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THE DYING BALSAM FIR AND SPRUCE IN MINNESOTA

By S. A. Graham, Division of Entomology and Economic Zoology

Minnesota forests are suffering from an insect epidemic which has already done inestimable damage. Much of the balsam fir and a part of the spruce, comprising a considerable portion of our northern forests, are dead or dying. The loss has been caused and is being caused by the spruce or balsam budworm *Tortrix fumiferana* Clem. Altho this pest is commonly called the spruce budworm, the name is not entirely appropriate, as spruce is only the worm's second choice as a food plant. The favorite food of the insect is the balsam fir; therefore it is referred to here as the balsam budworm.

Only a few years ago we were congratulating ourselves upon the fact that the outbreak of the budworm, which has caused such tremendous damage during the last 10 or 15 years to the coniferous forests of Maine and Eastern Canada, had failed to reach Minnesota. In fact, we felt that our forests of fir and spruce were comparatively safe, since the eastern outbreak was making but little progress toward the west.

But even as we congratulated ourselves upon our immunity, the budworm was becoming epidemic within the borders of our state, and is now just as destructive here as in the forests of Maine, New Brunswick, and Quebec.

This bulletin is not written primarily with the idea of presenting new facts as to the activities and control of this insect. It appears, however, that the budworm is becoming such a serious pest, and that the results of its attack upon our forests are so far reaching in their effects, that a summing up of the present status of the problem is desirable. The experience and findings of eastern workers will be supplemented by what data have been collected on the Minnesota situation, thus summing up the available information in one publication.

EFFECT OF THE BUDWORM OUTBREAK ON THE PAPER INDUSTRY

Balsam fir has in the past been regarded as a weed tree in our forests, and any factor which might bring about its destruction would have been greeted by many as a beneficent force. Today balsam stands second only to spruce for the production of wood pulp. Each year the pulp mills have been accepting larger and larger proportions of this species for use in the manufacture of paper, until now they are largely depending upon balsam to supplement the reduced amount of spruce and thus provide a permanent supply of accessible timber necessary to the industry.

Some idea of the magnitude of the loss resulting from this outbreak may be gained from the reports of damage in Quebec and New Brunswick. A careful survey of conditions in New Brunswick has been made by the Provincial Forestry Department. This survey showed that 80 per cent of the total forest area of the province was involved in the outbreak of the budworm. In 30 per cent of this area it was found that 30 per cent of the spruce and 100 per cent of the balsam had been killed. Even the reproduction was seriously injured during the final years of the attack.

The total amount of balsam fir killed in the province of New Brunswick was estimated at 6,000,000,000 feet, board measure, or 12,000,000 cords. The spruce killed amounted to 1,500,000,000 feet, board measure. Balsam fir and spruce comprise 45 per cent of all the standing timber in the province and 75 per cent of the annual cut. Thus the importance of these two species to the industry in that locality is evident.

Balsam fir deteriorates very rapidly, and must be cut and used almost as soon as it is dead if it is to be saved. Already 80 per cent of the balsam in New Brunswick is beyond the possibility of salvage. Spruce is more durable and for this reason it will be possible to save at least a part of the killed trees of that species before they have greatly deteriorated. The amount, however, is limited by the capacity of the drivable streams in the infested region. It is estimated that 800,000,000 feet, or 55 per cent, of the killed spruce is the maximum amount that can be removed during the next five years.

In Quebec the loss due to the budworm in the last ten years is estimated at 150,000,000 cords of standing pulpwood, which if manufactured into paper would have a value of at least $7,000,000,000. This is said to represent a loss in wood sufficient to supply the North American continent with news print for 45 years.

During the season of 1919 the writer, in employ of the Canadian government, was engaged in studying regions devastated by the balsam

budworm. In the course of this work extensive areas in both Quebec and New Brunswick were covered. This experience makes possible an intelligent comparison of the infested areas of Quebec and New Brunswick and the injured area in Minnesota.

It appears from general observations and from data gathered on a few sample plots scattered over the infested region, that the outbreak in Minnesota is very similar in character to that in the east. The loss in wood acre for acre is in all probability nearly the same in this state as in New Brunswick.

There are no accurate available data showing the area of balsam spruce forests in this state and the estimates which have been made vary greatly. The United States Forest Service estimates that in Minnesota there are 4,000,000 cords of spruce, and that in the Lake States the balsam fir totals only 3,400,000 cords. These figures were based on data furnished by operators and estimators and not on an actual survey. As much of the balsam fir in this region is not large, and as it has not been considered a valuable species, it is quite probable that a large proportion of the standing balsam fir has been omitted in these estimates.

The state survey of cut-over lands which is now under way indicates that in fourteen townships in eastern Lake County the balsam fir averages ten cords per acre, or 3,200,000 cords for this comparatively small area. From this it would appear that the estimate of 3,400,000 cords for the Lake States is much too low. Data collected by the State Forest Service indicate that the total stand of balsam fir in Minnesota amounts to at least 30,000,000 cords.

When we consider the large proportion of the forest area in the three northeastern counties upon which balsam fir is the predominant species, the higher estimate does not seem excessive. The bulk of the Minnesota balsam fir is in the infested area where at least 75 per cent will succumb to the budworm attack.

In view of the rapidly approaching shortage in spruce and the importance of balsam as a substitute, such a loss as this is a catastrophe. In the east the operators realize, at least in part, the magnitude of the disaster, as they see an immediate shortage of raw material ahead of them. The interest of this group is indicated by the great demands for help made by them upon entomologists, by the many articles regarding the budworm and its work which are appearing in the trade journals, and by the fact that a prize of $5000 has been offered by a Canadian conservationist for suggestions on the control and repression of the balsam budworm. In Minnesota the spruce shortage is not yet felt with sufficient force to bring home to the

operators the full importance of the loss of our balsam forests. However, it can be only a few years, at most, until a realization of this loss will be forced upon them.

EXTENT AND PROGRESS OF THE OUTBREAK IN MINNESOTA

The boundaries of the budworm outbreak in Minnesota have not been determined exactly, but the approximate extent is known.

The insect is spreading from the west toward the east and has almost reached the most easterly tip of the state. Practically all the forest area lying north of Lake Superior is infested. The eastern boundary of Koochiching County marks approximately the western boundary of the outbreak and it extends northward into Canada.

The center or centers from which the insect spread are not known. It is quite possible that this outbreak may have had its origin across the Canadian border. Examination of the annual rings of surviving balsam fir trees on the Wales Branch of the Duluth & Iron Range Railroad showed that the outbreak in that region began about 1915. That part of the outbreak is now over. North and east of Grand Marais the budworm is still actively working. A line that would approximately divide the balsam which is still alive from that which has already been killed might be drawn from Lake Superior at a point slightly west of Grand Marais northward to the Canadian boundary.

RESULTS OF OUTBREAK IN SPRUCE STANDS

Pure stands of spruce are for the most part exempt from budworm injury even in the most heavily infested regions. In mixture with balsam, however, spruce may be severely injured or even killed. Observations indicate that in mixed stands containing a large proportion of balsam the spruce is likely to be defoliated. Spruce as a rule is better able to recover from defoliation than balsam fir, owing in part to the greater number of its adventitious buds and in part to the greater vitality characteristic of the species. Thus we should expect that the injury would be much less severe on spruce than on balsam. This is actually the case and holds true in practically every stand observed. In some localities, however, spruce suffers much more severely than in others, even in stands of practically the same composition. Apparently the explanation of this condition is to be found in the comparative vitality of the trees growing on different sites. Spruce growing on thin, rocky soil, for instance, is much more susceptible to injury than the same species growing in favorable locations, as the vitality of the trees is lowered and they are therefore less able to survive the additional handicap of the budworm defoliation.

The spruce in Minnesota is not known to have been injured to any considerable extent by the budworm, but as observations in the injured region have been limited, it is quite possible that further work will modify this statement materially.

LIFE HISTORY AND HABITS OF THE BUDWORM

In order to discuss more intelligently the activities of the budworm, it is necessary to consider briefly the life history and habits of the insect.

The adults are inconspicuous grayish-brown moths with a wing spread of about three quarters of an inch. They appear in Minnesota in July. In 1922, many were flying from July 10 to 20. It is during this period that the eggs are laid. The moths congregate on the balsam fir and spruce and seem to prefer to rest and lay their eggs on the top parts of the trees. This habit may be due to the more suitable conditions of light which the moths find in such places. The moths may occur in such large numbers that they resemble a storm of grayish snowflakes whirling around the treetops.

The moths prefer to deposit their eggs on balsam trees. The larvae which soon hatch from these eggs apparently do not feed until the following spring. During the fall and winter they are hidden away in convenient crevices, usually on the tree upon which they hatched. For protection a thin silken web known as the hibernaculum is spun about each tiny larva.

In the spring, just as the buds of the balsam fir are expanding, the larvae emerge and begin feeding upon the fresh and tender foliage of the expanding balsam shoots. During the early stages they can only feed upon fresh foliage; therefore at that season of the year they are forced to feed almost exclusively upon balsam, as the spruce does not open until after they have been out of hibernation and demanding food for one or two weeks. The larvae hatching from eggs deposited on spruce find feeding conditions unfavorable during the first part of the season, and many of them drop by a thread and are blown by the wind to nearby balsams.

This habit of dropping on a silken thread makes it possible for the larvae to travel from tree to tree without touching the ground even though they have no wings. When a larva consumes all the food on one twig it drops from that twig and is blown to another, perhaps to another tree. After the early stages the larvae are not quite so exacting as to their food requirements and are then distributed over both the spruce and balsam fir.

The emergence of the budworm at the same time that the balsam buds open, and the requirements of the small larvae for fresh tender

foliage, doubtless explain the exemption of pure stands of spruce from injury.

The feeding period of the larvae is short, three weeks being as a rule sufficient for larval development. They then transform to the pupal stage upon the trees. The adult moth emerges during the first half of July and after mating begins to lay eggs. Thus the life cycle is completed.

THE COURSE OF AN EPIDEMIC INFESTATION

The balsam budworm is a native insect and is generally distributed throughout the range of its host plants. Usually it occurs in such small numbers that its work is not at all noticeable. In fact, the signs of its presence are never conspicuous until the larvae occur in sufficient numbers to defoliate the trees to some extent.

Under conditions favorable for budworm development, this normally harmless insect increases in numbers almost beyond belief. Then we have an epidemic infestation. During the first years of such an outbreak the trees are covered with browned tips the latter part of June and July, the stand appearing as tho a light fire had run through the crowns.

In succeeding years the trees become covered with dead and dying twigs. Frequently the top of the tree will be killed before the whole tree dies. After from three to five years most of the balsam fir in the stand is dead or dying and the spruce is often severely injured.

At this stage the destructive work of the budworm is usually supplemented and hastened by the attack of secondary insects which work beneath the bark of injured and weakened trees. The most common species engaged in this secondary work are the balsam bark beetle (*Pityokteines sparsus* Lec.) and the balsam bark weevil (*Pissodes dubius* Rand.). These two insects are commonly found in the injured forests of northern Minnesota and also in the devastated regions of Quebec and New Brunswick.

Three successive years of defoliation are sufficient to kill a part of the balsam in the stand, but after the third year the death rate is more rapid. The death of these trees reduces the amount of food available for the increasing number of the budworm larvae. Finally, usually in from five to seven years, the green balsam foliage has been reduced to such an extent that there is not sufficient available food to bring the budworm larvae to maturity. As a result they starve, having literally eaten themselves out of house and home. This marks the end of the epidemic.

FIRE HAZARD MATERIALLY INCREASED

The dead balsam fir decays rapidly at the base and in a few years falls to the ground. Where large areas have been killed the amount of dead material both standing and fallen is very great. In many cases the dead trunks lie one on top of the other like giant jack-straws. As this wood burns readily, the danger of forest fires in the devastated area is very materially increased.

The difficulty of fighting fire in such a locality is very great. The large amount of dry wood makes a hot fire that runs rapidly and is difficult to extinguish. Also, it is difficult to keep trails and roads open through a stand killed by the budworm, as trees are continually falling and blocking the way. Therefore it is often impossible to get to a fire quickly. Because of the tangle of fallen trunks it is often impossible to establish a line across the front of a fire, and as a result fires in such places are likely to be uncontrollable. Clearly the increased fire hazard is one of the effects of a budworm outbreak which can not be disregarded.

CAUSES OF AN OUTBREAK

The causes leading to an outbreak of the balsam budworm are not very clearly understood. It is certain, however, that an outbreak results from the action of certain natural laws which are universal.

For years the budworm lived in our balsam and spruce forests as an inconspicuous and practically harmless resident. Its enemies destroy the excess number so that the normal number of budworms is maintained. Thus we have a balance between the trees and the insects Sooner or later this balance may be disturbed by some change in conditions favoring the budworm, when it may increase rapidly in numbers and become epidemic. Not all the factors involved in bringing about such an epidemic are known, but an outbreak is almost always preceded by some change in the character of the forest, which is accompanied by less conspicuous but none the less important changes in both animal and plant life and the balance in the forest is temporarily disturbed. Sample plot studies in Northern Minnesota show that the greatest injury to the balsam fir occurs where the balsam has superseded other species and is growing in pure or nearly pure stands. In mixed stands the injury is often not more than 50 per cent of the balsam while in pure stands the loss is usually about 100 per cent.

This fact leads us to believe that the formation of pure stands of balsam favors budworm development. Several causes may be involved, but two factors are obviously important:

1. In pure stands of balsam or in balsam-spruce stands we find few birds as compared with the numbers living in the mixed forest. Doubtless the birds prefer the mixed forest because of the greater variety of

food found there. Thus a factor limiting budworm reproduction in mixed stands is reduced or lacking in the pure stand.

2. In the pure stand of balsam every tree provides suitable food for the larvae of the budworm, but in the mixed forest the food trees are scattered and many doubtless lose contact with their food and perish.

It is a universal law of nature that an organism if unrestrained will increase to the limit of its food supply. Thus the budworm when it is supplied with a super-abundance of food reproduces at an enormous rate.

Whether or not this explanation of the possible cause of a budworm outbreak is correct, the fact remains that this insect breeds much more rapidly and becomes much more injurious in pure than in mixed stands. This is true under conditions in eastern Canada and in Minnesota.

DIFFICULTIES OF ARTIFICIAL CONTROL

The use of artificial methods commonly applied in the control of farm and horticulture pests is impractical or actually impossible in a forest. Under farm or orchard conditions the most generally used means of checking the ravages of leaf-eating insects is to spray or dust the infested plants with a poison, usually an arsenical. This is a very effective and economical means of controlling defoliation if the crop involved is one which produces an immediate revenue and if the infested crop is accessible for prompt and thoro treatment. Neither of these conditions holds in the forest. Many years are required to produce a crop of wood, during which time the interest on the original investment and on operating expenses is being compounded. Under such conditions a small first investment and low operating cost are essential for the financial success of such a project.

The latest experiments in applying poisons to woodlands for the control of leaf-eating insects are now being carried on in Ohio and New Hampshire. In this work airplanes are used to distribute poison in the form of a dust over the forest. By this means it is possible to cover considerable areas in a very short time, but the cost of materials and application is still too high for general forest control work. Development along this line is still in its infancy and it is possible that cheaper effective poisons may be found and more economical methods of application may be developed, but we still know little or nothing as to the effect of extensive application of poison upon the forest life in general. The trees, undergrowth, and ground would unavoidably be covered with poison dust. Considerable quantities of poison would certainly fall upon the surface of lakes and streams and more would

be carried into them by rain. What would be the effect of this poisoning upon fish and other aquatic life? How would beneficial insects be affected by the treatment? As birds feed largely upon insects, what would be the effect upon bird life of a sudden reduction of their food supply? Would the animals inhabiting the forests be injured by the poison? We must always remember that in a forest there are many living things of economic importance other than the trees. Also there are many animals and plants which have no immediate economic value, but nevertheless play a part in the complex forest life, and contribute their share toward maintaining a more or less balanced condition. Such a balance is very desirable in a forest area, as it reduces the probability of outbreaks of injurious pests. Would the extensive application of poison over a forest disturb this balance and thus increase the probability of repeated attacks of dangerous pests? We must be reasonably certain that we are not destroying our best friends along with our enemies or we may accomplish in the long run more harm than good by our poisoning operations. Thus even tho an economical and effective means of application and a cheap and abundant poison may be found, these and many other questions must be answered before a general policy of poisoning for forest insect control can be safely advised.

THE POSSIBILITY OF NATURAL CONTROL

Even tho artificial methods of insect control can not be applied economically and safely under forest conditions, there are other possibilities which are more promising. In our studies we find that not all the stands in the infested areas are injured to the same extent; in some stands 100 per cent of the balsam fir has been killed, while in neighboring areas the injury may not be more than 50 per cent. Geographically there may be no reason for this difference so we are forced to seek the explanation within the stand itself. Apparently a large proportion of balsam fir increases the probability of an outbreak.

As a result of the budworm outbreak the proportion of balsam in the stand is materially reduced. Thus conditions favoring the rapid reproduction of the insect are succeeded by less favorable conditions during which the budworm is harmless. In time the balsam fir will usually again become the predominant species in the forest, and another outbreak of the budworm will follow. History shows that we may expect periodic outbreaks of this pest every 35 or 40 years.

In the light of the foregoing evidence, the application of silvicultural methods to the control of the budworm is a likely possibility. Limiting the reproduction of balsam and at the same time encouraging the reproduction of spruce, pine, and birch will undoubtedly reduce the

chance of a future budworm epidemic. In fact it seems very probable that this insect could never become epidemic in a particular locality if all or nearly all the forests in the region contained only a moderate amount of balsam fir. Unless something is done, another outbreak of the budworm in 30 to 40 years from now is almost certain.

Just what proportion of balsam fir is safe in a forest is not known, but it can be determined with a fair degree of accuracy by studying the effect of a budworm outbreak upon stands of different types. Such a study can be made only during the short time between the passing of the outbreak and the falling of the killed trees. Information of this sort will be of inestimable value to timber holders before the next budworm epidemic comes.

The importance of balsam fir in the future forests of northern Minnesota can not be doubted. In fact its present limited use is due largely to prejudice. True, green balsam logs are not easy to handle because of their slipperiness and excessively heavy weight, neither will a cord of balsam wood produce much more than 75 per cent as much pulp as will a cord of good spruce. Nevertheless, it has many admirable characteristics:

1. It reproduces abundantly.
2. It grows well on a variety of soils.
3. It grows much more rapidly than spruce.
4. It is tolerant of shade and can be grown as an understory.
5. It is well suited for lath and boxboards, as well as for pulp.

When the increasing value of balsam is considered, the importance of protecting it from future outbreaks of the balsam budworm is obvious. Many questions, however, must be answered before an intelligent course of procedure can be planned. We must know what proportion of balsam is safe in a stand. We should know the part played by parasites and birds in checking the rapid breeding of the budworm so that it may be possible to determine what dependence may be placed in these control agencies. There is much to learn regarding the early stages of an outbreak and its progress. Another question which has not yet been fully settled is the relation of secondary insects to the death of the trees. Do these constitute an important factor? None of these questions has been fully answered. The answers to these and many other questions naturally arising in connection with such an outbreak can only be determined by thoro and detailed investigations during and immediately following an attack, and further research will doubtless produce valuable results.

The present conditions in Minnesota are extremely favorable for such a study. The budworm is spreading rapidly and has almost reached the eastern tip of the state. However, there is still a small

area which will doubtless be defoliated for the first time in 1923. In this freshly infested forest it will be possible to observe the progress of an attack from beginning to end. This is an unusual opportunity, as the work in Canada was begun too late to furnish much information about the early years of the outbreak.

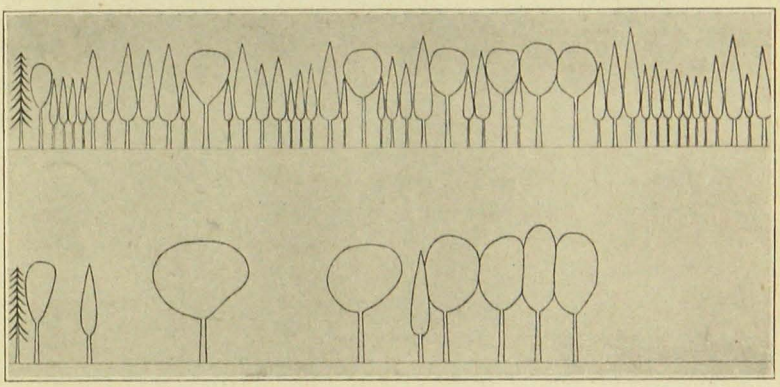

Fig. 1. Effect of Budworm Injury on a Stand Containing a High Percentage of Balsam

This represents a plot of 1/10 acre on the Wales branch of the Duluth & Iron Range Railroad. The trees are drawn to show as nearly as possible their relative size and position in the stand. The upper row represents conditions previous to the budworm outbreak, the lower row, conditions existing at present.

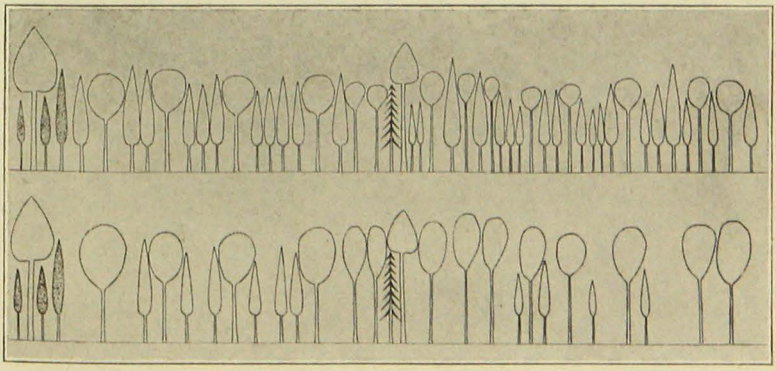

Fig. 2. Effect of Budworm in Mixed Stands in the Infested Region

This 1/10 acre plot was within two miles of the one shown in Fig. 1. It is improbable that the insect could ever become epidemic in such a stand as this if it were not for nearby pure or nearly pure stands.

Conical unshaded } =Balsam Conical shaded } =Cedar Broadly conical } =White Pine

Drooping branches } =Spruce Rounded crown } =Birch

The infested region in Minnesota also furnishes an equally important field of observation in the area where the balsam fir has been recently killed. These areas present a wide range of conditions as to soil and exposure as well as a variety of stands of many different types and composition.

SUMMARY

The present status of the budworm problem may be briefly summed up as follows:

1. Much of the balsam fir and part of the spruce in northern Minnesota is being destroyed by the balsam budworm, *Tortrix fumiferana* Clem.

2. The estimated quantity of balsam fir in Minnesota varies from 3,000,000 to 30,000,000 cords. At least 75 per cent of the balsam fir in the infested area will succumb to the budworm attack.

3. The eggs are laid on both spruce and balsam, but balsam is preferred.

4. The budworm is a native species which becomes epidemic periodically.

5. Several successive years of defoliation are required to kill a tree. After the third year the death rate of the trees is rapid.

6. The death of the trees is sometimes hastened by the work of secondary bark beetles.

7. From 50 to 100 per cent of the balsam in the stand usually succumbs to the budworm attack.

8. The dead material left after the outbreak greatly increases the fire hazard in the infested region.

9. The causes leading up to an outbreak of the budworm are not very clearly understood but are apparently connected with changes of forest conditions leading to an increase in the proportion of balsam in the stands.

10. As dusting with a poison can not be considered, the most promising possibility for controlling this insect is the silvicultural method. Evidence shows that by controlling the proportion of balsam in the stand, injury by the budworm can be much reduced, and it is possible that outbreaks can be prevented.