THE SPRUCE GALL APHID \textit{Aphidius coleyi} (Gill) IN UTAH.

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THE SPRUCE GALL APHID ADELGES COOLEYI (GILL.) IN UTAH.

INTRODUCTION:

This paper is the result of research started on the Campus of the Utah State Agricultural College in the Spring of 1928. It is the intention of the writer to give the economic importance of the insect in the State, kind and extent of damage done by the insect, life history and control as far as it has been found.

The problem is not completed, nor is all the material included the results of the writer's own investigation. However, it has been the object to study forms as they exist in Utah, and review the more important facts that are already known about this interesting insect.

ACKNOWLEDGEMENT:

The assignment of this problem was made by the late Dr. H. J. Pack. His unceasing advice and cooperation has been an incentive to utmost endeavor. The writer extends thanks to C. P. Gillette for determining the insects, Dr. W. W. Henderson, Verda Dowdle, and G. F. Knowlton for their helpful advice.

SCOPE OF PRESENT WORK:

This paper contains data from material collected from Malad and Preston, Idaho, Provo, Salt Lake City, Ogden, Hyrum, Logan, Smithfield, Providence, and Logan Canyon in Utah. In these localities Adelges cooleyi have been collected from the following Spruces: Picea canadensis, P. pungens, and P. engelmanii as primary hosts, and Pseudotsuga the secondary host.

METHODS OF WORK:

Adelges are very difficult forms with which to work; their diversification is gross structure giving considerable confusion; Being very small they must be studied with the aid of len-
ses from material prepared and fixed on glass slides. Several methods of fixation may be used. Specimens may be put directly into balsam on a slide, covered with a glass and allowed to stand until clear. This is a quick method and the antennae, and the legs clear fairly well, but the body offers complete resistance to light rays and it is therefore impossible under these conditions to bring out several valuable integumental structures that are important in classification. The method listed by Anand (1) is as follows: Boil insect in potassium hydroxide, clear and pass through 95 per cent alcohol into magenta, wash in water, clear in carbol xylene and mount in balsam.

The writer in collaboration with G. F. Knowlton has succeeded in clearing and mounting these insects very well by the following method: Allow insects to remain in a strong solution of potassium hydroxide until clear, then wash for two or three hours in distilled water and run up through alcohol, (35% 50% 75% 95% 100%, each about two hours) into cedar oil, 36-48 hours and mount in balsam. By allowing insects to remain in caustic potash and clear without boiling they are not so brittle as when they are boiled and are much more easily handled and are not so brittle as insects which have been boiled.

REVIEW OF PREVIOUS WORK:

The earliest work in reference to the galls of Adelges is credited to Clusius (8), a Dutch Botanist in 1583. It was not until the eighteenth century, however, that the insects were found within the gall by Grisch. In 1887 Blochmann (3) discovered sexuality in Adelges and described the males. Shortly after this Dreyfus (9), Blochmann (3), and Chlodovsky (6), working independently, discovered that these insects had two hosts, a primary host upon which the sexual life cycle was passed, and
a secondary host upon which the asexual life cycle was passed. Cholodkovsky (6) did excellent work; he wrote a monograph of European species. His Beiträge zu einer Monographie der Coniferen-Laus, published in 1896, afforded stimulus to the investigation of the biology and taxonomy of the group. This monograph set a standard and is one of the early works that is of value in today's research. Other writers were Nusslin (14) and Stebbing (17) on biological contributions, Stauffacher, (16) Becher (2) on morphological study, and Burdon (5) wrote largely on control. In 1907 Forner (4) contributed to the biology and taxonomy of adelgids and in 1908 published Eine Monographische Studie über die Charmiden. Marchall (13) published in 1906 entirely on biology of Adelgids. This was followed by Cholodkovsky's (6) Chermes injurious to conifers. (1915)

The more recent work was done by Chrystal (7) (1922-25) who contributed to the life history of Adelges, namely A. cooleyi, A. piceae, and A. nusslini.

In America outstanding work has been done by Gillete (12), who published in 1907 'Chermes of Colorado Conifers,' Patch (15), who in 1909 published description and life history notes on Maine Adelges. Essig (10) briefly reviews Adelges of Western America.

The latest and most complete work on Adelges is the work of Annand, (1) who published in 1928 a rather complete text of Adelges in America, having obtained specimens from most parts of the U.S. He gives a review of the literature on biology, description of forms and life history. A complete bibliography is listed at the end which includes the most important contributions.

**DISTRIBUTION, ECONOMIC IMPORTANCE:**

Annand (1) reports Adelges cooleyi geographically from...
widely separated localities in the U. S., especially from Eastern
Utah, also Colorado and Pacific coast, including Idaho and Mont-
ana, and has also been reported from Europe by Chrystal, (1922 and
1925).

Adelges cooleyi is found in parks and other places in Utah
where spruce is used in ornamental planting, and has been found
at Provo, Salt Lake City, Ogden, Logan, Hyrum, and Smithfield.
In these places the writer has found them to be doing consider-
able damage.

HOST PLANTS:

In this state the insect attacks particularly the white
spruce, Picea canadensis, but galls have also been found on
Colorado blue spruce, Picea pungens and the Engelmann spruce,
Picea engelmannii.

TAXONOMY

The spruce gall aphid belongs to the order Homoptera, family
Phylloxeridae of the superfamily Aphidoidea. The family Phylloxeridae
is divided into two subfamilies Phylloxerinae and Aldegininae. The
later is called Chermisinae by some authors, but inasmuch as
the name Chermes has been preempted by the old Psyllids, the name
Aldegininae is being accepted for general use. The family Phylloxeridae
is separated from the Aphids by the presence of three oblique veins
of the Phylloxeridae in the forewings, as compared with four in aphididae, and the stigma
is formed by the radius. All generations are oviparous. The Adelginae
are differentiated from the Phylloxeridae by the presence of a five
segmented antennae in Adelginae, the last three segments bearing
large sensorium; also the basal portion of the cubitus is separated from the
small vein in the forewing which coalesces in Phylloxerinae. The beak
and alimentary tract of the Adelginae function in the sexuals, which
is not the case with Phylloxerinae. The wings of the adelginae are
hard-rod-like when at rest while those of Phyloxerinae are held horizontally. Differentiating between Genera and Species is very difficult and must be done by one that is an authority on adelges.

**INJURY. Type.**

The injury done by the spruce gall aphid is rather severe. After the eggs from the stem mother hatch, the young lice attack the new growth, settle at the base of the needles and thrust them back time after feeding for some excessive time growth results about the base of the needle. The galls are formed by the hypertrophy and coalescence of the basis of the spruce needles.

Only the cells of the needles are affected by this abnormal growth. The pedicle of the leaf increases in size and in a short time grows to the extent that it coalesces with the other needles on the twig. The cells of the stem are little affected by the abnormal growth. In July the insect emerges from the gall. After the insect leaves the gall the latter dies, and the growth on that twig is stopped until another terminal shoot can be formed, causing a stunted and a very unsightly condition of the tree.

**EXTENT OF INJURY**

The writer has observed approximately 2000 galls on a white spruce about 15 feet tall, while on another white spruce adjacent to the heavily infested one the galls were very small and few in number. The calculation was based on counts made of the galls on various branches selected at random on the tree. In Utah the galls found P. pungens and P. engelmannii are small and few in number, and none were seriously free from galls as compared with those on infested P. canadensis. Patch (15) counted 990 galls on a white spruce three feet tall. Dr. Patch writes, "In severe infestations many of the branches are killed and often single young trees are
killed outright". When branches are severely infested with galls they begin to shed their leaves and the tree becomes ragged and unsightly in appearance.

The size of the galls vary with different trees, depending on the health and vigor of the tree. A healthy tree will produce large galls while a sick, scruffy tree produces small galls with very few chambers. The measurements of the galls ranged from 1.5cm. to 6.5cm. It sometimes happens that only a few needles are attacked; in this case the twig may continue to grow. In all cases the galls are terminal, and in color vary from a bright green when the gall is young, to a purple when the gall is mature; later, after the emergence of the insect, the gall turns yellow and dies. Some galls have from 75 to 150 chambers in each gall and the writer has found from 1 to 12 lice in each chamber.

**BIOLOGY OF A. cooleyi.**

Because of the complexities of the life cycle, and because of the number of forms which occur in the life cycle of this insect, it is necessary to adopt a definite terminology to describe the various forms of this insect. In the past a diverse terminology has been used by investigators of the biology of this group relative to the various morphological forms occurring. Of these Marshall's (13) appears to be the most satisfactory and is the one used in this paper.

**THE SEXUALIS.**

The sexuales are produced by the sexupara after the flight from the secondary to the primary host. They hatch beneath the wings of the sexupara, which remains attached to the needles after death. The sexuales became mature after four molts without leaving the shelter of the wings of the sexupara. They are very small when mature, usually not much larger that the first-stage larva,
the female being slightly larger than the male and not as slender. The male has longer legs and is more active than the female. Both sexes are apterous and are characterized by short rostral styles, and from the other apterous forms, by long, slender, four-segmented antennae. The female lays a single egg beneath the scales at the base of the spruce buds, from which the fundatrix hatches during the same season.

**THE FUNDATRIX.**

The fundatrix lives through the remaining part of the summer, fall, and winter in an immature stage, as a rule, and becomes mature in the fourth stadium, remaining wingless. She settles at the base of the bud, or possibly on the bud, or frequently may be found some inches below it, and lays eggs in large numbers. After a prolific egg laying period the fundatrix dies without moving from her position, and may be found there even after the galls produced by her progeny are mature, a period of two or three months.

**THE GALLOCOLA.**

The first-stage larvae, hatching from the eggs laid by the fundatrix, move toward the bud, where they settle at the base of the new needles, producing the characteristic gall of the species. They pass through three stadia, become pupae in the fourth, and adult alates in the fifth. They leave the galls after or just previous to the last molt, and, if gallicola migrantes, fly to the intermediate host. If gallicola monmigrantes, they lay eggs on the spruce and start an apterous generation on the primary host. They are relatively non-prolific.

**THE IMMIGRANS.**

The generations from the gallicola migrantes are spoken of as waxules, the first of which are the false stem mothers and
in the genus Adelges are sistentes. The neositens (first-stage larva) goes through the winter and matures, after three ecdyses, the following spring. It produces a large number of eggs, which hatch ordinarily early in the spring and which frequently develop into two types, the sexupara and the apterous progrediens. The latter may produce a large number of generations, progrediens, alternating as a rule with sistens, which may occur in the summer as well as in winter.

**THE SEXUPARA.**

The sexuparae are winged individuals arising from the eggs of the sistens. They fly back to the primary host, where they attach themselves and produce the sexucales. In morphology they resemble the gallicola migrantes very closely.

With the exception of the sexucales, all of these forms reproduce parthenogenetically. All stages reproduce oviparously.

**LIFE HISTORY.**

There appears in the life cycle of *A. cooley i* two distinct life cycles, a monoecious and a dioecious. The monoecious life cycle is passed entirely on the primary host, the spruce, and appears only in localities where the spruce are indigenous. The writer has never found this race in Utah.

The dioecious race or sexuals have been referred to by Ammand (1) and recently the writer has discovered on the twigs of *Pseudotsuga*, the sistens produced from the eggs of the alata that have overwintered on the twig and have started to develop. These according to Ammand, undergo three ecdyses, becoming mature in the third. They lay a number of eggs which hatch early in April and produce two generations, the sexupara and the apterous progrediens. The latter may produce a large number of generations of progrediens alternating as a rule with sistens, which may occur in summer as well as in winter. The sexupara are the
winged individuals which fly back to the primary host where they attach themselves and oviposit the eggs hatching in about 5 days, producing the sexes. The sexes become mature in four molts without leaving the wings of the sexupara, and produce a single egg which hatches to produce the funditrix. The funditrix lives the remaining portion of the summer and next winter in an immature stage and continues development the following spring.

On account of being called from the state the writer has been unable to complete the sexual part of the life cycle and has reviewed Annand with reference to it.

On April 20, 1928 females (fundatix) were found covered with waxy filaments, the body completely concealed within the waxy threads (Fig. II). And on April 25, 1928 they were found ovipositing. The body of the female completely concealed within the waxy threads were located on the underside of the twigs a few inches from the end. In 1928 they were very numerous, as many as sixteen to twenty females being found on a small twig one foot long. In the springs of 1929-30 there was a considerable decrease in the number of ovipositing females. In 1929 there were from eight to ten and in 1930 they appeared very scarce, only occasionally finding ovipositing females, as compared to the spring of 1928. The cause of the decrease is not known but is thought by the writer that the winter temperature would have some effect on them. In 1929 a temperature of 22 degrees C and in 1930 a temperature of 32 degrees C was reached in comparison with a temperature of 10 degrees C in 1928.

The number of eggs oviposited vary with different females. The writer counted a number of egg masses and found a range from 283 to 463, or an average of 379 eggs per female. One female had deposited only 23 eggs, some of which had hatched, this is an exception rather than a rule. Gillette (12) reports an average of 463 eggs per female.

During the time this insect is ovipositing there is a wonderful proliferation of egg cells. The writer has calculated that during this oviposition...
period she produces twenty-seven times the bulk of her body in eggs. After such a period there is little wonder for her immediate death.

Each egg is attached to a wax thread that is interwoven with the mass about the body; this is no doubt to secure the eggs to the host plant. Females often oviposit eggs in chains. One in particular was ovipositing in this way, each chain consisting of four eggs and deposited at the rate of one chain in one hour and twenty minutes. The eggs are oblong, elliptical in shape, and greenish yellow in color. Later they turn darker, but become yellowish before hatching.

The actual measurements of the different eggs ran from 0.12 x 0.25 mm to 0.17 x 0.34 mm with an average of about 0.15 x 0.29 mm.

The incubation period of the eggs varies with climatic conditions. Eggs hatch in favorable conditions in 3 days; and in unfavorable conditions they may go as long as 7 days. The average being about three to four days.

About the time the egg is ready to hatch it turns deep yellow in color and one end at which the head of the insect is located. The shell begins to crack open. This split continues on the ventral sides of the insect about one half the distance to the posterior end of the insect, and the young nymph slowly emerges, they remain on the egg cluster for some time after which it migrates to the bud or wanders around on the twig rather aimlessly. It seems to the writer that it is frequently a matter of chance that the lice reach the bud. These observations agree with those of Gillette and Annand regarding the influence of the fundatrix in gall formation. The writer has never found any evidence of gall formation before the young larvae begin to feed; in fact, the fundatrix is often as much as eight inches from the end of the twig where the gall is formed, although she may be closer. After the larvae begin to feed at the bases of the needles, the gall begins to form which later incloses them. In these chambers the larvae undergoes four molts,
as evidenced by the cast skins in the galls. They then become alates in the fifth stadium.

The first instar nymph is yellow in color and the appendages are more or less transparent. The eyes are dark in color; the antennae are three segmented, the first segment short and the two end segments about equal in length. There are no wax pores on the body. After the first ecdysis there is produced a waxy powder about the insect; therefore wax pores are then present. They are located on head and prothorax and possibly on the other body segments, but are not highly developed.

The fourth instar—nymph or pupa has a stout body with well developed wing pads. It is dark yellowish-green in color and noticeably pulverulent; its eyes are black and prominent and the legs are dark. This stage is of rather long duration which allows for considerable growth. The nymphs of all stages carry with them the liquid excrement which is held in the cast skins. These are called ghosts by Gillette(1).

The fourth stage nymphs usually leave the gall which opens about the time they are ready to emerge and molt on the needles. Amund (1) reports that some are not allowed to escape soon enough and molt within the gall. These individuals usually perish or are not able to fly away when the chambers do open because of the improper spreading of the wings. The writer has often found eggs, and in one case, living neosistens larvae, in the opened chambers.

The alates of this generation migrate to the secondary host and are spoken of as gallicolae migrants. The apterous form, called gallicolae non-migrants, lay eggs on the spruce and start an apterous generation which matures to fundatrix on spruce. They are relatively non-prolific.

On July 6, 1929 the galls had started to open and the insects were beginning to emerge; and by July 26th, all galls were opened and the insects had migrated to the secondary host. Various checks were made and was found that Pseudotsuga was the secondary host. On this tree the insects
were found attached to the needles and some had commenced to oviposit. The eggs accumulate under the wings and in a few days hatch into the sistens which over-winter in the mature stage. From the sistens the life history is repeated.

**CONTROL. Artificial.**

Control measures are only to be considered in nurseries and on ornamentals, as the extent of injury and infestations accruing in forests does not, except in rare cases, warrant the application of control measures on a large scale.

Applications of "Black Leaf 40", 1 part to 800 parts water killed 100% of the aphids. The same result was obtained in using "Black Leaf 40", 1 part to 2400 parts water a quantity enough to make one gallon plus 5 teaspoons penetrated. A miscible oil was used, a 4% solution (1 pint to 1 1/2 gallon water) completely killed all insects without damage to the tree.

Applications should be made when fundatrix is ovipositing and when spring forms are moving toward the bud. Either method is effective if application is made in proper time. Care must be taken to prevent burning of the leaves by use of high enough concentration of oil to cause burning of the leaves.

**NATURAL CONTROL**

The writer has observed numerous Coccinellids on the spruce tree, but has not observed them predaceous on the spruce gall aphid, although Coccinellidae, Chrysopidae, Syrphidae, and Chalcididae have been reported attacking *E. boleyi* by other authors. Each is of little economic importance but perhaps their cumulative effect is of considerable value. The insects within the gall are not liable to the attack of any parasite. No internal parasites were observed by the writer.
Certain spruces, namely the white spruce _Picea glauca_, Colorado blue spruce, _P. pungens_, and the Engelmann spruce, _P. engelmannii_, are infested with a species of aphid, _Adelges cooleyi_, which causes galls of a familiar pine-apple type on the branches, causing considerable damage to ornamental plantings of these species of trees, deforming, and often killing them outright.

The insect has a complex life cycle, having two hosts, a primary host upon which the sexual stage is passed, and a secondary host upon which the asexual life cycle is passed.

The life cycle is as follows:

Sexualis produced by the sexupara after the flight from the secondary to the primary host. The male fertilizes the female and a single egg is laid, both sexes being apterous.

_Fundatrix_. The fundatrix hatches from the egg laid by the sexualis the same season, lives the remaining part of the season and overwinters, and in the spring after a prolific period of egg laying, dies.

_The Gallocole_. The first stage larva hatched from the eggs of the fundatrix, move toward the bud and cause the characteristic gall. Within the gall it undergoes four molts to produce Gallocola migrants or non-migrants, the latter remaining on the spruce, being on prolific. The former, flying to the secondary host, oviposits a large number of eggs, and dies.

_Ersulis_. The generations hatched from the eggs of the Gallocola migrans, hatch in the fall and overwinter in a immature stage. After three ecdyses in the spring they become mature and oviposit.

_The Sexupara_. The sexupara are winged individuals arising from the eggs of the sistins (the over-wintering form). They fly back to the primary host and produce the sexualis to begin the life cycle again.

Control measures are “Black Leaf 40”, 1 part to 300 of water.
giving 100% killed. Mistletoe oils may be used at strengths of one to four. In forests no control measures are necessary, but in ornamental plantings and nurseries, control measures must be applied. There is no natural control of great value.

CONCLUSION.

1. Adelges cooleyi is doing considerable damage on the Campus of the U. S. A. C. Logan, Utah, and in places where spruce is used for ornamental plantings such as in parks and cemeteries.

2. The complexities in hosts and life cycles makes this a difficult group of insects with which to work.

3. Control measures need be applied to only nurseries and private and public plantings/ornamental trees. Control on a large scale in forests is unnecessary.

4. Damage is done only to the primary host by killing the end of the twig.
Fig. 1 Life Cycle Of Adelges cooleyi. (cont.)
Fig. II Ovipositing Funditrix On Stem Of Spruce
Fig. III Characteristic Galls Caused By The Spruce Gall Aphid. Cut Gall To Show Insect Chambers
LITERATURE CITED.


6. Cholodkovsky, N. "Beit rage zu einer Monographie der Conifera-Lause." "Ibid., 30 (1895); 31 (1896).


