have very little, if any, other nutritional value. They express their principles in two distinct ways in their extreme cases. Either an attractant (or excitatory) principle can be present in all normal host plants, or a repellent (or inhibitory) principle can be present in all rejected plants. Intermediate conditions involving near threshold concentrations of these substances or mixtures of these substances, one effecting a masking of the other under certain conditions, are conceivable.

Workers in both extreme groups have presented convincing evidence in support of their views, particularly those supporting Fraenkel. The importance of many secondary plant substances in restricting certain insects to certain hosts is unquestionable. However, it is also unquestionable that all individuals within a population do not respond homogeneously to olfactory and gustatorial stimuli. This is due, in large part, to their being in variable physiological states, which is, in turn, greatly influenced by nutrition. It is probable that the basis for host specificity in most cases will fall between the two extreme explanations mentioned above, an insect being influenced in its selection of host plant by the presence or absence of secondary substances as well as by a given level of sugar or other primary substances.

What does this do to the defoliator problems that we as forest entomologists encounter every day? It means that the study of insect nutrition can offer some very real and important leads in developing insect resistant forests of the future. A study of the nutrition of leaf-feeding insects should not only tell us what substances are necessary for their growth and development and what concentrations and proportions are required, but it could also tell us why certain insects are restricted to certain hosts and not to others.

The presence or absence of all chemical plant substances among the various plants is governed by genetic principles. These principles also govern the concentrations of these substances found among plants within a species. Once we know what these chemical substances are that we are looking for and the concentrations necessary to bring about a given effect, these traits could therefore be genetically selected for. In the case of defoliators, the result will be the selection for foliage which will be more or less rejected by the insect pest with which we are concerned.

The detailed laboratory study of the specific nutritional requirements, both of primary and secondary plant substances, is still necessary for more or less obvious reasons. However, many of us can make significant contributions in this area without having a highly specialized background in insect physiology, nutrition, or biochemistry. A keen observer with a little knowledge and imagination could recognize a tree or limb that is more resistant to defoliator attack, and make use of this "sport", in horticultural jargon, as breeding stock in varietal development. Or he could call it to the attention of a geneticist. One of the most efficient ways to determine the nutritional basis of resistance to insect attack is through the use of resistant and susceptible "isogenic" pairs.

Another important contribution that many of us can make to the question of host specificity is to determine the potential range of host plants for a given defoliator in a manner similar to that of Yamamoto and Fraenkel (1960. Ann. ent. Soc. 53: 503-507) and Chin (1950. Tijdschr. Plantenziekten 56: 1-88). By force-feeding larvae under certain controlled conditions and by forcing adult females to oviposit on "exotic" plants, much indirect information could be gleaned as to the basis of specificity for the defoliator in question.

The goal of any program in the nutrition of defoliators should be the development of tree varieties that are resistant to insect attack, which must have been in the mind of R.E. Balch when he wrote in 1958, "Prevention is better than cure and the ideal solution is the creation of (insect) resistant forests."

Current Status and Future Of Nutritional Studies With Bark Beetles

by

Dr. W.D. Bedard

When seen from an ecological point of view, the future of nutritional studies with bark beetles looks very promising.

The present status of chmical nutritional studies with bark beetles can be grouped into three classes: 1) studies dealing with the identification of digestive enzymes; 2) technique studies aimed at developing a controlled environment, eventually a chemically defined diet; and 3) studies dealing with feeding stimulents or feeding preferences. The first group of studies show that beetles may be able to utilize most of the foods available to them except cellulose. These tests did not attempt to identify all the enzymes present nor did they attempt to evaluate symbiotic microorganisms as a source of the enzymes identified. In the second group of studies, chemically defined diets have been developed which are suitable for some adult feeding only. Diets for larvae still contain yeast (chemically undefined) and the more artificial diets produce low yields. In the third group of studies, sugars appear to act as token stimuli in the feeding of both the adult and larval bark beetles studied.

Past and present studies on the gross nutrition of bark beetles have shown that: 1) two qualities of host material may influence brood survival, water content and risk class; 2) quality of host material can influence the production of attractant; 3) beetle growth and development takes place in the absence of extracellular microorganisms which can be both harmful and beneficial to beetles in artificial environments; and 4) survival at low temperature is enhanced by feeding and food quality.

In the future, studies on the chemical nutrition of bark beetles could yield knowledge of what is optimal and tolerable chemical nutrition (including feeding stimulants etc.) for each stage of the beetle.

Once this information is available, we can investigate the role nutrition plays in determining variations in the biology and ecology of bark beetles. More specifically, we might be able to determine the influence of food quality and quantity on: 1) production of attractants; 2) attack density; 3) survival ratios (of both parent adults and brood); 4) developmental rate (of both parent adults and brood); 5) quality of offspring; and 6) associated organisms (both beneficial and harmful to the beetles).

Rearing Techniques and Artificial Diets For

Dendroctonus frontalis and Ips calligraphus

by

Dr. E.W. Clark

When commencing any intensive laboratory research on insects a requisite is effective handling and rearing techniques. The Forest Insect Physiology Laboratory at Durham, N. C., has developed or adapted collecting and handling techniques for these two beetles (Dendroctonus frontalis and Ips calligraphus), five rearing techniques utilizing either pine bolts or sections of inner bark and two artificial diets with accompanying rearing techniques.

The most important collecting-handling procedure exploits the bark beetles' strong phototaxis. Emergence collectors are made from trash cans or 50-pound lard cans by adding a Mason jar at the base of the can. Infested material is placed in the collector, all light is excluded except for that passing in the jar, and the beetles are collected as they mature and emerge. Tissue paper placed in the jar serves as support, footing, and concealment thus minimizing mutually inflicted injuries and also aids in handling the beetles.

The simplest rearing technique utilizes transparent, plastic breadboxes. Infested material can be placed in these boxes for development and procurement of adults, or beetles can be reared by confining adults in boxes containing fresh bolts. Another technique that has proved quite useful for observational studies is the clamping of sections of inner bark between plastic plates.

Two short-bolt techniques have been extremely valuable. In one technique a pair of beetles is imprisoned in a gelatin capsule cemented to a bolt and is used in such studies as behaviour, fecundity, and inbreeding vs crossbreeding. In the other technique 6-12 pairs of beetles are confined to a chamber constructed over the end of a bolt. This technique furnishes the laboratory with a constant source of eggs and young larvae which is of upmost importance in our nutritional studies and other physiological research.

Of major importance is the development of a continuous laboratory mass rearing technique for these two species, particularly for the southern pine beetle. In this technique adults are confined to the previously mentioned, modified, trash can which contains fresh pine bolts, hence rearing and collecting manipulations are combined for efficiency. To avoid excessive moisture a small amount of air is continually passed through the container. These beetles have been continuously cultivated at our laboratory for 18 months or about 15 generations with an average yield of 9 brood adults per 1 parent adult. The southern pine beetle culture has served the dual purpose of supplying all the beetles required in our research and simultaneously adding to our knowledge of this species through accurate detailed records, observations, and continual experimentation.

Two artificial diets have been developed, the first of which is composed of blended inner pine bark supplemented with yeast, carbohydrates, fatty acids, and protein source, and other ingredients. The second is a variation in which powdered cellulose has been substituted for bark. Bark beetles, flatheaded borers, and roundheaded borers, all have been successfully reared on the pine bark diet. In general growth, development, and life history have been normal. To date no oviposition has been obtained on these media either by freshly paired adults or older gravid females.

The carbohydrate requirements of the southern pine beetle on artificial media led us to start analyses of pine bark. At present carbohydrate, amino acid, and inorganic analyses are being conducted. This research on the natural diet has just begun and will take a considerable number of years to complete. We are not interested just in the nutritional constituents but in the interrelationships between the insect and its environment, the host and its environment, and how changes in one affect the other.

PREDISPOSITION OF TREES TO INSECT ATTACK

R.W. Stark, Panel Chairman

TERMS OF REFERENCE. -- K. Graham (read by R.W. Stark).

We are interested in the predisposition of trees to attack for three practical reasons:

1. Criteria of predisposition provide bases for identifying trees that have a high probability of being attacked--so that (a) they may be selectively removed, or (b) vigilance increased to keep insects down artificially if removal is not immediately practical.

2. Knowledge of predisposing causes and conditions provides guidelines for controlling or avoiding the risks of attack that come with stress caused by (a) crowding (= lack of thinning) or (b) exposure from overthinning or site deterioration or from (c) age. Also, knowledge of predisposing causes may serve protection by increasing vigilance when causes cannot be controlled.

3. Knowledge of specific susceptibilities provide the criteria for forest genetics to select for those specific chemical, physical, and biological factors which make a tree less susceptible to specific insects or groups of insects.

In the broader sense of tree physiology, the term "predisposition" may pertain not only to (a) inherent and induced attractiveness, but also to (b) easy invasibility, and (c) inclination to morbid response. Since our interest is largely practical, we must include (b) and (c) in the definition. In the ecological and silvicultural sense we must recognize also as factors in predisposition, the role of circumstances which increase the probability of insects converging on certain individual trees. The role played by circumstance must be recognized as a pitfall in the interpretation of experimental evidence, inasmuch as errors of interpretation could frustrate the purposes which we initially defined above. Certain trees may thus be more severly affected, not only because of characteristics within, but also because of non-tree factors which affect the distribution pattern of insects. Disparities in intensity of insect attacks may be simply the result of random distributions. Also, departure from the expectations of a random distribution, such that some trees are more and others less heavily attacked than randomness would produce, may be the result of aggregative factors causing statistical contagion. The recognition of these causes of differences in attack then bears directly on the choice and validity of criteria for assessing predisposition.

With these few remarks to introduce the topic we will present examples from current work which we hope will demonstrate some aspects of "predisposition."

Douglas-fir beetle. -- L. McMullen.

The following is a resume of some of the factors or incidences of predisposition of Douglas-fir leading to attack by the Douglas-fir beetle in British Columbia.

Douglas-fir beetle populations built up following severe winter injury during 1952-53 in the British Columbia interior region. Weather conditions during January, 1953 fluctuated widely within the range - 36°F to 34°F. During the first four days of February maximum temperatures reached the high 60's, with minimums in the 40's. This was followed by normal temperatures (max. 30's; mins. 10-20's). Heavy attack by the Douglas-fir beetle occurred during the warm spell in February. The explanation for similar damage during early spring thaws has been that excessive transpiration occurred with little or no water available from the frozen soil and/or water conducting elements in the bole, predisposing the trees to attack in a manner similar to that caused by summer drought. Perhaps also the warm period was enough to initiate physiological activity in terms of spring growth with consequent reduced resistance after return to normal weather conditions.

Weather can also provide a population pressure which is capable of overcoming trees which might otherwise escape attack. This may occur when climate affects duration of development and concentrates the emergence period of the beetles.

Windfall can act in various ways to affect the surrounding stands. For example, it can attract large populations of the insects, and also, populations can build up in the windfall.

Defoliation by the hemlock looper appears to be a factor pre - disposing Douglas-fir to bark beetle attack. A hemlock looper outbreak on Vancouver Island from 1944-46 resulted in tree mortality. Douglas-fir mortality occurred only in severely defoliated stands and in many cases had regained their full complement of needles before dying. However, in these heavily defoliated stands, trees with defoliation comparable to that in less severely defoliated stands died. All Douglas-fir trees killed contained Douglas-fir beetle. The beetle population probably built up in the most severely defoliated trees to the point where it was later successful in overcoming the recovering trees.

Finally, sudden environmental stress can cause serious stress to trees. Logging operations can change soil moisture relationships of trees along margins and roads. Moreover, the opening of the stand must have other direct effects on the trees.

The European pine shoot moth. -- H.J. Heikkenen.

This study explores the possibility that the resistance of red pine (*Pinus resinosa* Ait.) to attack by the European pine shoot moth (*Rhyacionia buoliana* (Schiff.)) is proportionate to site quality as measured by soil water factors. Since the introduction of this insect, red pine has been the most seriously damaged host. Entire plantations of this important tree species have been ruined.

Variations in tree damage have been observed. In this study these variations could not be attributed to the oviposition habits of the insect, as counts showed large numbers of eggs on adjacent lightly and severely damaged trees. The dating of old attacks revealed annual differences in the intensity of attack. Outbreaks appeared to vary in place and in time, associated with droughty sites and hot, dry summers, respectively.

The susceptibility of red pine to shoot moth attack was considered to be associated with the internal moisture stress of the tree. The possibility was investigated in Ottawa and Wexford Counties, Michigan. Tree growth, insect damage, and the accumulative soil water deficits were determined in 65 young red pine plantations growing on sandy soils. The data were analyzed by a step-wise multiple regression.

Reductions in the mean annual number of branches per whorl and the percentage of stem deformities were significantly associated with soils where the accumulative percentage of the available water capacity within the root zone dropped to approximately 40 per cent or less in July.

The amount of available soil moisture is influenced by the water-holding capacity of the root zone, precipitation, and evapo-transpiration. This study found the water-holding capacity of the root zone to be associated with the depth of rooting, which can be predicted if the degree of erosion, presence of a cemented hard pan, level of the water table, and the presence of texture-gravel bands are known. The water-holding capacity of the root zone determines where a susceptible host condition can occur. Shoot moth outbreaks do not occur where the root zone has a water-holding capacity of more than six inches. Perennial damage to the tree occurs on sites of less than two inches. Between two and six inches of water-holding capacity, outbreaks of the shoot moth can occur only when spring and early summer temperatures are above normal and precipitation below normal for two consecutive years.

The conclusion is drawn that when the needles of red pine are subject to moisture stress, early instar larvae are able to complete the needle-mining stage and then attack the buds. Thus the majority of damage occurs during the summer on poor, droughty sites. Red pine should not be planted on soils where the root zone will hold less than four inches of water. This condition occurs on soils eroded to the "C" horizon or the root zone is restricted to 18 inches by a hard pan, bedrock, or free water. Red pine will be occasionally damaged on soils where the root zone can store less than six inches of water. Damage can be avoided on these sites by not planting red pine where the roots will reach a depth of less than 78 inches. Shallow rooting occurs where a fluctuating water table is within six feet of the surface and texture-gravel bands do not occur within 10 feet of the surface. Where red pine is not recommended, more resistant species such as jack pine should be planted.

The western pine beetle. -- R.W. Stark

There are undoubtedly many factors which predispose host trees to attack by the western pine beetle. Because of time limitations I would like to discuss only one of the many--namely the role of oleoresin exudation pressure (o.e.p.) in tree vulnerability. Vulnerability is used in the strictest sense--liability to injury (if attacked) which condition may arise from various predisposing factors.

It has been postulated by various workers that a tree--ponderosa pine in this example--with a high o.e.p. (100 p.s.i. or greater) is relatively invulnerable and one with a low o.e.p. (less than 60 p.s.i.) vulnerable to beetle attack. Invulnerability in this case depends on the obstacles the beetle faces--large amounts of resin under pressure. Other characteristics of resin are recognized as being as important as or more important than pressure alone. Such include rate of crystallization, viscosity and toxicity of resin vapors.

The data I wish to present deals only with the role of pressure and is the result of three years' study in westside Sierra second-growth ponderosa pine stands. The pressures of about 700 trees were measured several times a year since 1961 and monthly and daily in 1963.

Pressures were arbitrarily divided into four classes: 0-5; 6-59; 60-99, and 100+ p.s.i. The first data from 1962 presented show that in May almost 74 per cent of the trees were in the lower two classes; in July this percentage dropped to 38 and in August rose to 49 per cent. The trees in the lower two pressure categories in August 1961 was 50 per cent. These data were substantiated in 1963 when the following results were obtained. The percentages of trees in the less than 60 p.s.i. classes were: May, 87 per cent; June, 53 per cent; July, 42 per cent; September, 47 per cent; December, 100 per cent. These illustrate a difference from earlier postulates and has an important bearing on the suitability of pressure measurement as a criterion for measuring stand vulnerability.

During the course of the study over 100 study trees were killed by the western pine beetle. These victims were classified according to the pressure reading taken prior to beetle attack. Almost 39 per cent of the trees killed were in the 60+ p.s.i. group. About 29 per cent were in the greater than 100 p.s.i. class. This apparently contradicted the postulate that high pressure trees were resistant. However, because of the large seasonal variation in pressure it was thought that daily pressure might also vary greatly.

The pressure of selected high pressure trees was measured over a 24-hour period each month. It was found that diurnal pressures did fluctuate markedly and this may be a critical factor in insect attack. For example:

At 6:00 a.m. tree A read 110 p.s.i.; at noon, 17 p.s.i.; at 6:00 the following day, 80 p.s.i.

Tree B read 109 p.s.i. at 6:00 a.m.; 14 p.s.i. in mid-afternoon, and 134 p.s.i. the following morning.

There were many such examples. The point that this illustrates is that the usual early morning measurement does not demonstrate the actual pressure state of the tree at a time when the beetles are active. The lowest pressures occur in mid-afternoon when beetle flight is usually at a peak and a "high-pressure tree" may be in a vulnerable state, "low pressure", when attacked by the western pine beetle.

I have deliberately avoided any discussion of the governing factors of resin pressure. As these are associated with the water relations of the tree many of the findings reported here could be anticipated. The magnitude of the fluctuations was surprising in view of previous work and is of considerable importance if pressure were to be considered in some type of stand vulnerability rating.

MINUTES OF FINAL BUSINESS MEETING

March 11, 1964

The Chairman called the meeting to order at 1:30 p.m. in the Solarium, Cascade Hotel, Banff, Alberta.

P.G. Lauterbach moved that reading of the initial business meeting be dispensed with. Seconded. Carried.

Chairman K.H. Wright briefly discussed the items of business arising from the initial business meeting, as follows:

1. Meeting sites

1965 - Denver, Colorado
1966 - Victoria, B.C.
1967 - Ogden-Salt Lake City area

An invitation to hold the 1968 Work Conference at Juneau, Alaska was extended to the members by Don Schmiege.

2. Meeting theme

Topics suggested for the 1965 meeting at Denver were: (1) Effects of pesticides on wildlife and other forest organisms, and (2) Economics of control, or a combination of these two themes. Some members felt these topics were too restrictive for a joint meeting but all agreed that they would serve as a broad framework for the 1965 Program Committee.

3. Joint meeting with Central International Forest Insect and Disease Work Conference - 1965

Chairman Wright outlined the proposal for a joint meeting and subsequent follow-up. F.E. Webb asked that our group make the initial program proposal to the CIFIDWC. He urged that the programme theme be of general interest and practical in scope. Liberal use of the workshop format is urged by the Executive.

By lengthening the program to four days at the Denver meeting, more time could be allowed for personal communication. The 1965 Program Committee will decide if the additional time is necessary.

4. Joint meeting with the Western International Forest Disease Work Conference

Plans for this joint meeting at Victoria, B.C., in 1966 were discussed. The Chairman of our group is directed to correspond with the pathologists to inform them of our decision and to arrange details of program and planning.

5. Program format

Discussion of the workshop technique followed. Concurrent sessions should be kept to a minimum. However, fewer workshops mean larger groups. Limit size of workshops. Perhaps a panel approach might be followed by a discussion session in large workshops.

6. Foreign translations

A committee consisting of M.M. Furniss, Chairman, J.A. Schenk and J.A. Chapman, members, was appointed to explore the need and desirability of procuring translations of foreign works dealing with forest entomology. The committee will report at the 1965 Work Conference at Denver.

7. Standing committees

a. Common Names Committee

Chairman P.C. Johnson reported that the Committee is still undecided as to what to do about common names for newly erected members of the genus Dendroctonus. Until such time as it receives direction from the Executive, this Committee will continue to operate under the Executive's instruction to postpone action on Dendroctonus for the present.

The Committee recommends that the Conference Chairman appoint two new members to replace V.M. Carolin and N.E. Johnson whose terms expire with this meeting.

P.C. Johnson advised the members that his Committee has drawn up a new form for the proposal of a common name. He also urged that members be aware of the need and method of suggesting a common name.

b. Education Committee

The Committee recommends that Ron Stark's review of Dana and Johnson's book entitled, "Forestry Education in America Today and Tomorrow," be published in the Journal of Forestry or other suitable periodical. Editorial comments on Stark's review are solicited. No action was taken.

c. Ethical Practices Committee

The report was given by the outgoing Chairman, G.T. Silver. Many new members were considered for chairmanship and the hard choice was made--Don Dahlsten for his admirable performance with Bison bison bison in the paddock.

8. Special committee reports

A special committee was constituted at the initial business meeting to study the impact of S.L. Wood's revision of the genus Dendroctonus. The Committee, composed of C.L. Massey, Chairman, P.C. Johnson and G.R. Hopping, members, reports as follows:

"In the opinion of the Committee, Wood's monograph of the genus Dendroctonus must be considered valid. It is also the opinion of the Committee that it is the prerogative of individuals working with the insects of this group to disagree with the species concepts as put forth by Dr. Wood, but that the burden of proof rests with these individuals and that the changes which they propose must be published with documented proof of their validity."

B.M. McGugan reported that J.B. Thomas' work on immature forms of the genus Dendroctonus largely confirms S.L. Wood's species.

R.E. Stevens moved acceptance of the special committee report. Seconded. Carried.

9. Directory of forest entomologists

K.H. Wright reviewed the background on the proposal to compile a directory of forest entomologists in Canada and the United States. H.J. Heikkenen asked the Chairman to determine the Conference members wishes. In discussion that followed it was pointed out that this directory would duplicate some others and was, therefore, unnecessary and a great deal of work.

B.H. Wilford moved that the Western Forest Insect Work Conference go on record as disapproving in principle the establishment of such a directory of forest entomologists in Canada and the United States. Seconded. 14 yeas. 18 nays. Motion lost.

To bring the matter to a head, N.E. Johnson moved that the Western Forest Insect Work Conference does not support in principle the establishment of a directory of forest entomologists in the United States and Canada, but the Conference does not object to members completing forms if some agency sponsors compilation of the directory. Seconded. Carried.

The Nominating Committee reported the selection of the following slate of candidates:

Chairman - - - - - - -J.M. Kinghorn
Secretary-Treasurer - A.F. Hedlin
Councilor - 1966 - - F.M. Yasinski

No nominations from the floor. B.H. Wilford moved nominations be closed. Seconded. Carried.

The candidates were elected by acclamation.

Move to rescind a 1963 motion to continue binding and distributing survey reports made by F.W. Orr. Seconded. Carried.

Dr. J.B. Simeone assessed the 1964 Work Conference. He felt the breadth and depth of the papers and workshops were good. He thanked the Conference for the invitation to this Conference and expressed hope that he would be able to attend future Work Conferences.

B.M. McGugan discussed the FAO meeting to be held at Oxford University following the Entomology Congress at London this summer. The program will deal with pathological and entomological subjects.

F.E. Webb expressed his appreciation for having been invited to the 15th Annual Work Conference and stated the Central International Forest Insect and Disease Work Conference looks forward to the joint meeting in Denver in 1965.

The fine work done by the calgary group in arranging the 1964 Work Conference was recognized by Chairman K.H. Wright. Special acknowledgement was given Roy Shepherd for the program; Rob Reid for arrangements; Cliff Brown for finances; and George Hopping for transportation.

Meeting adjourned 2:45 p.m.

THE BUG MEN [*]

(To the tune: Mocking Bird Hill.)

1. There are men in this country
Who study the bugs
The bugs in the tree stumps
Not the ones in the rugs
They travel all over
Seeing what they can find
And try to discover
Where the bugs all have dined.

2. If you want to see Hopping
Just hopping about
The five spined engraver
Can make him fair shout
There are all kinds of beetles
Ask Ray, Mac and Mike
And moths too are plenty
They do make a sight

Chorus: Tra la la tweedle dee dee dee
They act just like thieves
And when they get real hungry
They chew off the leaves
Tra la la tweedle dee dee dee
They come to the park
And then they get all settled
And chew off the bark.

3. There's a thing called the looper
Just ask Mr. Clark
It attacks the big Hemlock
All over the park
Val Carolin tells us
They come in the Spring
And chew them to pieces
And then they take wing.

4. There's a worm called the budworm
Which has a black head
And a guy named Tom Silver
Wishes they were all dead
There are flatheaded borers
Roundheaded ones too
They get on the leaves and bore holes
Through and through.

Chorus: Tra la la tweedle dee dee dee
We must do our best
To send these awful critters
Right out of the West
Tra la la tweedle dee dee dee
If everyone tries
We'll make our stately forests
As bright as the skies.

---

[*] Composed and sung at W.F.I.W.C. annual banquet, Banff, Alberta, 1964, by the "Choral Belles" of Calgary.

MEMBERSHIP ROSTER

WESTERN FOREST INSECT WORK CONFERENCE

Note: Active members registered at the Conference in Banff, Alberta, March 9 - 11, 1964, are indicated by an asterisk (*)

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Western Forest Insect Work Conference 4(a)

PROPOSAL FOR COMMON NAME

Date ____________________

The undersigned recommends the adoption by the Conference Committee on Common Names of Western Forest Insects of the common name hereinafter proposed (see "NOTE"):

1. Proposed common name ____________________________
2. Scientific name of the insect ____________________________

   Order ____________________; Family ____________________
3. General reasons for proposing this common name:

   a. Economic importance ______ d. Already in general usage ______
   b. Striking appearance ______ e. Other (explain) ______
   c. Abundance ______
4. Proposed by (Dr., Mr., Mrs., Miss) ____________________________
5. Address ____________________________

INFORMATION SUPPORTING THE PROPOSAL

6. Metamorphic stage(s) to which the proposed common name applies:

7. Characteristic appearance of the stage(s) to be named, if proposed common name is to be based on this appearance:

8. Habits of the stage(s) to be named, if proposed common name is to be based on these habits:

NOTE: Before submitting this form, the proposer is urged to familiarize himself with the following references:

METCALF, C. L. 1942. Common names of insects. Jour. Econ. Ent. 35(5): 795-797. (editorial).

ANONYMOUS. 1953. An appeal for a clearer understanding of principles concerning the use of common names. Appendix to the proceedings of the 64th annual meeting of the American Association of Economic Entomologists, Philadelphia, Penn., December 15-18, 1952. Jour. Econ. Ent. 46(1): 207-211.

LAFFOON, JEAN L. 1960. Common names of insects approved by the Entomological Society of America. Bul. Ent. Soc. Amer. 6(4): 175-211.

FURTHER INSTRUCTIONS: Complete this form in duplicate. Send to Conference Secretary or to Common Names Committee Chairman.

CNC Form 1 (1/1/64)

Western Forest Insect Work Conference 4(b)

RECORD OF ACTION ON PROPOSAL FOR COMMON NAME

Common name proposed ______________________________

Scientific name of insect ______________________________;

Order ____________________; Family ____________________

Proposed by ______________________________

Address ______________________________

VOTING RECORD OF COMMITTEE MEMBERS

Committee Members	Proposal approved	Proposal rejected

FINAL ACTION

	Approved	Rejected	Date
WFIWC, Committee on Common Names			
WFIWC, Membership at large			
ESA, Committee on Common Names			

WFIWC Committee Chairman Date ____________

CNC Form 2 (1/1/64)