THESIS

on

DUSTING FROM AIRPLANES TO CONTROL FOREST INSECTS

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WALLER H. REED

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INTRODUCTION

The tremendous damage to our forests annually by insects constantly confronts us. Foresters as well as entomologists agree that the loss runs into tens of millions of dollars each year--a loss greater than is inflicted by the ravages of forest fires. No little of this damage is caused by that group of insects known as defoliators, insects which when in the larval stages feed upon the foliage of trees and other plants, often stripping them of every green leaf. One has only to cite the disasterous epidemics of the gypsy moth (Porthetria dispar), the larch sawfly, (Lygaeonematus erichsoni), or the spruce bud worm, (Cacoecia fumiferana), each of which has caused untold damage in the past, in order to bring this home. Conservative estimates by our most reliable authorities place the damage by the spruce bud worm alone at a figure greater than the aggregate value of spruce and balsam that has been cut in this country and Canada.

The only known control of an insect (defoliator) epidemic when the natural control factors have failed, is the use of insecticides. However, spraying or dusting of large forest areas, except possibly those timber lands embraced in our State and National parks, has heretofore been an economic impossibility. To take heavy dusting equipment similar to that which is used to combat farm insects, into the woods would be mere folly--the monetary

outlay would be too great in relation to the timber value involved in most cases. So man has had to "sit idly by" and allow each epidemic to run its course, hoping that the natural checks would stop the devastation before the timber in question was completely destroyed.

The past fifteen years has changed this picture. Since the turn of the twentieth century, the civilized world has come to know a new invention, the airplane. This machine is destined to become one of man's best "tools" in protecting his forests and farms from the ravages of defoliating insects.

The airplane can be used as a dust (insecticide) applicator only on large areas, however. The cost of the set-up prohibits its use on a small scale. But this just fits in with our forest protection. It is not feasible to attempt to curtail the normal annual loss which occurs year in and year out, but the airplane will enter the picture when large areas are in danger of severe defoliation during intensive epidemics. Actual examples cited later in this paper will serve to illustrate this.

A BRIEF HISTORY OF AIRPLANE DUSTING

In Ohio in 1921 it was discovered that several acres of catalpa trees were being severely defoliated by the catalpa sphinx, (*Ceratomia catalpae* Bois), and an adjacent area of hardwoods by canker worms. Being of high value to

the owner, it was decided to attempt to curb the epidemic by the use of the much discussed, but never attempted dusting from airplanes. Members of the Bureau of Entomology were called in, and the work was carried on as an experiment. The two catalpa groves of six and four acres and the thirty-acre wood lot were dusted with calcium arsenate. True enough, the equipment was crude and the crew inexperienced, but the results proved very encouraging nevertheless. This work pointed favorably toward sound economic forest protection from defoliators in the future when proper equipment and favorable conditions were available.

European foresters and entomologists quickly grasped the idea and began experimental work. In Germany where stumpage values are considerably higher than in this country, the work progressed rapidly. Austria, France, Sweden, Russia, and other European countries have followed step; and the airplane as an insecticide applicator is rapidly becoming an important part of European forest management plans.

The method of dusting has progressed decidedly in this country, for farmers operating large area farms (as the cotton raisers of the south) quickly realized its value. The airplane allows them to dust such large areas in such short time that the ground dusting equipment heretofore used, will undoubtedly soon be a thing of the past. With the airplane, crops can be protected quickly enough

that damage is kept to a minimum.

The demand for dust applying airplanes has increased to a point where some commercial airplane manufacturers are now offering specially built airplanes for dusting purposes only. Also, many companies are now operating dusting airplanes as a business, and contract themselves to dust the farmers' or foresters' crops when needed.

True enough, the past few years of depression has slowed down the development of this insecticide application business, for farmers and foresters have had no desire to protect crops that would not produce income. However, now that conditions are improving, the airplane is certain to become an important part of our farm and forest protection equipment.

INSECTS WHICH CAN BE CONTROLLED BY THE METHOD

Any of the insects which can be controlled by ground spraying or dusting can be combatted from the air. During past years successful work has been carried on in this country against the Gypsy moth (Porthetria dispar L.), the larch sawfly (Lygaeonematus (Nematus) erichsoni Hart.), the catalpa sphinx (Cerotomia catalpae Bois), and the hemlock looper (Ellopia fiscellaria).

Examples of other forest insects which can be controlled when the occasion arises are as follows:

The Spruce bud worm - Cacoecia fumiferana Clems.

The white pine butterfly - Neophasia menapia Feld.

The pine pandora - Coloradia pandora Blake.

The silver-spotted Halisidota - Euschauria argentata Pack.

The white-marked tussock moth - Hemerocampa leucostigma Sward.

The Douglas fir tussock moth - Hemerocampa pseudotsugae McD.

The satin moth - Stilpnotra salicis L.

The brown-tail moth - Nygmia haeorrhoea McD.

The pine saw-fly - Neodiprion burkei.

Abbot's saw-fly - Neodiprion pinetum Norton.

Leconte's saw-fly - Neodiprion lecontei Fitch.

THE DUSTING EQUIPMENT

As with the development of any business employing man-made machinery, the equipment used on dusting operations has constantly changed and been improved. The early work was hazardous, for the early airplane was often known to "react other than was desired by the pilot". However, with the mounting years of experience, the job today is a comparatively safe one.

Any of the several makes of commercial airplanes on the market today can be used for the work. The principal requirements of a dusting airplane are that it must be stable

at low altitudes, must have sufficient lifting power to handle the heavy loads of insecticides, must be capable of slow speeds, i.e., 80 to 100 miles per hour at low altitudes, and must be small enough to permit quick maneuvering. As was brought out earlier, many airplane manufacturers are now offering special built airplane dusting equipment. It is not the intention of the author to go into the technical phases of the factors required of an efficient dusting airplane, but it can be safely stated, that prospective buyers can be assured of quality by purchasing from reputable firms.

The hopper, or container from which the dust is released, is the most important piece of equipment. In general, it consists of a metal box which is carried behind the pilot's cockpit, and is provided with an aperture at the bottom which can be regulated to allow the proper amount of dust to be released at all times. The hopper must be supplied with some sort of churning power in order to insure an even flow of the dust. In the earlier work this was accomplished by operating a hand-turned crank which was connected by a sprocket and chain to a revolving vane within the hopper. This set-up required that a hopper-operator be carried in the observer's cockpit of the airplane; thus greatly adding to the weight, thereby reducing the amount of dust that could be carried at one time. Today, the hoppers in use have a capacity of 1000 to 2000 pounds of dust and are operated by electrically or air driven agitators. The size of the aperture through which

the dust is released is controlled by the pilot by operating a lever. This modern set-up is capable of treating from 50 to 100 acres per dusting trip as contrasted to five or six acres with the early equipment.

The loading equipment must be constructed to provide as quick and efficient refilling of the hopper as possible. As the length of the dusting day is limited, this is of utmost importance. The equipment can either consist of a power loader or one operated by hand, depending, of course, upon the size of the operation and the number of airplanes using it. At any rate, it is built upon a platform to facilitate loading directly into the hopper in the airplane.

The location of the landing field in reference to the area to be treated must be carefully planned in order to avoid long runs which consume time that could otherwise be used on the actual work. It should be on high enough ground to allow its use in the early spring when the lower areas are too muddy. Also it should be large enough to enable the heavily laden airplanes safe distance for taking-off. In some of the rougher timbered areas the locating of suitable landing fields presents quite a problem. This can be solved by using amphibians instead of land airplanes and utilizing various lakes as landing places. In this case the loading equipment is constructed upon improvised piers or pontooned floats.

THE INSECTICIDES USED

To date, calcium arsenate is generally considered to be the best poison to use. It is very toxic to the insects, adheres well to the foliage, and does not cause any scorching damage of the leaves. Usually it is used in an undiluted form, i.e., it is not mixed with any carrier or other chemical. Success with calcium arsenate carrying both high and low percentages of arsenical acid has been enjoyed in past work.

Experimental work with other commercial insecticides, especially on farm and orchard work, has met with some success. Paris green when properly applied and mixed with some carrier, as ordinary white flour, proved to do the work well. On the other hand, lead arsenate is not recommended, for its larger particles are not sufficiently broken up by the action of the airplane's slipstream, and as a result, it falls to the ground too quickly.

Sulphur has been used a good deal on citrus fruits and other farm crops in the past. However, its use is being curtailed because of its inflammability. It has been known to catch afire within the hopper and send the airplane down in flames.

Due to the many complaints, particularly from nature lovers and stock men, that the use or arsenic as a poison causes the loss of forest fauna and domestic animals which happen to be within the dusted area, the Germans have been at-

tempting to develop a contact poison which will be effective against the insects and not cause any damage to the foliage. Work along this line has also been prompted by the fact that the stomach poisons must possess the ability to adhere to the foliage until devoured by the larvae. With contact poisons the results are attained as soon as the insecticide comes in contact with the body of the insect. Contact poisons have proved less effective than stomach poisons when used on dense-foliaged trees. In Germany some success has been enjoyed by using mixtures of pyrethrum and rotenone as contact insecticides.

Some work has been done along the line of liquid spraying from airplanes. To date, however, its use has been against farm pests only. It is mentioned here because the system has possibilities and may develop to a point where it will be used to combat forest tree pests.

The first liquid spray applicator was developed by the Hawke Crop Dusting Company. The exhaust from the motor was used to break up and distribute the spray. The set-up was unsuccessful, however, due to the excessive heat of the exhaust.

Today, two main types of applicators of liquids are in use and are proving quite successful. One consists of a steel bristle, rotary brush driven by a small propellor. The liquid enters the hollow base of the brush and is

swished into a fine spray by the rapidly rotating unit. Upon leaving the brush, the spray is subjected to the influence of the slipstream of the airplane much the same as in the case of the dust. The other type is based on the same principle except that hollow propellor blades are used instead of the brush. In each case one each of the rotors is connected to the struts under each wing next to the fuselage.

Oils are used instead of water, for the latter will evaporate from the leaf surfaces after being applied. The oils may or may not carry insecticides, and they are made miscible in order that they will not be repelled by any moisture contacted.

The liquid has two distinct advantages over the powdered insecticides. First, it will not be blown from nor easily washed from the leaf surfaces; and secondly, the oil is not only instrumental in killing the defoliating insects, but it will destroy any existing external fungal disease or rust with which it comes in contact.

The cost of liquid spraying is usually less than dusting, depending, of course, upon the individual conditions involved.

THE IDEAL DUSTING CONDITIONS

The degree of success of a dusting operation depends upon the time that the work is done. If it is delayed too

long, the larvae reach maturity and the damage is done. Dusting too late is less effective because much of the dust passes through the thinned foliage and drops to the ground, and a greater amount is required to kill the mature larvae. The ideal time to dust is as soon as the eggs hatch. More of the dust is retained on the, as yet, undamaged foliage, and less dust is required to kill the young larvae.

The operating is usually restricted to the early hours of the day, i.e., from about daylight until nine o'clock in the morning. During these hours the air is calm and the dust settles easily and evenly. Also, the presence of the morning dew upon the foliage tends to increase the adhesiveness of the dust particles to each individual leaf. As the temperature rises, the dew is evaporated and the air becomes "rough" making later dusting dangerous and ineffective.

Rain, snow, fog and other adverse climatic conditions seriously hamper the work. Dusting is not only uneffective when these conditions prevail, but due to poor visibility the work is extremely dangerous. The only alternative is to wait until the weather changes.

Wind is probably the main determining factor of the time of dusting when other atmospheric conditions are satisfactory. When the air is in motion, the dust cannot be controlled and made to settle upon the strip desired; thus making for uneven distribution of the insecticide. The

dusting operation should be ceased when the wind velocity rises above eight or ten miles an hour.

THE ACTUAL OPERATION

To picture the actual work it is deemed best to describe an actual commerical operation which was carried out here in our Douglas fir forests.

For several years prior to 1931 the hemlock looper (Ellopia sommiaria) had been seriously defoliating thousands of acres of virgin timber in Pacific County, Washington. By 1931 some 32,000 acres of standing timber were infested, many of the trees having already died. After due deliberation it was decided to attempt to curb the epidemic by dusting from an airplane. The Weyerhaeuser Timber Company and the State of Washington cooperated on the work and shared the expenses.

The airplane used was a Ryan monoplane equipped with a 300 horsepower motor. The hopper was built to a capacity of 1000 pounds. Two electrically driven agitators were used to keep the dust in motion within the hopper and to assure a constant flow through the aperture which was controlled by a lever by the pilot. The insecticide decided upon was calcium arsenate applied at the rate of twenty pounds per acre. A suitable landing field was located on the sand at Ocean Beach. Here a loading platform and hopper ~~was~~ were so constructed that the hopper in the air-

DUSTING FOR CONTROL OF THE HEMLOCK
LOOPER IN BRITISH COLUMBIA

Pictures the courtesy of
Mr. George Hopping
Canadian Dept. of Agric.
Div. of Forest Insects

DUSTING FOR CONTROL OF THE HEMLOCK
LOOPER AT MANICOUAGAN, QUEBEC

Picture the courtesy of
Mr. E. B. Watson
Canadian Dept. of Agric.

plane could be loaded in eight minutes elapsed time.

In order to give a clearer picture, the following paragraph describing the operation from the time the airplane leaves the landing field until the time that it returns is related in the present tense.

The ground crew has all in readiness just before dawn, and at 5:00 A.M. the plane takes to the air. The flight to the area to be treated is made quickly, and as soon as the airplane passes the boundary of the infested area, the pilot pulls the lever and the dust begins to swirl out. The plane is flying about forty feet above the canopy of the forest and at a speed of approximately 100 miles per hour. Due to the forward motion of the airplane and the rotation of the propellor, the plane is surrounded by a body of air which is moving backward faster than the plane is moving forward. This air current, or slipstream, as it is called, is extremely powerful, and as the dust is forced into it, the dust particles are influenced by it for some distance behind the plane. Due to the action of this slipstream, the dust particles are further broken up, the result being a swirling, tumbling, decidedly hollow-spiral, white cloud. As the plane progresses, the dust ceases to be influenced by the slipstream and settles over the foliage in a thin, vapor-like layer. The width of the strip depends upon the height of the plane above the tree-tops and the speed at which it is traveling, as well as the

atmospheric conditions prevailing. In most cases each strip dusted is from 100 to 200 feet wide. On the return strip and on each succeeding strip, the dust cloud is allowed to overlap the preceding strip a few yards in order to insure a uniform coverage. As the dust cloud reaches the canopy of the trees, there is still sufficient air motion to force it through the foliage to the ground and rebound it, so that at least some of the under sides of the leaves are also dusted. The airplane's hopper is exhausted after treating approximately fifty acres, and the pilot returns for another load. By nine o'clock the flying and dusting conditions become poor, and the work is ceased for the day.

On the operation some 5,400 acres were treated in thirteen days elapsed time, which included some adverse flying and dusting conditions. It was decided not to attempt to treat the entire infested area, for the defoliation had advanced greatly by July 18. It was hoped that if the best of the remaining timber was treated the epidemic could be controlled sufficiently to allow the natural checks to handle it. This proved to be exactly what happened.

The cost of the operation was surprisingly low, proving beyond doubt that the dusting of tall western forests is an economically sound venture. The entire job cost $15,000 or $2.75 per acre treated. This amounted to approximately nine cents per thousand feet of timber on the 5,400

acres.

It came to light during the work that twenty pounds per acre was insufficient for the taller western forests. The figure was borrowed from early eastern experience where the forests treated consisted of trees not over seventy or eighty feet in height. However, in spite of this small dosage, observation at the end of the year showed that the trees in the areas treated supported good, even and fairly dense crowns, while the trees on the untreated areas were either dead or practically devoid of foliage.

THE DEVELOPMENT OF AIRPLANE DUSTING IN EUROPE

The first attempt to control insects defoliating forest trees in Europe was in the form of experimental work in Germany about ten years ago. Since that time (up to and including the year 1934) some 63,930 hectares (about 158,000 acres) have been dusted in Germany, Russia, France, Sweden, Czechoslovakia and other countries. The great desire to continue this work can be evidenced by the great amount of research work done by the Germans to convince the public that the poisonous dusts are not injurious to the fauna of the forest. The results of this research work will be brought out later in this paper.

Two distinct types of airplane dusting are in use in Europe today, the German system and the Russian method. The former is the most exclusively used at the present

time, but it is by far the costlier.

Calcium arsenate is the insecticide employed with the German system. The percentage of arsenical acid in the dust is approximately fifteen. As a result the dosage per acre is heavy, in the neighborhood of 50 kilograms per hectare (2.471 acres). The cost of the entire operation amounts to about 50 gold marks per hectare.

The Russians, on the other hand, have developed a method whereby the costs are greatly reduced. It is doubtful if the system has been used outside of Russia as yet. The work is begun as soon as the eggs hatch in order to take advantage of using a smaller dosage per unit treated. As with the German system, calcium arsenate is used, but the dust contains nearly 70 percent arsenical acid, and only 8 to 10 kilograms are applied per hectare. As the airplane can cover a much greater area by using this smaller dosage, the saving is not only in the cost of insecticide per hectare, but in the cost of the equipment per unit as well.

To bring out some noteworthy example of European work is deemed appropriate here. In Germany the production of forest products, especially cord wood, is a necessity. Therefore, the protection of the growing forests is of utmost importance. In the past forest owners have been able to develop excellent fire protection, but to rid a forest of an insect epidemic meant tedious and costly spraying or

dusting from the ground. Today, with the airplane as the applicator, the work is made simpler and the cost is within reason.

In the examples cited below, American units of measurement and value will be used in order to make the situation easily understandable.

The nun moth, (Lymantria monacha), and the pine moth, (Panolis flammea), reached an epidemic stage in spruce and pine forests in Germany in 1928. It was decided to attempt airplane dusting. After careful analysis and experimentation, calcium arsenate was found to be the best poison to use because of its high toxic content, its excellent adhesive quality, and because it needed no admixture to prevent its damaging the foliage. As the nun moth was found to be fairly resistant to insecticides, a larger dosage was used on the spruce than on the pine. The result of the work was that practically all of the caterpillars were dead within five or six days.

Because of the excellent success in 1925, the method was tried again the following year on an oak forest in Westphalia which was severely infested with Tortrix viridana. In all, some 4,700 acres were treated. However, poorer weather conditions were encountered than in the previous year. On May 9 and 10 a heavy rain washed much of the dust from the trees on the 250 acres that were treated on the two previous days, but in spite of this some eighty

percent mortality was recorded. The remainder of the area was treated beginning May 14; and as no rain was encountered, the mortality neared 100 per cent.

During the same year a large area near Haste was treated to curb an infestation of Hybernia defoliaria. The method was practically the same as was used in the above case, for the same equipment was employed. In spite of rains every other day during the operation, the work was a complete success.

A year later, France, no doubt influenced by Germany's success, decided to treat 2,200 acres in the Forest of Haguenau to check the ravages of Bupalus piniarius. Due to many delays, the work did not get under way until late summer when many of the caterpillars had already reached maturity. But, in spite of the delays, a dosage of twenty-two pounds per acre killed some thirty-five percent of the larvae. This, together with the numbers of pupae which were destroyed by grazing hogs, curtailed the epidemic and prevented a serious outbreak the following year.

By carrying out the work at the proper time and enjoying good meteorological conditions, French forest managers have been convinced that airplane dusting is a paying proposition and a sound protection measure to use when needed.

Russia saved a fine pine forest from complete defoliation by the pine geometrid in 1930. Some 5,000 acres containing 500 to 56,000 caterpillars per tree were dusted with

calcium arsenate, between the first of July and September 5. Some ground methods of control had been practiced in Russia, but the complete success of the dusting from the air made futher ground work uneconomical.

ADVANTAGES AND DISADVANTAGES OF AIRPLANE DUSTING

The speed with which the work is accomplished is the most important advantage of airplane dusting over other systems of artificial control. With average flying conditions, the modern airplane can cover a tremendous area in a dusting day of four to seven hours. This factor is of utmost importance, for the success of the operation depends upon the rapidity of controlling the epidemic. As soon as the eggs hatch, the dust is applied, and the young larvae are killed before they inflict any serious damage to the foliage. Not only is the forest saved from severe defoliation, but the cost per unit treated is reduced as well, for it takes less insecticide per unit to kill the young larvae.

Dusting from the ground is practically unknown in this country, but in Europe, where high stumpage values make forest protection a necessity, some ground dusting has been employed in certain cases of severe infestations. Due to the wet soil conditions which prevail in the spring (the time when the dusting should be done), it is almost impossible to move the heavy ground machinery over the muddy

ground. The airplane solves this nicely. As soon as the landing field (which is purposely located on high ground) is dry, the work can be accomplished.

Success in controlling a serious outbreak is insured where the work is properly done, for the covering of dust laid down is a continuous and even one. In no case have I found any reference to the failure of an operation due to any cause other than unfavorable climatic conditions or inexperience of the operators.

Probably the biggest disadvantage is that precipitation immediately following the operation will nullify much of the work. Rain washes the poison from the leaves before the caterpillars are poisoned; thus, often making it necessary to redust the area. This drawback can be overcome to a great extent by consulting reliable weather forecasts prior to starting the work.

Rough air during the hotter parts of the day causes the dust to settle unevenly and adds to the danger of low flying. The operation should cease when wind velocities greater than eight or ten miles per hour are encountered.

The forest canopy is usually broken, i.e., here and there a tree taller than the others protrudes above the general canopy. As the pilot must fly very close to the tree tops, he must be constantly on the alert to avoid a

"crack-up".

Finally, may be mentioned the difficulty of obtaining uniform coverage of the area when dusting very tall timber. Erection of strip markers has been advanced to overcome this difficulty, but this is impractical and would add considerably to the cost of the operation. No doubt, as time passes, a system will be devised to solve this problem.

THE ALLEGED DAMAGE TO THE FAUNA OF THE FOREST

Often it is the case when forested areas are to be dusted, that enterprising citizens, especially nature lovers, express the belief that the animals and birds of the forest will be destroyed as well as the insects. During the infant years of forest airplane dusting in Europe, this opposition furnished a serious drawback to the use of the method.

Also, during the early stages of the work, some wild life was destroyed on airplane dusted areas. This was due to the excessive amounts of arsenic used.

As the work progressed in Germany, it was found that a much smaller dosage was required, and that the smaller dosage was not injurious to forest fauna or grazing animals. These encouraging conclusions prompted a series of experiments in order to prove that the dusting was not injurious to the animals in the forest.

The amount of arsenic required to kill various animals

was definitely determined to be as follows:

Cattle	15 to 20 grams
Horses	8 to 10 grams
Sheep and Goats	8 to 10 grams
Swine	0.5 to 1.0 grams
Fowls	0.1 to 0.15 grams

The poison dust layer, when properly applied, is so exceedingly thin that it requires a microscope to see it. Therefore, under the present day dusting conditions, it is impossible for the animals to receive enough of the poison to cause death.

Research shows that it takes only 0.0000001 gram of arsenic to kill a winter instar of Lepidopterous larva. An insectivorous bird must consume over 50,000 of the poisoned larvae before it is affected by the poison. Again this is impossible, and futhermore, the bird prefers live to dead caterpillars.

Therefore, it can be safely stated that the dusting operation is not dangerous to the fauna of the forest when it is properly done.

It can be mentioned here, however, that a great many beneficial insects as scavengers and predators are destroyed by feeding on the poisoned larvae. But since the dusting is resorted to because the noxious insects have reached or will reach the epidemic stage, this loss of bene-

ficial insects which normally keep the pests in check must be tolerated.

COSTS OF DUSTING FROM AIRPLANES

As with any new line of endeavor, dusting from airplanes has passed, and in some sections is still passing, through experimental stages. Experimental costs are usually high, but in most cases, airplane dusting has proved to be an economically sound venture in spite of the high costs.

As time has passed, and the work has developed from experimental status to that of commercial standing, the costs have been reduced several hundred percent. Early work in this country necessitated costs of six, eight, or ten dollars per acre treated. Today, the work can be done at a figure definitely within reasonable financial limits. In the example cited earlier in this paper, the work in Pacific County, Washington was completed for nine cents per thousand feet of timber protected.

Past work in Europe and Canada as well as in this country tend to show that two-dollar per acre airplane dusting is not an impossibility in the near future. As a matter of fact, some past work in Canada has very nearly approached that figure. It was definitely concluded that the expenditure of $2.75 per acre on the Pacific County, Washington, operation was perfectly justifiable; therefore, any

further reduction of cost in the future will only tend to make the work more desirable when it is required.

The managers of forest lands in Sweden have been desirous of taking advantage of the airplane dusting success for some time enjoyed in other European countries; but the cost in Swedish Crowns (approximately eleven cents) has been prohibitave. By applying the Russian method of application mentioned elsewhere in this report, airplane dusting has been made financially possible in Sweden. The airplane makes eight trips per day and applies ten kilograms of dust per hectare. Considering the flying cost at 150 Swedish Crowns (which is extremely high figure) the costs are as follows:

Flying cost	6	Swedish	Crowns	per	hectare.
Cost of poison	5	"	"	"	"
Other costs	9	"	"	"	"
Total cost...	20	"	"	"	"

The "other costs" include all labor, preparation of landing fields, loading equipment, etc. In our monetary system this cost would amount to approximately $2.20 per acre. With the cost of airplane dusting at this figure, European authorities advance the opinion that the dusting would be a safe venture even where the defoliation is restricted to a damage resulting only in decreased growth.

CONCLUSION

Fifteen years of experiment and experience have est-

ablished the method of applying insecticides from the air as both feasible and economically sound. By constant effort the cost has been reduced to a figure within reason, the equipment has been developed to a high degree of efficiency, and the results obtainable when favorable climatic conditions prevail are a certainty.

Thus man has made another long stride in forest protection. Vast areas of valuable timber can now be rid of serious defoliating insects which threaten their destruction--a task that was a financial folly before the advent of the flying machine.

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