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AN ANNOTATED BIBLIOGRAPHY OF THE BALSAM WOOLLY APHID (ADELGES PICEAE (RATZEBURG))

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Abstract

A total of 353 published references on the balsam woolly aphid are listed. Author and subject indexes are provided and most references are accompanied by an annotation. Appendices list 89 unpublished reports on the balsam woolly aphid and 165 references dealing with closely related Adelgid spp. which infest conifer tree species.

Résumé

On a fait une liste totale de 353 références publiées sur le puceron lanizére et la plupart des références sont annotées. Les appendices donnent la liste de 89 rapports non publiés sur le puceron lanizére, et 165 références concernant l'Adelgid spp. des coniféres.

INTRODUCTION

The balsam woolly aphid, Adelges piceae (Ratz.) is a widely distributed forest pest of true firs (Abies species). This insect causes only minor damage in Europe, however, in North America, most host species are very susceptible, and the aphid is causing significant losses in forest productivity. The aphid problem has been studied at many research centres and results are distributed in a large number of reports and publications. This bibliography has been assembled to provide a basis on which to assess existing knowledge and to determine areas for further study.

The bibliography is complete through 1979. It is indexed by author and subject. Most citations are accompanied by an abstract. These have been omitted only where titles are very explicit. The following abstracting journals were the source of most annotations; Forestry Abstracts, Abstracts of Entomology and Biological Abstracts. Titles of foreign language papers have been translated to English and the original language indicated symbolically as follows:-

Czechoslovokian - Cz.
Danish - Dan.
Dutch - Du.
French - F.
German - G.
Hungarian - Hun.
Italian - It.
Norwegian - No.
Polish - P.
Romanian - Rom.
Russian - Ru.
Spanish - Es.
Swedish - Sw.

The results of initial studies of the balsam woolly aphid are commonly issued as unpublished reports. All such reports encountered during the preparation of this bibliography are listed as Appendix I. Many published papers describing Adelgid species that are closely related to the balsam woolly aphid and which attack conifers are listed as Appendix II.

BIBLIOGRAPHY

1. Adams, J.B. and J.W. McAllan. 1958. Pectinase in certain insects. Can. J. Zool. 36:305-308.

   Pectinase was found in the saliva of 23 species of aphids, one species of leafhopper, and Adelges piceae. The enzyme was not found in four species of aphids in their apterous form, and one species of psyllid, or in the saliva of the alate form of five species of aphids that contained pectinase in the apterous form. These results emphasize the need to consider each form of a species of aphid individually.

2. Adlung, K.G. 1962. (The effect of a control operation against Choristoneura murinana on the predators and parasites of the genus Dreyfusia Adelges.). Z. angew. Ent. 50:239-241. (G.)

   When a stand of Silver Fir in the Black Forest, heavily infested with C. murinana, D. piceae, D. nusslini and D. merkeri, was sprayed by helicopter with 1.5 kg DDT in 40 litres diesel oil/ha in late April, most of the Laricobius erichsonii and Cremifania nigrocellulata imagos, the most active predators at this period, were killed, and most others (including Cnemodon and Syrphus larvae and Chrysopa ventralis) also suffered heavy mortality. On a group of trees from which about 24 L. erichsonii were collected before treatment; only 4-5 were collected one week after.

3. Aldrich, R.C. and A.T. Drooz. 1967. Estimated fraser fir mortality and balsam woolly aphid infestation trend using aerial colour photography. For. Sci. 13:300-313.

   Abies fraseri, in each of five defined forest types, on 22,000 acres near Mt. Mitchell, N. Carolina were sampled by 215 one-acre plots on 1:7920 scale aerial color photos. Mortality of fir, and live spruce and fir, were counted on the photos, using 4.5-power steroscopic magnification. Aphid populations were measured, and fir mortality and live spruce and fir were counted, on 30 photo plots located on the ground. Regression lines were developed to enable photo estimates made from the larger photo sample to be adjusted. The initial estimate of dead fir was 13.9 + 0.8 trees/acre. An upward trend occurred for four years and reached 21.3 + 1.0 dead fir per acre. Equations were developed to compute an index of fir mortality.

4. Amman, G.D. 1961. Predator introductions for control of the balsam woolly aphid on Mt. Mitchell, North Carolina. U.S. Dept. Agric. For. Serv., Res. Note SE-153. 2 pp.

   Six predator species were introduced in 1959-60.

5. Amman, G.D. 1962. Seasonal biology of balsam woolly aphid on Mt. Mitchell, North Carolina. J. Econ. Ent. 55:96-98.

   Distributed throughout 7,000 acres of spruce/fir (Abies fraseri) in this area and causing the death of thousands of the firs, this aphid is shown, by quadrat charts (3 x 3-in. plots on the bark) and by laboratory studies, to produce as many as three generations a year, most of the population completing two. Details of climate and a calendar of the instar appearances are given.

6. Amman, G.D. 1966. Some new infestations of the balsam woolly aphid in North Carolina with possible model of dispersal. J. Econ. Ent. 59:508-511.

   Three recent infestations of Chermes piceae were examined to determine approximately when they began and by what means the aphid may have reached the infested areas. Infestations were dated by the numbers of trees involved and by sectioning recently killed fraser fir trees and examining them for red wood caused by aphid feeding. The aphid reached Mt. Sterling in the Great Smoky Mountains National Park prior to 1958, Roan Mountain in 1958, and Grandfather Mountain in 1959. Of the possible dispersion agents, it is concluded that wind is the most likely.

7. Amman, G.D. 1966. Aphidecta obliterata (Coleoptera: Coccinellidae) an introduced predator of the balsam woolly aphid, Chermes piceae established in North Carolina. J. Econ. Ent. 59:506-508.

   Aphidecta obliterata (L.) was introduced into North Carolina from Germany in 1960 to aid in control of C. piceae which has killed more than 1/4 million fraser fir trees in the Mt. Mitchell area. The beetle was recovered each year since its release, except in 1961 and appears to be established.

8. Amman, G.D. 1966. A study of the native predators of the balsam woolly aphid, Chermes piceae Ratz. (Homoptera: Chermidae) in North Carolina. Ph.D. Dissertation Univ. of Michigan, U.S.A.

   A field key to 18 predators was prepared. The biology and ecology of the 5 most important predators were studied, and the effect of predation on a population of the aphid was evaluated. Conclusions are that: the strongest influence on the trend of aphid population was fecundity during the spring generation, and crawler survival during the summer generation; predators fed on stages which were unimportant in determining population trends; and the condition of the host tree was the most important factor in regulating fecundity and aphid density.

9. Amman, G.D. 1967. Effect of minus 29° F on overwintering populations of the balsam woolly aphid in North Carolina. J. Econ. Ent. 60:1765-1766.

   Although mortality among Adelges piceae on Abies fraseri at Mt. Mitchell during winter 1965/66, when this low temperature (rare in North Carolina) was recorded, was higher than usual (58% and 50% on two sites sampled), significant control of the aphid population by low winter temperatures is considered unlikely.

10. Amman, G.D. 1968. Effects of temperature and humidity on development and hatching of eggs of Adelges piceae. Ann. Entomol. Soc. Amer. 61:1606-1611.

    In a biological study of A. piceae on Abies fraseri in North Carolina, the development and hatching threshold was at 5-7°C and the upper limit for development was at about 30°C. Eggs hatched best, and crawlers lived longest at intermediate temperatures. Humidity had a pronounced effect on the incubation period, on successful hatching, and on survival of crawlers. Immersion of eggs in water did not affect, but desiccation reduced, the success of subsequent hatching, while freezing had an adverse effect only when the temperature was < -8°C. The results are discussed in relation to field observations of temperature and humidity.

11. Amman, G.D. 1969. A method of sampling the balsam woolly aphid on fraser fir in North Carolina. Can. Ent. 101:883-889.

    Populations of Adelges piceae on Abies fraseri were sampled. Sampling frequency was based on the embryological period at mean monthly temperatures in the field. The sample for each date consisted of 16 pieces of bark, 1/2 in. in diam. from each of 10 trees. The precision of the method was usually within + 10% of the mean. The largest proportion of variance was within trees. Stratification of samples by levels within trees decreased variance estimates. Frequency distributions of counts of most stages of the aphid fitted approximately the negative binomial distribution, and the data were therefore transformed to logarithms.

12. Amman, G.D. 1969. Annotated list of insects infesting bark and wood of fraser fir. J. Econ. Ent. 62:249-250.

    Insects found in association with the bark and wood of fraser fir were collected over a 7-year period. Fourteen species were recovered from within the bark and wood, and 5 species which fed from outside the bark. The Scolytid,

Taenioglyptes fraseri was the most abundant species infesting the bark, the melandryids in the wood, and Adelges piceae on the bark.

13. Amman, G.D. 1970. Distribution of redwood caused by the balsam woolly aphid in fraser fir of North Carolina. U.S. Dept. Agric., For. Serv. Res. Note SE-135. 4 pp.

    Examination of 5-foot sections of felled Abies fraseri trees infested or killed by Adelges piceae revealed that the height of the first annual ring of aphid-caused redwood increased as the height of the trees increased. The number of red rings varied from two in a tree 5 inches in d.b.h. to five or six in all trees 9 or more inches in d.b.h., indicating that larger trees can sustain aphid attacks for longer periods before death than can smaller trees.

14. Amman, G.D. 1970. Field keys to predators of the balsam woolly aphid in North Carolina. U.S. Dept. Agric. For. Serv. Res. Note SE-145. 4 pp.

    Presents a key to larvae of native and introduced insects, adult mites and slugs preying on Adelges piceae with illustrations of some.

15. Amman, G.D. 1970. Phenomena of Adelges piceae populations (Hemoptera: Phylloxeridae) in North Carolina. Ann. Entomol. Soc. Amer. 63:1727-1734.

    Describes a two-year study of populations of A. piceae on Abies fraseri and factors affecting them. The condition of the host tree was the most important factor influencing the survival of aphids after the population reached its peak. Predators had little effect on the population. Weather factors were primarily responsible for large losses of eggs, but were unimportant in the dynamics of the aphid because crawlers, neosistentes and adults were well adapted to withstand them.

16. Amman, G.D. and C.F. Speers. 1964. Release of predators of the balsam woolly aphid in North Carolina. U.S. Dept. Agric., For. Serv. Res. Note SE-32. 4 pp.

    Describes experimental release of 15 more predators (2 German species and 13 from India and Pakistan), and gives a preliminary evaluation of the 6 species released in 1959-60. Laricobius erichsonii shows the best promise.

17. Amman, G.D. and C.F. Speers. 1965. Progress in biological control of the balsam woolly aphid in North Carolina. Southern Lumberman Mag. 211(2632):147-149. (See Abstr. of paper 16.)

18. Amman, G.D. and C.F. Speers. 1965. Balsam woolly aphid in the southern Appalachians. J. For. 63:18-20.

    In the southern Appalachians Adelges piceae is rapidly killing Abies fraseri. Stem infestation causes reddish-brown wood with thickened cell-walls (resembling compression wood), leading to poor conduction and death after 2-5 years. For control, a 1/8% BHC water emulsion spray is effective for < years, but is practicable only over small areas; four insect predators, introduced from Europe in 1959, show promise.

19. Amman, G.D. and R.L. Talerico. 1967. Symptoms of infestation by the balsam woolly aphid displayed by fraser fir and bracted balsam fir. U.S. Dept. Agric. For. Serv. Res. Note SE-85. 7 pp.

    Stands of Abies var. phanerolepis in Virginia and A. fraseri in North Carolina were examined to determine the difference in symptoms shown by the trees after attack by Adelges piceae. In A. balsamea var. phanerolepis, injury was chiefly 'gout' (abortion of buds and swelling of the terminal shoots), branches dying from the top of the tree downwards, but the trees survived several years of aphid attack. In A. fraseri, injury was primarily from stem infestations, and mortality of branches started at the base of the crown and proceeded to the top, the trees dying after a short period of infestation.

20. Amman, G.D. and G.F. Fedde. 1971. Infestation trends of the balsam woolly aphid in an Abies alba plantation in North Carolina. U.S. Dept. Agric. For. Serv. Res. Note SE-148. 6 pp.

    Infestations of Adelges piceae were studied on 21 trees of A. alba at 5,700 ft. alt. from 1960 to 1967. Average tree height was 22 ft. in 1960. Light infestations, occasionally increasing to severe, were found on most of the trees in each year. Severe infestations declined within 1 to 2 years without killing the trees or causing them apparent damage. In an adjacent plantation of A. fraseri, of similar age, only 6 out of 70 trees were still alive in 1967.

21. Amman, G.D. and C.F. Speers. 1971. Introduction and evaluation of predators from India and Pakistan for control of the balsam woolly aphid (Homoptera: Adelgidae) in North Carolina. Can. Ent. 103:528-533.

Briefly reviews the introduction into North Carolina between 1961 and 1965 of 15 predator species from India and Pakistan for control of Adelges piceae. Recovery studies have revealed no evidence that any predators have become established. Possible causes of the failure are discussed.

22. Annand, P.N. 1928. A contribution towards a monograph of the Adelginae (Phylloxeridae) of North America. Stanford Univ. Publ. Biol. Sci. 6:7-146.

Adelges piceae, 1st stage and adult sistens, adult progrediens, nymph and adult of progrediens alata described with 12 other known species taken in North America.

23. Anon. 1941. (The fir chermes Dreyfusia nusslini and D. piceae.) Ann. Ec. nat. For. 8:103-107. (F.)

D. nusslini has one sexual generation on Picea orientalis and one parthenogenetic generation on fir, mostly on Abies pectinata. The insects attach themselves to the needles which become curled, wither away, and die; eventually the tree is killed. D. nusslini is a dangerous pest in fir stands at low altitude, especially if these are exposed to great heat. It can be controlled by a 5-percent, lysol spray. D. piceae attacks the bark of young firs, but it is less noxious than D. nusslini.

24. Anon. 1944. (Damage to silver fir by Dreyfusia spp.) Schweiz. Z. Forstw. 95:1-11. (G.)

The biology of D. nusslini and D. piceae, with special reference to Switzerland is outlined. Major damage due to D. nusslini first occurred in 1913, and soon this insect proved much more dangerous to Swiss silver fir stands than D. piceae, which had attacked them for many years previously. The present distribution of D nusslini is insufficiently known. A major cause of the occurrence of new centres of infestation seems to be the transport of the insect with planting stock. Recently, the virulence of D. nusslini appears to have increased. Control frequently consists of felling young infested trees; chemical control methods are being investigated. In 1943 there was a surprising increase in populations of D. piceae, and it now appears desirable to pay more attention to this species than has been done hitherto.

25. Anon. 1946. Adelges attacking spruce and other conifers. Brit. For. Comm. Leafl. 7 (Rev.) 1-5.

Adelgidae occurring in Great Britain are: 1. Larch-spruce adelgids: A. viridis and A. strobilobius; 2. Spruce silver fir adelgids: A. nusslini, A. piceae; 3. Spruce-pine adelgids: A. pini, A strobi. 4. Spruce-Douglas fir adelgid: A. cooleyi. Spruce plantations injury is serious only when the planting has been done on an unfavorable site. On other conifers injury consists of the destruction of foliage and general lowering of the vitality of the plant. Control measures (spraying) in plantations probably are uneconomical. It may be practicable for nurseries and ornamental trees. A nicotine or paraffin emulsion is recommended.

26. Anon. 1952. Summary of parasites and predators liberated in Canada in 1951. Can. Dept. Agric. Insect Pest Rev. 30:284-296.

Liberations made against the balsam woolly aphid and other pests are listed by species, host and province giving the number released and their origin.

27. Anon. 1958. Here's how the aphid changed everything: roadbuilding, logging plans, logging methods, protection. Timberman Mag. 59(5):48-50.

Describes salvage methods in about 40,000 acres of Abies amabilis damaged or killed by Adelges piceae in E. Washington. The progress of attack is watched on coloured stereo-strip aerial photographs superimposed on the logging maps. Dead and infected trees are easily spotted, and where 'prism-cruising' finds < 180 sq. ft. basal area in the residual stand, clear felling is done on contract. Very close fire patrols are set.

28. Anon. 1980. Pesticides: The continuing saga of soap. Truck Logger Mag. 3(4):52-53.

Insecticidal soaps kill balsam woolly aphids.

29. Atkins, M.D. 1967. An evaluation of the threat posed by the balsam woolly aphid to Abies forests in British Columbia. Can. Dept. For. and Rural Devel. Inf. Rept. BC-X-12, 16 pp.

Evaluates the hazard of balsam woolly aphid infestation in relation to climate and concludes the pest will persist and spread throughout the high hazard zone. Probably the most serious threat is to high-value A. amabilis in central Vancouver Island.

30. Atkins, M.D. 1972. Development variability among laboratory reared balsam woolly aphid (Hemoptera: Chermidae). Can. Ent. 104: 203-208.

Neosistentes of Adelges piceae, reared from eggs of the final generation of the year, developed only under a regime of fluctuating temperature. Progeny of the first generation of the following spring developed under both constant and fluctuating temperature. The latter group showed a developmental variability that might form a basis from which distinct ecological races could develop. Rapidly developing individuals showed little variability in the time required to complete development, while slowly developing individuals showed more variability. There was no evidence of two distinct developmental groups among individuals reared under a regime of temperature cycling between 55 and 75°F, since the entire group developed rapidly; this treatment also gave the least mortality.

31. Atkins, M.D. and T.A.D. Woods. 1968. Survival of the balsam woolly aphid on Abies logs. Can. Ent. 100:412-420.

Active stages of Adelges piceae on A. grandis survived submergence of logs in sea water for 7 days, and periodic sprinkling with sea water for three weeks. Dormant stages survived submergence for up to 28 days. Active aphids survived on logs in the forest for 5 months. Crawlers frequently re-established themselves on logs and completed a second generation there. Dormant neosistentes on autumn-felled trees persisted over winter and resumed development in spring. Precautions are suggested when moving infested logs through uninfested areas.

32. Atkins, M.D. and A.A. Hall. 1969. Effect of light and temperature on the activity of balsam woolly aphid crawlers. Can. Ent. 101:481-488.

Trials gave no evidence of light-orientated movement of crawlers of Adelges piceae on the host, but rising light intensity and temperature increased the numbers of crawlers dropping from the host. The vigour and activity of crawlers may also influence dropping, but activity declines with increasing age, particularly at high temperatures. Populations at forest margins are probably those most subject to long-range dispersal.

33. Bajzak, D. 1966. Detection and appraisal of damage by balsam woolly aphid on Abies balsamea (L.) Mill. by means of aerial photography. Can. Dept. For. Bi-Mon. Res. Notes 22(6):1-2.

Experiments in Newfoundland showed that best results were obtained from photographs (scale 1:720) on Ektachrome Infrared film. Accuracy of interpretation was 63% when 7 injury classes were used, and 90% when these were combined to form 4 classes - not infested, light to moderate, severe infestation and dead.

34. Bajzak, D. 1967. Detection and appraisal of damage by balsam woolly aphid on Abies balsamea (L.) Mill. by means of aerial photography Ph.D. Dissertation. N.Y. State Univ. College of Forestry at Syracuse, N.Y., U.S.A. (See Abstr. of paper 33.)

35. Bakuzia, E.V. and H.L. Hansen. 1965. Balsam fir. A Monographic Review. Univ. Minn. Press. Minneapolis, U.S.A., pp. 169-173.

Literature on the importance, life history, control and insects associated with balsam woolly aphid is reviewed.

36. Balch, R.E. 1931. Forest insects in Nova Scotia. For. Chron. 7:63-69.

Balsam woolly aphid was one of many species described.

37. Balch, R.E. 1932. Report of forest insects of Nova Scotia in 1931. Nova Scotia Dept. Lands and For. Rept. 1931:46-52.

Peronea variana occurred in serious numbers over 200 sq. mi. for 2 yrs. in Cape Breton. Balsam fir was killed in mature stands only. Dreyfusia piceae was found to be the cause of the 'gout disease' on balsam fir, and has brought about serious deterioration and some mortality throughout the Province. Dying of beech stands following attack by Cryptococcus fagi continues.

38. Balch, R.E. 1932. Dreyfusia piceae (Ratz.) and its relation to 'Gout Disease'. 62nd. Rept. Entomol. Soc., Ont. 1931:61-65.

Describes symptoms of balsam woolly aphid damage.

39. Balch, R.E. 1932. The 'Gout Disease' of balsam fir. For. Chron. 8:46-51.

Describes symptoms of balsam woolly aphid damage.

40. Balch, R.E. 1934. The balsam woolly aphid, Adelges piceae (Ratz.) in Canada. Sci. Agric. 14:374-383.

A. piceae, apparently introduced from Europe, occurs throughout Nova Scotia, Prince Edward Island, southern New Brunswick, and parts of New England, where it is killing Abies balsamea, causing 'gout disease'. Giant cells with enlarged nuclei occur in the cortex at the point of feeding and are later surrounded by periderm. The cambium is also stimulated. A. nusslini has not been found in Canada. An European predator, Leucopis obscura, has been introduced.

41. Balch, R.E. 1936. The balsam woolly aphid (Adelges piceae Ratz.) Can. Dept. Agric., Ent. Branch, Div. For. Ins., Spec. Cir. 4 pp.

Provides a brief outline of A. piceae, its damage and the size of the infestation.

42. Balch, R.E. 1945. Spread of beech scale and balsam woolly aphid in Maritimes. Can. Dept. Agric. Bi-Mon. Prog. Rept. 1(2):1.

Winter temperatures of -30° F limit population levels of the balsam woolly aphid.

43. Balch, R.E. 1946. The balsam woolly aphid (Adelges piceae Ratz.) Can. Dept. Agric. Bi-Mon. Prog. Rept. 2(6):1.

Outlines the results of aphid studies conducted in the Maritime Provinces of Canada.

44. Balch, R.E. 1949. Studies of Adelges piceae Ratz. and its effect on Abies balsamea (L.) Mill. Ph.D. Dissertation. N.Y. State College of Forestry. Syracuse Univ., N.Y., U.S.A. (See Abstr. of paper 45(.

45. Balch, R.E. 1952. Studies of the balsam woolly aphid Adelges piceae (Ratz.) and its effect on balsam fir, Abies balsamea (L.) Mill. Can. Dept. Agric. Pub. No. 867, 76 pp.

A comprehensive study covering biology, seasonal history and life history, habits and behaviour of sistentes, natural control, effect on the tree, effect on the stand, and control of the balsam woolly aphid.

46. Balch, R.E. 1953. Susceptibility of species of fir to balsam woolly aphid, Adelges piceae Ratz., Can. Dept. Agric. Bi-Mon. Prog. Rept. 9(4):1.

Observations made in Europe and in Canada indicate that most species of fir are resistant to attack by this aphid, and that its greater destructiveness in Canada (where it was introduced from Europe) is due to the higher sensitivity of Abies balsamea and the allied A. fraseri to the salivary injections of the insect as well as to lack of natural control.

47. Balch, R.E. 1954. Spread of balsam woolly aphid in relation to climate in Newfoundland. Can. Dept. Agric. Bi-Mon. Prog. Rept. 10(6):1.

A. piceae has been present in Newfoundland for about 15 years. Rate of spread has averaged less than 10 miles/year and is probably limited by the direction of the prevailing summer winds.

48. Balch, R.E. 1955. Effects of balsam woolly aphid on the quality of pulp. Can. Dept. Agric. Bi-Mon. Prog. Rept. 11(4):1.

The salivary injections of Adelges piceae into the bark of balsam fir cause a stimulation of cambial activity and the production of an abnormal wood similar to compression wood. The annual rings during a period of moderately heavy infestation are dark, hard, and brittle. Trees so affected are unsuitable for lumber owing to uneven shrinkage causing warping and splitting. Pulp ground from this wood was short and brittle; 'burst' and 'tear' were low and the density of the wood was high. The pulp is inferior to that from normal wood and a high percent should not be brought into the mill at one time. By proper mixing with normal wood, however, it should be possible to use all infested wood.

49. Balch, R.E. 1956. Damage caused by balsam woolly aphid. Can. Dept. Agric. Bi-Mon. Prog. Rept. 12(5):1.

Reports on a reconnaissance made in 1956 to determine the damage caused by this European insect to balsam fir in New Brunswick and Nova Scotia.

50. Balch, R.E. 1960. The approach to biological control in forest entomology. Can. Ent. 92:297-310.

Discusses the general approach to biological control of forest insects in Canada, and some of the basic principles involved, in relation to a brief review of two recent projects in the Maritime Provinces, viz. control of (1) Diprion hercyniae and (2) Adelges piceae.

51. Balch, R.E. and W.J. Carroll. 1958. The balsam woolly aphid. Can. Dept. Agric. For. Bio. Div. Pub. No. 977 (Rev.):8 pp.

The importance, habits, damage, control and ways to recognize infestations of the balsam woolly aphid are described.

52. Balch, R.E., R.C. Clark and N.R. Brown. 1958. Adelges piceae Ratz. and its biological control in Canada. Proc. 10th Int. Congr. of Entomol. Montreal, 1956, pp. 807-817. (Can. Dept. For. Rept. No. 372.)

Reviews briefly what is known about A. piceae in Canada, discusses some questions that have arisen in the course of the introduction of natural enemies from Europe, and summarizes progress to date.

53. Balch, R.E., J. Clarke and J.M. Bonga. 1964. Hormonal action in products of tumors and compression wood (in Abies balsamea) by an aphid (Adelges piceae). Nature (London) 202 (4933): 721-722.

It is suggested that the various symptoms of 'gout' result from a disturbance of the normal balance of growth-regulating substances in the tree. It is possible that the insect's saliva actually contains such substances, but the fact that the response is greater in more vigorous trees suggests rather that saliva produces abnormal activity of substances already in the tree by enzymatic or synergistic action.

54. Balch, R.E. and R.G. Mitchell. 1967. The balsam woolly aphid Adelges (= Dreyfusia, Chermes) piceae (Ratz.). In: Important Forest Insects and Diseases of Mutual Concern to Canada, the United States and Mexico. Can. Dept. For. and Rural Devel. Queens Printer, pp. 70-74.

The importance, distribution, hosts, damage, life history, and control of the balsam woolly aphid in North America are described.

55. Baldon, J. 1839. Diseases of silver fir. Trans. Highland Soc. 12:510-553.

Balsam fir unsuccessful in Scotland because of aphid.

56. Blais, J.R. 1965. Discovery of the balsam woolly aphid, Adelges piceae (Ratz.) on the Magdalen Islands. Can. Dept. For. Bi-Mon. Prog. Rept. 21(1):1-2.

Studies recently made on these islands in the Gulf of St. Lawrence indicate that A. piceae reached the islands between 1940 and 1950, possibly transported by wind, but more probably on balsam fir logs imported from Cape Breton or Prince Edward Island where it has been established since about 1910.

57. Bonga, J.M. and J. Clark. 1965. The effect of β-inhibitor on histogenesis of balsam fir bark cultured in vitro. For. Sci. 11:271-278.

Describes and illustrates an experiment to determine the effects of high concentrations of β-inhibitor (an acidic growth inhibitor believed to be abnormally abundant in the bark of Abies balsamea attacked by Adelges piceae) on the growth of bark from healthy A. balsamea. Extreme hypertrophy of phloem parenchyma and ray cells of the bark, cultured aseptically on a nutrient medium, occurred when β-inhibitor was added. Conspicuous swellings developed, resembling the bark malformations known as 'gout disease' caused by A. piceae.

58. Borner, C. 1907. (Systematics and biology of Chermidae.) Zool. Anz. 32:413-428. (G.)

59. Borner, C. 1908. (Theories on the biology of Chermidae.) Zool. Anz. 33:647-663. (G.)

60. Borner, C. 1908. Dreyfusia piceae Ratz. and D. nusslini nev. sp. Zool. Anz. 33:737-750. (G.)

61. Borner, C. 1908. (A monograph of studies on Chermidae.) Arb. Kaiserl. Biol. Anst. VI:81-320. (G.)

62. Borner, C. 1909. (The biology and systematics of Chermidae.) Biol. Centralbl. 29:118-146. (G.)

63. Bowden, P.B. 1962. Parasites and predators of forest insects liberated in the United States through 1960. U.S. Dept. Agric. Handbook No. 226.

64. Brower, A.E. 1947. The balsam woolly aphid in Maine. J. Econ. Ent. 40:689-694.

Adelges piceae, is the most destructive insect on fir in the coastal half of Maine. It is most injurious on wet waterlogged areas of soil. Injury is of two types. The 'twig phase' produces swollen and gouty tips and nodes, commonly arresting growth and killing the top or whole tree. The 'trunk phase' attacks the stems and kills especially trees of merchantable size. Attack causes the production of 2-3 thick abnormal rings

of ligniferous wood but the average growth of trees attacked was reduced from 26 to 49% before death. Two complete generations develop. Numbered trees on 16 quarter acre plots showed that when the infestation passes the medium stage, physiological disturbances occur in the host and death occurred in an average of 3.15 years. Temperatures below -15°F may kill all above the snow line. No parasites were found. A few syrphid fly larvae of the lycaenid butterfly Feniseca tarquinius were found for the first time attacking the aphid. Recommended sprays are dormant lime sulfur 1 to 19, nicotine sulfate 1 to 400 and suitable miscible oils.

65. Brown, N.R. 1947. Spread of an important predator of the balsam woolly aphid. Can. Dept. of Agric. Bi-Mon. Prog. Rept. 3(6): 6-7.

Leucopis obscura was introduced into the Maritime Provinces in 1933, 1934, 1936 and 1941 to help combat Adelges piceae, upon which its larva is predacious. In the 14 years since its first liberation, this small fly has spread 110 miles from the release points. Preliminary studies on its effectiveness indicate that a medium to heavy attack by the aphid is necessary before the predator becomes well established.

66. Brown, N.R. and R.C. Clark. 1956. Studies of predators of the balsam woolly aphid, Adelges piceae (Ratz.). I. Field identification of Neoleucopis obscura (Hal.), Leucopina americana (Mall) and Cremifania nigrocellulata Cz. (Diptera, Chamaemiidae). Can. Ent. 88:272-279.

The eggs, larvae, puparia and adults are described and figured.

67. Brown, N.R. and R.C. Clark. 1956. Studies of predators of the balsam woolly aphid, Adelges piceae (Ratz.). II. An annotated list of the predators associated with the balsam woolly aphid in eastern Canada. Can. Ent. 88:678-683.

An annotated list is given of introduced predators, native predators, spp. probably predaceous and possibly predaceous.

68. Brown, N.R. and R.C. Clark. 1957. Studies of predators of the balsam woolly aphid. IV. Neoleucopis obscura (Hal.) an introduced predator in Eastern Canada. Can. Ent. 89:533-546.

N. obscura has been liberated in New Brunswick (1933-36), Nova Scotia (1941), Prince Edward Island (1941) and Newfoundland (1955-56). Surveys in 1947 and 1948 showed that the predator had spread over almost the entire range of the

host in New Brunswick and Nova Scotia. Adelges piceae is the chief host in eastern Canada, although Pineus strobi is an occasional host. N. obscura is a bivoltine species; the puparium is the chief overwintering stage. The larvae feed mostly on host intermediate stages and adults, rarely on eggs. As much as 33% parasitization of N. obscura by Pachyneuron altiscutum has been recorded. N. obscura suffers high mortality from climatic factors during hibernation whereas the overwintering host suffers relatively less. A lack of adequate control by N. obscura is caused by poor timing of the predator larval period; it feeds too late in the host developmental period.

69. Brown, N.R. and R.C. Clark. 1959. Studies of predators of the balsam woolly aphid, VI. Aphidecta obliterata (L.) (Coleoptera: Coccinellidae), an introduced predator in eastern Canada. Can. Ent. 91:596-599.

A. obliterata adults were released on 6 occasions between 1941 and 1955 in New Brunswick, and twice (in 1957 and 1958) in Newfoundland. With summer releases, a complete generation was observed in the field during the year of release, but no recoveries were made in the following year because adults were unable to survive winter conditions.

70. Brown, N.R. and R.C. Clark. 1960. Studies of predators of the balsam woolly aphid, Adelges piceae (Ratz.) VIII. Syrphidae (Diptera). Can. Ent. 92:801-811.

Gives descriptions for field identification of Syrphus torvus, Metasyrphus lapponicus and Neocnemodon coxalis, and presents data on their life history and habits, parasitization by Hymenoptera, population fluctuations and control value. In general, they can reduce the rate of increase of A. piceae, but cannot reverse the upward trend of the adelgid population in the summer generation, unless other controlling factors are operating. Brief notes are included on other syrphids found on infested balsam fir.

71. Brown, N.R. and R.C. Clark. 1962. Studies of predators of the balsam woolly aphid, Adelges piceae (Ratz.) X. Field identification of Laricobius erichsonii Rosen. (Coleoptera: Derodontidae). Can. Ent. 94:191-193.

Presents illustrated descriptions of all stages of the predator.

72. Bryant, D.G. 1963. Notes on Laricobius erichsonii, an introduced predator of the balsam woolly aphid in Newfoundland. Can. Dept. For. Bi-Mon. Prog. Rept. 19(6):1.

Notes based on recovery records and field observations on adult beetles in the Humber Valley, where nearly 8000 were released in 1958 and 1959. L. erichsonii has become established, but appears to have been unable to maintain aphid densities at an acceptably low level.

73. Bryant, D.G. 1963. The means of dispersal and the recommended quarantine practices of the balsam woolly aphid, Adelges piceae (Ratz.) in Newfoundland. Phytoprotection Quebec 44:42-46.

Dispersal being partly by wind, partly by the introduction of larvae and eggs on imported wood or foliage, etc., quarantine (voluntary) measures are considered useful, but not sufficient to stop spread. Aerial surveys and ground surveys are complementary.

74. Bryant, D.G. 1964. Balsam woolly aphid Adelges piceae (Ratz.) development on branches of balsam fir. M.Sc. Thesis, McGill University, Montreal.

75. Bryant, D.G. 1968. Effect of Sumithion on the balsam woolly aphid in Newfoundland. Can. Dept. For. and Rural Devel. Bi-Mon. Res. Notes 24:47.

Aerial spraying with Sumithion at a rate of 2 oz. concentrate/ acre, was carried out in July 1968 to control Lambdina fiscellaria fiscellaria. At the same time an assessment was made of the effect of the spray on Adelges piceae. There was no evidence to show that sessile aphids were killed, but the results indicated that Sumithion restricted the establishment of crawlers and that a significant reduction in numbers might be obtained if the insecticide were applied before eclosion began.

76. Bryant, D.G. 1971. Balsam woolly aphid Adelges piceae (Homoptera: Phylloxeridae) seasonal and spatial development in crowns of balsam fir, Abies balsamea. Can. Ent. 103:1411-1420.

In Newfoundland, A. piceae is dimorphic and has three generations a year in crowns of A. balsamea. Two generations of the sistens predominate. Progredientes are more common than elsewhere in N. America and occur on nearly all parts of a branch. They do not

mature on current needles. The ratio of progredientes to sistentes is about 1:40 in flowering years, and 1:80 in non-flowering years. Aphid development in the spring is earliest at flowered internodes, is 11-14 days later at 2-year nodes, a further 4-8 days later at older nodes, and latest at the shoot tips. Intra-crown and inter-tree differences in aphid development are small but measurable. Stratification of the tree crown is necessary for sampling during the first aphid generation.

77. Bryant, D.G. 1972. The measurement of population density of the balsam woolly aphid, Adelges piceae (Ratz.) (Homoptera: Phylloxeridae), a highly aggregate insect. Ph.D. dissertation. Yale Univ. 169 pp.

The study was designed to determine the distribution and survival of aphids on branches of Abies balsamea in Newfoundland, to determine the correlation between aphid numbers and the degree of damage, and to develop precise methods for sampling aphid populations. The abundance and survival of aphids varied with the age and position of the nodes and flowered internodes within branches, and varied inversely with branch age. However, the numbers of aphids within the stand remained constant. The quality of host tissue and the occurrence of late frosts were apparently the major causes of aphid mortality; predators were present in very low numbers. Sampling methods for detection surveys and for measuring aphid population sizes were developed from the data, and are being applied in current studies.

78. Bryant, D.G. 1974. Distribution of first instar nymphs of Adelges piceae (Homoptera: Phylloxeridae) on branches of balsam fir, Abies balsamea, after colonization. Can. Ent. 106:1075-1080.

Nodes on 4- or 5-year-old branches of A. balsamea trees 3-5 m high were colonized with eggs of A. piceae, and the distribution over the branches of the first-instar nymphs was recorded. Results showed that the nymphs dispersed towards the apical portion of the branches and settled in the apical 3 years' growth.

79. Bryant, D.G. 1974. A review of the taxonomy, biology and importance of the adelgid pests of true firs. Can. For. Serv., Inf. Rept. N-X-111. 50 pp.

Reviews the taxonomy, distribution, life cycle, habits, seasonal development, population behaviour, morphology and biochemistry of the eleven species of adelgids that infest Abies spp. in different countries; summarizes data on the distribution and susceptibility of various Abies spp.; and

describes the effects of adelgids on their host trees, with particular reference to Adelges piceae on Abies balsamea and other firs in N. America.

80. Bryant, D.G. 1976. Distribution, abundance, and survival of the balsam woolly aphid, Adelges piceae (Homoptera: Phylloxeridae) on branches of balsam fir, Abies balsamea. Can. Ent. 108: 1097-1111.

Over 95% of feeding balsam woolly aphids occur in crevices on balsam fir branches and the highest density occurs within the 3-year tip of branches. The crevices occur under the bud scales at nodes, the base of each season's growth, and among staminate flower buds or among and within flower bracts. The abundance and survival of aphids as well as mortality factors vary with the location of the nodes in a branch, the type of branch, and aphid generation. The significant differences show that there are 9 to 13 strata within the 3-year tip of a branch. For ecological studies and measuring population levels, the cluster of aphids within a defined crevice, for example, under the bud scale at the base of a cluster of shoots, can be selected as a sample unit.

81. Bryant. D.G. 1976. Sampling populations of Adelges piceae (Homoptera: Phylloxeridae) on balsam fir, Abies balsamea. Can. Ent. 108:1113-1124.

The balsam woolly aphid, A. piceae, has a complex distribution in the crown of trees. The sample universe and sample units are defined, and methods of detecting, monitoring and measuring population levels at stated levels of confidence, accuracy, and assurance are described. Suggestions are given for sampling aphids on the stems of trees.

82. Bryant, D.G. 1976. The impact of balsam woolly aphid damage on balsam fir stands in Newfoundland: Discussion, with reply, by G. Page. Can. J. For. Res. 6:557-559.

In discussing the effect of balsam woolly aphid damage on balsam fir stands in Newfoundland (Canada), D.G. Bryant presents an equation for recalculation of the basic data presented by G. Page (1975). In reply the original author (Page) defends his calculation and states that in calculating undamaged equivalent volumes the original equations are correct and are sufficiently detailed for use by forest managers. They are the most realistic representations of the complex site relationships between aphid damage, site conditions and balsam fir stands in Newfoundland.

83. Bryant, D.G., L.J. Clarke and N.D. Bhure. 1972. Suggested guidelines for fertilizer trials in stands affected by the balsam woolly aphid. Can. For. Serv., Inf. Rept. N-X-81. 13 pp.

84. Buckhorn, W.J. and P.G. Lauterbach. 1957. Timing of aerial surveys for balsam woolly aphid. U.S. Dept. Agric. For. Serv. Res. Note. PNW-142, 2 pp.

85. Buffam, P.E. 1962. Observations on the effectiveness and biology of the European predator Laricobius erichsonii Rosen. (Coleoptera: Derodontidae) in Oregon and Washington. Can. Ent. 94:461-472.

A total of 10,125 adults of L. erichsonii collected in Europe was released in 1958-59 in an attempt to control Adelges piceae in Washington and Oregon. In 5 of the 8 release areas the predator is well established. Maximum observed dispersal two years after release was 850 ft. Larvae and adults were also observed feeding on an unknown species of Pineus on Picea engelmannii. Detailed studies on 4 trees in 3 areas showed, in 3 cases, a significant reduction in host population. In laboratory studies a fourth-instar larva consumed 50 A. piceae eggs in 24 hrs. Notes are given on the life cycle of L. erichsonii in three different areas in Oregon and Washington. No parasites, predators, or diseases of L. erichsonii were observed.

86. Burdon, E.R. 1907. Note on the origin of the name Chermes or Kermes. J. Linn. Soc. London 30:5-9.

87. Busby, R.J.N. 1962. Species and forms of the silver fir adelgid in Scotland. Scot. For. 16:243-254.

Six species and forms of the silver fir adelgid have now been described. Of these, only three have hitherto been recorded in Britain. Infested material was collected from three Scotland east coast and two west coast sites. The identify of the collected populations was determined by counting the number of pores in ten central gland areas of the mesial-plate wax glands of each insect. On the basis of these pore counts, the populations were separated into six statistically distinct groups, which correspond closely to the published data for the six species and forms. Not all the groups could be identified with complete certainty, but the results suggest that more species and forms of Adelges exist in Scotland than have been previously recorded.

88. Busby, R.J.N. 1964. A new adelgid on Abies grandis causing compression wood. Quart. J. For. 58:160-162.

Describes identification of a new form, Adelges piceae f. grandis which may be synonymous with A. piceae f. canadensis, and causes serious compression-wood formation in grand fir in Britain, probably through the action of its saliva on the cambium. A. piceae f. typica may not attack grand fir, and does not cause compression wood on those firs it does attack.

89. Carroll, W.J. and D.G. Bryant. 1960. A review of the balsam woolly aphid in Newfoundland. For. Chron. 36:278-290.

First recorded in Newfoundland in 1949, this is now the most serious forest insect pest in the Province, its host being Abies balsamea. The outbreak is described and possible control measures discussed.

90. Carrow, J.R. 1967. Some effects of the host tree nutrition on establishment and survival of balsam woolly aphid, Adelges piceae (Ratz.). M.Sc. Thesis, Univ. British Columbia, Canada.

91. Carrow, J.R. 1969. An apparatus for field study of the balsam woolly aphid. Can. Ent. 101:132-134.

The apparatus consists of a stereo zoom microscope mounted on a supporting platform. Metal support bolts are not used so that stem populations can be studied without the contamination of the phloem sap by the insertion of metal into the tree.

92. Carrow, J.R. 1971. Foliar application of nitrogen to the host trees and its effect on the life history and population growth of the balsam woolly aphid, Adelges piceae (Ratz.). (Can. For. Serv., Inter. Rept. BC-26.) Ph.D. Dissertation Cornell Univ. 113 pp. (See abstract of paper 95).

93. Carrow, J.R. 1973. Establishment and survival of balsam woolly aphid on second growth Amabilis fir at intermediate elevations. Can. For. Serv., Bi-Mon. Res. Notes 29:10-11.

A study of the infestation of second-growth Abies amabilis (15-30 years old) by Adelges piceae at three altitudes (2300, 2850, and 3500 ft.) in British Columbia, indicated that the insect can establish itself and survive at such heights, but the infestation index and incidence of attack on crowns were significantly lower at 3500 ft. presumably because of the greater severity of winter and summer drought, than at lower altitudes.

94. Carrow, J.R. and K. Graham. 1968. Nitrogen fertilization of the host tree and population growth of the balsam woolly aphid, Adelges piceae. Can. Ent. 100:478-485.

Sixty trees of Abies amabilis growing in the greenhouse on (a) a nutrient-deficient mineral soil, and (b) an enriched humic soil, were artificially infested with A. piceae larvae. Subsequently, groups of 10 trees were given foliar treatments of various concentrations of NH_4NO_3 and urea. In the following year, fertilizer trials were made with 32 trees in Seymour Valley, British Columbia, to determine the effect of fertilizing uninfested trees on the establishment of aphid larvae. In the greenhouse, foliar sprays of 1% NH_4NO_3 solution gave a 23% decrease in population in 10 weeks, as contrasted with a 31% increase on controls. In the field, larval establishment was 31-37% lower on NH_4NO_3-treated trees than on controls. Since there was no increased mortality of aphid, it was inferred that the fertilizer acts by inhibiting the settling of larvae.

95. Carrow, J.R. and R.E. Betts. 1973. Effects of different foller-applied nitrogen fertilizers on balsam woolly aphid. Can. J. For. Res. 3:122-139.

In British Columbia, Adelges piceae were reared on young Abies grandis trees maintained in a controlled environment or outdoors. Solutions of various N fertilizers were applied repeatedly to the tree, and the effects on aphids and the amino acids of the bark were studied. On urea-fertilized trees populations multiplied 16.5 times in five generations, compared with an increase of 5.7 times on unfertilized trees and of 1.4 times on trees fertilized with NH_4NO_3. Urea promoted aphid establishment and reproduction, whereas NH_4NO_3 affected both these processes and survival adversely. The highest survival and establishment rates resulted from potassium ammonium nitrate. These differences may be related to fertilizer-induced changes in the amino-acid diet of the aphids. Thin-layer electrophoresis and chromatography revealed that urea, NH_4NO_3, and $Ca(NO_3)_2$ each increased arginine concentrations in the bark, the highest concentrations resulting from treatment with NH_4NO_3. Traces of phenylalanine and asparagine, found in other treatments, were absent from trees fertilized with NH_4NO_3.

96. Carrow, J.R., G.S. Puritch and P.C. Nigam. 1977. Field tests of Furadan and Baygon against balsam woolly aphid in British Columbia. Can. For. Serv. Bi-Mon. Res. Notes 33:10.

In stem injection tests, Baygon (propoxur) was not sufficiently mobile to affect aphid (Adelges piceae) populations of young Abies amabilis. Furadan (carbofuran) caused small increases in the mortality of aphids on A. grandis and was tested in the field in 1974. When applied in combination with urea fertilizer to the rooting zone, Furadan increased the mortality of crown populations of aphids by 30-50%. Stem populations were

unaffected. The beneficial effect lasted only one generation and the insecticide did not have sufficient residual life to affect recolonization by the subsequent generation.

97. Carter, C.I. 1971. Conifer woolly aphids (Adelgidae) in Britain. Brit. For. Comm. Bull. 42:51 pp.

Discusses the systematic position and generalized life cycles of the adelgids, and describes and illustrates the British species of Adelges and Pineus. Keys are given to the 14 winged morphs of the 9 species having alatae; a key is also provided to the adult apterae of Pineus. Only for A. viridis and A. abietis gallicolae, and for P. orientalis and P. pini sexuparae, is it necessary to have information on the life cycle for specific identification. Methods of preparing specimens for microscopic examination, and a world check list of species of Adelgidae are appended. Both genera are broadly delimited, the other genera recognized by Borner and Heinze being treated as subgenera.

98. Ceianu, I. and I. Teodorescu. 1973. (Dendrocerus (Macrostigma) serricornis (Boh.)), parasite of the dipteran chamaemyiid Neoleucopis obscura Hal., predaceous on colonies of Dreyfusia piceae ratz. (Homoptera: Adelgidae)). An. Univ. Bucur. Biol. Anim. 22:65-72. (Rom.).

N. obscura a chamaemyiid predaceous in the larval stage on the chermesid D. piceae, and its principal parasite, D. serricornis (Ceraphronoidae) are recorded for the 1st time from Romania. Ecological observations are also presented on N. obscura.

99. Ceianu, I. and I. Teodorescu. 1975. (A little known pest of Abies alba: Dreyfusia piceae (Homoptera: Adelgidae)) Revista Padurilor-Industria Lemnului, Celuloza si Hirtie Silvicultura si Exploatarea Padurilor 90:234-237. (Rom.).

D. (Adelges) piceae was identified as the cause of infestations on smooth-barked stems of A. alba in the Eastern Carpathians (NE Rumania). Dominant trees were most severely attacked. The life cycle in the Carpathians is described. In another population of A. piceae on A. nordmanniana in an arboretum in S. Rumania, two predatory flies, Neoleucopis obscura and Aphidoletes sp., were present in large numbers. Observations on N. obscura and three of its parasites are described. The importance and control of A. piceae in Central Europe and North America is discussed.

100. Cerda, M.L. and R.I. Gara. 1977. (The aphid Adelges: a serious problem for Chilean Abies spp.) Chile Forestal 3(27):15 (Es.)

A severe infestation of A. nordmanniana by Adelges sp. (probably A. piceae) is reported from Traiguen, 70 km N. of Temuco. S.-central Chile. Because the area of the infestation is still small it may be possible to eradicate the pest by felling and burning the trees most seriously affected and treating the rest with an insecticide (e.g. Lindane). Damage to the stem is often sufficient to cause breakage in the upper part of the crown at the point of attack.

101. Cholodkovsky, N. 1903. (Chermes damage to silver fir.) Zool. Anz. 26:258-259. (G.).

102. Choldkovsky, N. 1905. (Nutrition of Chermidae.) Ztschr. f. wiss. Insektenbiol., 1:167-169. (G.).

103. Cholodkovsky, N. 1907. (Chermes, aphid enemies of conifers). Feinde der Nadelholzer. Verlag R. Friedlander & Sohn, Berlin. 44 pp. (G.)

Reviews damage by various Chermes species on conifer trees.

104. Chrystal, R.N. 1926. The silver fir Chermes. Brit. For. Comm. Bull. 7, 27 pp. (see Abstr. of paper 341, a revised printing).

105. Chrystal, R.N. 1926. The genus Dreyfusia in Britain and its relation to silver fir. Phil. Trans. Roy. Soc. London B, 214:29-61.

Summarizes information on Dreyfusia found on fir in Great Britain.

106. Clark, J. and J.M. Bonga. 1963. Evidence for indole-3-acetic acid in balsam fir, Abies balsamea (L.) Mill. Can. J. Bot. 41:165-173.

An ether-extractable auxin was discovered in the inner bark of balsam fir. Characterization of the auxin by paper chromatography, Avena bioassay, and chromogenic tests indicates that it is IAA. A strong growth inhibitor was extracted together with the auxin.

107. Clark, R.C., N.R. Brown and B.C. Smith. 1954. Biological control of balsam woolly aphid. Can. Dept. Agric. Bi-Mon. Prog. Rept. 10(6):1.

Of the European predators released in New Brunswick in 1951-54, Laricobius erichsonii and Pullus impexus appear to have established themselves.

108. Clark, R.C. and N.R. Brown. 1957. Studies of predators of the balsam woolly aphid, Adelges piceae (Ratz.) III. Field identification and some notes on the biology of Neoleucopis pinicola Mall. (Diptera: Chamaemyiidae). Can. Ent. 89:404-409.

109. Clark, R.C. and N.R. Brown. 1958. Studies of predators of balsam woolly aphid. V. Laricobius erichsonii Rosen (Coleoptera: Derodontidae) an introduced predator in eastern Canada. Can. Ent. 90:657-672.

A history is given of liberations into the Atlantic Provinces from 1951 to 1955, establishment and spread are reviewed and information is given on the life history, habits and natural control of L. erichsonii. Population sampling methods for prey and predators are described. When the predator is present the normal upward trend from hieosistentes to aestivosistentes prey generation was reversed. L. erichsonii is more effective than Neoleucopis obscura because the peak larval feeding period occurs at an earlier date and because the larvae destroy prey eggs. This has resulted in an almost complete loss of the aestivosistentes prey generation.

110. Clark, R.C. and N.R. Brown. 1959. Predator introduction for balsam woolly aphid control. Can. Dept. Agric. Bi-Mon. Prog. Rept. 15(6):1.

Notes on the present status of 9 species introduced since 1951: Laricobius erichsonii, Pullus impexus, Aphidecta obliterata, Cremifania nigrocellulata, Aphidoletes thompsoni, Exochomus quadripustulatus, and Scymnus pumilio.

111. Clark, R.C. and N.R. Brown. 1959. A field cage for rearing syrphid larvae and other predators of the balsam woolly aphid, Adelges piceae (Ratz.) (Homoptera: Adelgidae). Can. Ent. 91:723-725.

Describes a rearing cage of plywood and plastic that is fixed to the stems of infested trees.

112. Clark, R.C. and N.R. Brown. 1960. A method for adapting a microscope for observation of non-motile insects on tree trunks. Can. Ent. 92:79-80.

An old-style binocular microscope with a U-shaped base was removed from the base and attached to small metal plates that had previously been fastened to the tree stem. Illumination was provided by a flash-light on a light metal arm attached to the microscope body.

113. Clark, R.C. and N.R. Brown. 1960. Studies of predators of the balsam woolly aphid Adelges piceae (Ratz.) VII. Laricobius rubidus Lec. (Coleoptera: Derodontidae) a predator on Pineus strobi (Htg.) (Homoptera: Adelgidae). Can. Ent. 92:237-240.

Short notes on life history and habits. L. rubidus is not a common predator of A. piceae, but is included in the series because of its close taxonomic similarities to L. erichsonii, which is.

114. Clark, R.C. and N.R. Brown. 1960. A laboratory method for rearing predators of the balsam woolly aphid, Adelges piceae (Ratz.). Can. Ent. 92:696-697.

Describes a method whereby a continuous flow of moist air was passed through a series of glass jars set up in an adapted laboratory fume chamber. This prevented or retarded mould growth and drying out of the bark and prey.

115. Clark, R.C. and N.R. Brown. 1961. Studies of predators of balsam woolly aphid Adelges piceae Ratz. IX. Pullus impexus (Muls.) (Coleoptera: Coccinellidae) an introduced predator in eastern Canada. Can. Ent. 93:1162-1168.

Describes life history and habits of P. impexus, introduced into New Brunswick, Nova Scotia, and Newfoundland during 1951-60. The predator has failed to establish itself, because of high winter mortality.

116. Clark, R.C. and N.R. Brown. 1962. Studies of the predators of the balsam woolly aphid, Adelges piceae (Ratz.). XI. Cremifania nigrocellulata Cz. (Diptera: Chamaemyiidae) an introduced predator in eastern Canada. Can. Ent. 94:1171-1175.

C. nigrocellulata was released in A. piceae infestations round Fredericton, N.B. from 1952 to 1957, and although dispersal was slow at first, the predator has now been recovered up to 40 miles from the original release points. While all larval stages of the predator feed on A. piceae, only the final-instar larvae feed extensively, and this almost entirely on adult adelgids that have already laid most of their eggs. Hence, although large numbers of adult adelgids are destroyed, generation survival is little affected, and adelgid populations are not markedly reduced.

117. Clark, R.C., D.O. Greenbank, D.G. Bryant and J.W.E. Harris. 1971. Biological control of forest pests in Canada, 1959-1968. Adelges piceae (Ratz.) balsam woolly aphid (Homoptera: Adelgidae). In Biological Control Programmes Against Insect and Weeds in Canada. Commonw. Inst. of Biol. Control, Tech. Comm. No. 4:113-127.

Outlines the aphid problem in Canada, describes introduced predators and their effectiveness and recommends that the effectiveness of other control methods be tested.

118. Claydon, N. and J.F. Grove. 1979. Insecticidal secondary metabolic products from entomogenous fungus Fusarium larvarum pathogen of the balsam woolly aphid, Adelges piceae. J. Invert. Path. 33:364-367.

119. Cote, Jr. W.A., N.P. Kutscha, B.W. Simson and T.E. Timell. 1968. Studies on compression wood. VI. Distribution of polysaccarides in the cell wall of tracheids from compression wood of balsam fir, (Abies balsamea (L.) Mill.). Tappi 51, (1):33-40.

Adelges piceae feeding is discussed as possible cause of high galactose residues in balsam fir wood.

120. Cros, E.T. Du. 1975. (First lessons from a progeny test of Picea abies of the Kertoff stand in Vosga.) Annales des Sci. For., France. 32(3):143-155. (F.).

Date of flushing was positively correlated with resistance to attack by Adelges piceae and both characters were determined by additive genetic effects.

121. De L'Armee, T. and G.S. Purich. 1974. Biocidal effect of fatty-acids and soaps on the balsam woolly aphid. Can. For. Serv. Bi-Mon. Res. Notes 30:35-36. (See Abstr. of paper #293).

122. Delucchi, V. 1953. (Aphidecta obliterata L. (Coleoptera: Coccinellidae) as a predator of Dreyfusia (Adelges) piceae Ratz.). Pfl. Sch. Ber. 11:73-83 (G.).

Notes on the life history of A. obliterata and its parasites. A. obliterata has only one generation year and attacks A. piceae in late spring. Its value in control of the pest is fairly small, but the adults were sent to Canada in 1951 and 1952 to help to control outbreaks there. Brief notes are presented on rearing and transport.

123. Delucchi, V. 1954. Pullus impexus (Muls.) (Coleoptera: Coccinellidae) a predator of Adelges piceae (Ratz.). (Hemiptera: Adelgidae) with notes on its parasites. Bull. Entomol. Res. 45:243-478.

A profusely illustrated study of the beetle and its parasites, the preliminary work to a plan for mass rearing and shipment to Canada. Mass rearing was begun in Germany in 1951 and in Switzerland in 1952. Notes are presented on the methods used and the shipment of the first consignments.

124. Delucchi, V. 1956. (General notes on the predators of Dreyfusia (Adelges) piceae and their parasites). Boll. del Laborat. di Zoolggia Generale e Agraria Filippo Silvestri, Portici 33:283-302. (It.)

Notes on the European predators and their parasites, and the introduction into Canada of the most effective (Pullus impexus, Aphidecta obliterata, Laricobius erichsonii and Cremifania nigrocellulata).

125. Delucchi, V., H. Pschorn-Walcher and H. Zwolfer. 1957. (Species of Cnemodon (Syrphidae) preying on Adelges piceae. II. Morphology and biology of C. dreyfusia, with some observations on C. latitarsis.) Z. angew. Ent. 41:246-259. (G.)

126. Delucchi, V. and H. Pschorn-Walcher. 1954. (Cremifania nigrocellulata Czerny (Diptera: Chamaemyiidae) a predator of Dreyfusia (Adelges) piceae Ratz.). Z. angew. Ent. 36:84-107. (G.)

Notes on the morphology and biology of this species, which is common in all outbreaks of A. piceae in central Europe. Notes are also presented on methods of mass rearing and transport.

127. Delucchi, V. and H. Pschorn-Walcher. 1955. (Species of Cnemodon Egger (Diptera: Syrphidae) preying on Dreyfusia (Adelges) piceae Ratz. Part I.) Z. angew, Ent. 37:492-496 (F.)

Part I is a systematic revision of the genus. A new species C. dreyfusiae is described. It is a frequent predator of A. piceae.

128. Dinther, J.B.M. van 1951. (Two Coccinellidae as predators of Dreyfusia piceae). Tydschrift voor Entomol., Amsterdam 94:169-188. (Du.).

Reports on a study of the morphology of Aphideita obliterata and Anatis ocellata and the biology of Adelges abietis and these two predators.

129. Doerksen, A.H. 1964. The effects of balsam woolly aphid infestation on the anatomy of true firs. M.Sc. Thesis Oregon State Univ.

130. Doerksen, A.H. and R.G. Mitchell. 1965. Effects of the balsam woolly aphid upon wood anatomy of some western true firs. For. Sci. 11:181-188.

Describes an investigation of the anatomy of xylem tissue in the stems of Abies grandis, A. lasiocarpa, and A. amabilis infested with Adelges piceae and containing typically large amounts of abnormally dark-red wood. In the abnormal wood, cells were circular, not rectangular, in cross-section; secondary cell-walls contained numerous diagonal checks; the percent of thick-walled traumatic resin canals were numerous; early-wood cell-walls were about 50% thicker, tracheids about 40% shorter, and fibril angle 2-3 times greater than normal; and the number of rays per unit area was nearly doubled.

131. Dowden, P.B. and D. Crosby. 1958. Present status of the balsam woolly aphid in the United States. Proc. 10th Int. Congr. Entomol. Montreal, 1956. 823-825.

132. Dreyfus, L. 1889. (New observations in the genera Chermes L. and Phylloxera Boyer de Fonsc.) Zool. Anz. 12:65-73, 91-99 and 223. (G.).

133. Dyer, H.L. and R.T. Thaxter. 1957. Yield and quality of pulp made from balsam fir wood possessing abnormally high density caused by the balsam woolly aphid. (Adelges piceae.) Tappi, 40(3):65A-74A.

Abnormal A. balsamea wood caused by A. piceae in sulphite pulping yielded less pulp with lower brightness, poor strength and a greater amount of uncooked chips than normal wood.

134. Eckstein, K. 1890. (The biology of the genus Chermes L.) Zool. Anz. 13:86-90. (G.)

135. Eckstein, K. 1890. (The biology of the genus Chermes L.) Ztschr. f. Forst-u. Jagdw., Jg. 22:340-351. (G.).

136. Edward, D.K. 1966. Observations on the crawlers of the balsam woolly aphid, Adelges piceae (Ratz.). Can. Dept. For. Bi-Mon. Res. Notes 22(5):4-5.

Physiological and behavioural studies are being made on the neosistentes of A. piceae, which is threatening large volumes of Abies spp. in British Columbia. Observations on 1966 spring and summer populations are reported here.

137. Edwards, W.A. and Harris, J.W.E. 1965. Balsam woolly aphid infestation serious in B.C. woods. The Truck Logger 21(9):28-32.

138. Eichhorn, O. 1957. (A third dangerous fir aphid of the genus Dreyfusia in southern Baden.) Forsch. u. Fortschr., 30:289-293. (G.).

139. Eichhorn, O. 1958. (The spreading of injurious fir aphids and their control.) Allg. Forstz. 13:307-311. (G.).

Tests with trap boards indicated that sistens larvae and even egg clusters were spread by wind. Tests on 5- to 6-year transplants infested with Dreyfusia nusslini and D. merkeri, malathion, Gesapon and E605f achieved 98% kills, Metasystox about 80% in a fortnight. Extreme care and thoroughness are essential to avoid leaving residual populations, possibly of resistant strains. Silvicultural measures (felling infested trees in winter when there are no mobile larvae or eggs, broadleaved screens between infested stands and plantations etc.) are discussed.

140. Eichhorn, O. 1958. (Morphological and paper chromatographical investigations into the differentiation of species of the genus Dreyfusia.) Z. angew. Ent. 42:278-283. (G.).

The chromatograms (of which 12 are reproduced in color) show similar patterns for D. merkeri and D. nusslini on the one hand, and D. piceae f. typica and D. prelli on the other. There were differences between developmental stages, but not between stem- or shoot-infesting forms of the same species, and only minor differences between individuals taken from Abies alba or A. nordmanniana.

141. Eichhorn, O. 1963. (The overwintering behaviour of fir aphids of the genus Dreyfusia.) Z. angew. Ent. 51:358-363. (G.).

Ten years' investigations on silver fir in the Black Forest and in Switzerland indicated that D. piceae hibernates almost exclusively as first-instar larvae (L_1), D. nusslini f. typica and f. schneideri to 75% as L_2 and 10% as L_1, and D. merkeri to about 33% as L_1 and 45% as L_2, but with considerable variations; D. prelli developed during normal winters and began egg-laying in January. On Abies nordmanniana, D. nusslini f. typica overwintered almost exclusively as L_3.

142. Eichhorn, O. 1966. (The progrediens/sistens ratio in the genus Dreyfusia (Adelges)). Z. angew. Ent. 57:310-320. (G.).

The % of progredientes in offspring of (a) twig-sucking, and (b) stem-sucking hiemosistentes was estimated from partial counts: for D. nusslini, (a) 20, (b) 1.5-9; D. piceae, 2, 0; D. merkeri, 5, 0; and D. prelli, 25, 0.1-1%. Some mothers produced sistentes only, but none progredientes only. There was no apparent correlation with population density or with age or condition of silver firs attacked by the three first named.

143. Eichhorn, O. 1967. On methods of differentiating the species of the harmful white woolly aphids (Dreyfusia = Adelges) on fir and the consequences for forest protection. Commonw. Inst. Biol. Control Tech. Bull. No. 8:53-82.

In central Europe, four species of Dreyfusia attack true firs: D. piceae, D. nusslini (D. nordmannianae), D. merkeri and D. prelli. These species are compared as to: (1) structural criteria (morphological structures bio-chemical constituents); (2) phenotypic criteria (variation in duration of embryonic development, post-embryonic development); (3) bionomic

characterstics (life cycles, phenology of single generations, overwintering behaviour); and (4) effect on the host (macroscopic and microscopic damage). These investigations, gave hints in connection with control of the pests by means of mechanical methods and of mechanically applied liquids. The hypothetical possibilities for the control of a harmful white woolly aphid by a less harmful one through interspecific competition are discussed.

144. Eichhorn, O. 1968. Problems of the population dynamics of silver fir woolly aphids, genus Adelges (= Dreyfusia), Adelgidae. Z. angew. Ent. 61:157-214.

Discusses the chief biotic and abiotic factors affecting reproduction, phenology, generation cycles and mortality in A. piceae, A. nusslini, A. prelli and A. merkeri in Europe. The activity of the aphids stimulates an increase of proteins in the bark which in turn increases fecundity and speeds up phenology, until a degeneration of the bark tissue after about 2 years of mass attack and a sudden collapse follows. Outbreaks of A. piceae and A. merkeri last about 4-5 years from latency to collapse, those of A. nusslini somewhat longer. Two outbreaks within a period of 10-12 years may be expected, but generally only on a limited number of trees. Understory silver firs are never attacked, and some light on the crowns appears to be necessary to make trees susceptible. There appears to be some evidence that in species competition A. nusslini displaces A. piceae. A predator study in 3 S.W. German and 1 Swiss infestation areas indicated that in mass attacks (where egg laying is advanced in time) predators are not completely synchronized and not sufficiently frequent to affect reproduction materially. Predators appear to be inversely density-dependent and probably unable to assist greatly in the control of existing outbreaks. However, predators may be of considerable importance in preventing or retarding infestation development and spread, and their use in biological control is considered justified.

145. Eichhorn, O. 1969. Investigations on woolly aphids of the genus Adelges An. (Hemiptera: Adelgidae) and their predators in Turkey. Commonw. Inst. Biol. Control, Tech. Bull. No. 12, pp. 83-103.

Three species A. nusslini, A. prelli and Adelges sp. are endemic in Turkey. Investigations give support to the assumption that predators play a decisive role in keeping aphid populations at a low, uneconomic level. Leucopis sp. is recommended for introduction to North America.

146. Eichhorn, O. 1969. (Natural distribution areas and areas of introduction of fir woolly aphids (Dreyfusia = Adelges) and possibilities of biological control.) Z. angew. Ent. 63:113-131. (G.).

Discusses: the present distribution and distribution history of the insect in relation to that of the genus Abies; reasons for the absence of indigenous Dreyfusia spp. in N. America; the mechanisms of isolation which enable the closely related species D. knucheli and D. joshii on the one hand, and D. nusslini and D. prelli on the other, to inhabit the same host or hosts; and reasons for the failure, so far, of biological control. Finally, a considerable predator effect, chiefly attributable to a Leucopis sp. nov. is described from twig attacks of D. nusslini on Abies bornmuelleriana in the West Pontic mountains of Turkey.

147. Eichhorn, O. 1969. Problems of the determination of morphs in the genus Dreyfusia CB (Homoptera: Adelgidae). Z. angew. Ent. 64:437-446.

Summarizes present knowledge, including results of recent experiments on D. (Adelges) nusslini (D. nordmannianae), with special reference to the progeny of the parthenogenetically produced and reproducing hiemosistentes (h.). All three 'morphs'-sistentes (s.) progredientes alatae (p. al.) and progredientes apterae (p. apt.)- can, but need not, develop from the eggs of one h. mother. The ratio of twig-dwelling s. to needle-dwelling p. appears to be determined pre-natally. The number of p. increased during short-daylight treatment, and was higher in fast than in slow developing h. and higher in h. originating from h. mothers than in h. originating from s. mothers. The proportion of p. al. to p. apt. increased rapidly with population density, pointing to environmental conditions as preponderant or solely determinant factors. The onset of the increase in p. al. under conditions of comparatively low population densities appears to exclude the physiological condition of the host as contributing factor.

148. Eidmann, H.H. and B. Ehnstrom. 1975. (On the establishment of Scymnus impexus Muls. (Col. Coccinellidae) in Sweden). Ent. Tidskr 96:14-16. (Sw).

Reports the establishment of this predator of Adelges (Dreyfusia) spp. infesting Abies alba (especially A. nordmannianae, A. piceae and A. merkeri) after the release of 19 000 adults imported from Germany on Visingso Is. (Lake Vattern) and in Ostergotland in 1967.

149. Eidt, D.C. and H.G. MacGillivary. 1972. Resistance of seven fir species to spruce budworm and other insects. Can. For. Serv. Bi-Mon. Res. Notes 28:2-3.

150. Falck, J. 1928. (Chermes damages of the fir trees of England and Denmark). Forstarchiv. Nr. 4. (G.).

151. Fedede, G.F. 1971. A parasitic fungus disease of Adelges piceae (Homoptera: Phylloxeridae) in North Carolina. Ann. Entomol. Soc. Amer. 64:749-750.

Preliminary observations on the occurrence and symptoms of a disease of A. piceae caused by Fusarium nivale found on aphids attacking Abies fraseri in a pole stand at 6500 ft alt. in Mt. Mitchell State Park. All stationary stages of the aphid are attacked, but the potential of F. nivale as an agent of natural control of A. piceae is still unknown.

152. Fedde, G.F. 1972. Status of imported and native predators of the balsam woolly aphid on Mt. Mitchell, North Carolina. U.S. Dept. Agric. For. Serv. Res. Note SE-175, 4 pp.

Reports a study from June to Oct. 1968, in which 20 stands of Abies fraseri infested with Adelges piceae were examined for (a) native predators, and (b) 22 species of previously imported predators. Five species of (a) were present, three of them mites; the commonest (and the only identified) species was the mite Allothrombium mitchelli. Laricobius erichsonii, the only species of (b) present, was of minor importance.

153. Fedde, G.F. 1973. Cone production in Fraser firs infested by the balsam woolly aphid, Adelges piceae (Homoptera: Phylloxeridae). J. Ga. Entomol. Soc. 8:127-130.

A perennially infested natural stand of Abies fraseri in W. North Carolina produced cones during the seed-year of 1969, but the cones were borne only in the upper third of the crown (not on the whole crown as in uninfested trees). Mortality in 1970 was high, but not significantly higher than in previous years.

154. Fedde, G.F. 1973. Impact of the balsam woolly aphid (Homoptera: Phylloxerida on cones and seed produced by infested Fraser fir. Can. Ent. 105:673-68C

Reports further research on a stand of Abies fraseri heavily infested by Adelges piceae in western North Carolina, showing that the cones were significantly shorter, and contained seed uniformly smaller and lighter, than those from adjacent, uninfested trees. X-ray examination indicated that the proportions of full seed from infested and uninfested trees averaged 27 and 69% respectively; germination % varied in a similar way. An important factor affecting survival of seed from the two sources appeared to be the relative susceptibility of seed to attack by the chalcid Megastigmus specularis: 3% of seed from uninfested trees contained the chalcid compared with 31% of seed from infested trees.

155. Fedde, G.F. 1974. A bark fungus for identifying Fraser fir irreversibly damaged by the balsam woolly aphid, Adelges piceae (Homoptera: Phylloxeridae). J. Ga. Entomol. Soc. 9:64-68.

Eight green-crowned trees with incipient fructifications of the bark fungus Lachnellula agassizii were identified in 1969 in an infested Abies fraseri stand. Seven of these died in the winter of 1969/70 and the eighth died in late 1970. The dying trees were not chronically, but acutely infested with A. piceae, as shown by the significantly smaller number of 'redwood' rings (a reaction to aphid attack) and reduced vigour of the aphid population compared with other infested trees. It is concluded that L. agassizii is a reliable indicator of dying trees.

156. Foottit, R.G. and M. Mackaner. 1977. Morphometric variation within and between populations of the balsam woolly aphid, Adelges picea (Ratz.) in North America. Report on Can. For. Serv. Contract No. BC-07-155X. (Scientific authority: J.R. Carrow.)

157. Forbes, A.R. and D.B. Mullick. 1970. The stylets of the balsam woolly aphid, Adelges piceae (Homoptera: Adelgidae). Can. Ent. 102: 1074-1082.

The morphology and fine structure of the stylets, labial clamp, and crumena of the balsam woolly aphid, A. piceae (Ratz.), are described from sections studied in the electron microscope.

158. Foulger, A.N. 1968. Effect of aphid infestation on properties of grand fir. For. Prod. J. 18(1):43-47.

Describes tests on samples from Abies grandis logs (infested by Adelges piceae and uninfested) from a stand in Oregon, confirming earlier findings that wood formed during aphid infestation had shorter tracheids, greater fibril angle, wider growth rings, higher late-wood %, higher sp. gr., reduced modulus of elasticity and greater longitudinal shrinkage than would be expected in the absence of aphid attack. It is concluded that a prolonged, widespread A. piceae infestation would be detrimental to wood quality, particularly in stems approaching merchantable size.

159. Francke-Grosmann, H. 1938. (Dreyfusia piceae on exotic fir species.) Tharandt. forstl. Jahrb. 89:35-49. (G.).

The possibility of growing exotic firs in Germany in place of Abies pectinata, which is dying out in some localities and does not reproduce well on clearcut areas, depends partly on their susceptibility to damage by woolly aphids (Dreyfusia). In the arboretum at Tharandt, A. nobilis, A. grandis, A. arizonica, A. subalpina (lasiocarpa), and A. balsamea are attacked by D. piceae. Buds of vigorously growing A. grandis often exude sufficient resin to kill the aphids; weak buds are often killed or develop into galls. A. grandis of suitable climatic origin is suitable for planting in the open. In the shade it grows slowly and is liable to serious damage by D. piceae.

160. Franklin, J.F. and R.G. Mitchell. 1967. Successional status of subalpine fir in the Cascade Range. U.S. Dept. Agric. For. Ser. Res. Pap. PNW-46. 16 pp.

Discusses the distribution of Abies lasiocarpa in the area, associated tree species, succession on typical and severe sites, pests (especially Adelges piceae), and its significance in land management (e.g. as a pioneer on lava flows, avalanches and areas devastated by fire, or for its aesthetic value in recreational areas).

161. Franz, J. 1953. (Laricobius erichsonii (Coleoptera: Derodontidae) a predator on woolly aphids). Z. Pflkrankh. 60:2-14. (G.).

Discusses its distribution in Europe, development, biology, ecology, and the most important mortality factors and its use for biological control of Adelges piceae and A. nordmannianae.

162. Franz, J. 1954. (The occurrence and mass exchange of fir-stem aphids Adelges (Dreyfusia) piceae Ratz. in North America and Europe.) Verh. Dtsch. Ges. f. angew. Ent. 117-124. (G.).

163. Franz, J. 1955. (The bark aphid Adelges piceae Ratz. under a fungus cover of Cucurbitoria pithyophila (Kze. et Schm.) with observations of Aphidoletes thompsoni Mohn (Diptera: Itonididae) and Rabocerus mutilatus Beck (Coleoptera: Pythidae) as predators of A. piceae.) Z. Pflkrankh. 62:39-61 (G.).

A heavy infestation of A. piceae in all stages were found under extensive cover provided by the structures of C. pithyophila on the stems of two sickly silver fir trees. The fungus gives some, but not complete protection against predators. A. thompsoni and R. mutilatus larvae were found under the fungus cover, preying on the aphids. The life history of these two predators is discussed. Crowding of the aphids, under the fungus cover, the presence of the predators, and the fact that C. pithyophila probably occurs only in sickly trees, are factors preventing permanent colonization by the aphids in these conditions.

164. Franz, J. 1956. The effectiveness of predators and food as factors limiting gradations of Adelges (Dreyfusia) piceae Ratz. in Europe. Proc. 10th Int. Congr. of Entomol., Montreal 1956:781-787.

General discussion of the build-ups of populations of A. piceae in Europe.

165. Franz, J. 1956. (Natural enemies and host plants as biocoenotic limiting factors in epidemics of Adelges piceae (Ratz.)). Mitt. biol. Bundesanst. Land-u Forstw., Berlin No. 85:27-30 (G.) (Abstr. F.A. 19:2028.)

The life history of A. piceae populations on the stem of an 80-year-old silver fir were compared when (a) completely protected by a wire cage, (b) in a wire cage allowing access by predators, and (c) in the open. There was little difference in the 3 populations until the end of August, when (b) and (c) were noticeably reduced by predators. The protected populations persisted for a year or more after the mass infestation had disappeared from the rest of the stem, indicating that under natural conditions both host reactions and predators contribute to its collapse.

166. Franz, J. 1958. Studies on Laricobius erichsonii Rosen. (Coleoptera: Derodontidae) a predator on Chermesids. Entomophaga, Tome 2:111.

167. Franz, J. and H. Karafiat. 1958. (The suitability of serial plotting and photographs of fir aphids for population studies.) Z. angew. Ent. 43(1):100-112. (G.).

A detailed refutation of the criticisms of Pschorn-Walcher and Zwolfer including new photographs.

168. Frost, F. 1958. The balsam woolly aphid and prescribed burning. Publ. Newfoundland Res. Comm. St. John's 1:19-35, and 64-65.

Describes the spread of the Newfoundland infestation from 185 sq. miles, in 1949 to 2400 sq. miles in 1957, the damage to yield, pulpwood quality etc., and suggests promoting regeneration of the resistant black spruce in place of balsam fir by a system of clearfelling and prescribed burning, leaving 10-20 black spruce trees per acre.

169. Gentry, T.R. & E.T. Wilson, Jr. 1966. A technique for rapid collection of balsam woolly aphid eggs. U.S. Dept. Agric. For. Serv. Res. Note SE-58. 2 pp.

In connection with the introduction of egg predators from Europe to control Adelges piceae, laboratory studies of prey acceptance and predator potential with known numbers of aphid eggs were conducted. To facilitate these studies, a technique was developed (and is here described) for rapid collection of eggs. By this method, one man can prepare 10 boxes of 200 eggs each in 30 min., vs. several hours required by the old method.

170. Gerber, R. 1950. (What birds feed on woolly aphids and scale insects?) Anz. Schadlingsk 23:39-43. (G.).

Reviews and lists European bird predators.

171. Graf, P. and M. Kriegl. 1968. (Methods of collecting large numbers of European predators of Adelgidae and some notes on their ecology). Anz. Schadlingsk 41:151-155. (G.).

From 1954 to 1966 about 321,000 predators of Dreyfusia were collected in Europe for the biological control of D. piceae in N. America. Information gathered over this period on life cycles and habits and on suitable times and methods of collection are presented for: Aphidecta obliterata, Pullus impexus, Laricobius erichsonii, Aphidoletes thompsoni, Cremifania nigrocellulata, Leucopis sp. nov. L. atratula, Neoleucopis obscura and Metasyrphus lapponicus.

172. Graham, K. 1963. Concepts of Forest Entomology. Reinhold Pub. Corp., N.Y., U.S.A. pp. 94 and 301.

173. Graham, S.A. 1952. Forest Entomology. McGraw-Hill Book Co. Inc., N.Y., U.S.A. pp. 229-234.

174. Greenbank, D.O. 1970. Climate and the ecology of the balsam woolly aphid. Can. Ent. 102:546-578.

Adelges piceae was introduced from Europe into the Maritime Provinces of Canada and established on Abies balsamea > 60 years ago. The probability of aphids freezing increases at temperatures below -5°F; after even brief exposure to -35°F there are no survivors. Dispersal is mainly through wind dissemination of crawlers and eggs. In the maritime climatic regions; crown populations are freely dispersed, and damage is general. In the continental climatic regions, the probability of the occurrence of -30°F is 0.46, and populations are restricted to the basal area of the stem where snow gives protection. Wind speeds below the canopy are low, and infestations remain small and isolated, while damage from stem attack accumulates slowly. In the transitional climatic regions, with irregularly occurring severe winters, some stands are found where tree mortality is heavy, while infestations in adjacent stands have been arrested by severe winters.

175. Hall, J.P. 1971. Conversion of balsam fir cutovers to red and Sitka spruce. Can. For. Serv., Inf. Rept. N-X-63, 15 pp.

176. Hall, J.P. and J. Richardson. 1973. Replacement of balsam fir by other softwood species in the forest of western Newfoundland. Can. For. Serv., Inf. Rept. N-X-98, 30 pp.

177. Hall, J.P., P. Singh and H.O. Schooley. 1971. Survival and growth of some exotic firs in Newfoundland. For. Chron. 47:279-281.

Describes the early development of six Asiatic species (nine provenances) of Abies and of A. balsamea (a New Brunswick provenance), planted as 2 + 2 stock. Two of the Japanese A. veitchii

provenances are probably immune to attack by Adelges piceae and may not be particularly susceptible to Armillaria mellea. These characteristics, combined with good survival and growth rates, suggest that A. veitchii may be useful as a replacement for native A. balsamea in some aphid-infested areas of Newfoundland.

178. Harris, J.W.E. 1959. The balsam woolly aphid, Adelges piceae (Ratz.) in British Columbia. Can. Dept. Agric. Bi-Mon. Prog. Rept. 16(2):3-4.

Reports further infestations of A. piceae on Abies amabilis and also on A. grandis in S.W. British Columbia. In sample plots on Grouse and Seymour Mountains, > 50% of A. amabilis was attacked. Aerial survey in the Sechelt-North Shore area showed a considerable number of dead and dying trees. In a ground check on 4 plots at Cypress Creek, an average of 32% of A. amabilis was attacked. The infestations are expected to spread. Successful galleries of a bark beetle Pseudohyelinus sp. were found in A. amabilis damaged by A. piceae, but not in green trees.

179. Harris, J.W.E. 1964. The balsam woolly aphid in British Columbia. Can. Dept. For. Bi-Mon. Prog. Rept. 21:3-4.

Summarizes results of 1962, 1963, and 1964 work on population and tree mortality studies of Adelges piceae which started in 1959.

180. Harris, J.W.E. 1968. Detection surveys for balsam woolly aphid, Adelges piceae (Ratz.) in British Columbia. Can. Dept. For. and Rural Devel. Inf. Rept. BC-X-29, 8 pp.

181. Harris, J.W.E. 1968. Balsam woolly aphid in British Columbia. Can. Dept. For. and Rural Devel. For. Res. Forest Pest Leaflet BC-1. 5 p. (revised).

182. Harris, J.W.E., S.J. Allen, D.C. Collis and E.G. Harvey. 1966. Status of the balsam woolly aphid, Adelges piceae (Ratz.) in British Columbia 1965. Can. Dept. For., Inf. Rept. BC-X-5, 12 pp.

183. Harris, J.W.E., J.C.V. Holms, and A.F. Dawson. 1968. Balsam woolly aphid predator studies, British Columbia, 1959-1967. Can. Dept. For. and Rural Devel. Inf. Rept. BC-X-23, 18 pp.

184. Harris, J.W.E. and A.F. Dawson. 1979. Predator release program for balsam woolly aphid, Adelges piceae in British Columbia 1960-1969. J. Ent. Soc. British Columbia 76:21-26.

185. Hastings, F.L., P.J. Barry. and I.R. Ragenovich. 1979. Laboratory screening and field bioassays of insecticides for controlling the balsam woolly aphid (Adelges piceae) in Southern Appalachian

fir (Abies fraseri). U.S. Dept. Agric., For. Serv. Res. Note SE-279. 3 pp.

186. Heie, O.E. 1970. A list of Danish aphids, 9: Thelaxidae, Pemphigidae, Adelgidae and Phylloxeridae. Entomol. Med. 38:197-214.

The list of aphid species found in Denmark is completed with this paper, the 9th installment, which comprises records of the Danish species belonging in the families. Thelaxidae (8), Pemphigidae (21), Adelgidae (10), and Phylloxeridae (2).

187. Heikkenen, H.J. 1966. Balsam woolly aphid on grand fir. J. For. 64:546-548.

Reviews the distribution of Adelges piceae on Abies grandis in Oregon and Washington. An extension southwards of 100 miles is reported, and if this trend continues, A. concolor in California may be threatened.

188. Henry, H.K. 1939. The fir bark louse in New York. Notes For. Invest. No. 35, pp. 2.

June and early September are the best times to examine balsam fir trees, for the white waxy threads which indicate the presence of this insect. Infested trees should be cut close to the ground, preferably in the winter, and the bark burned if possible. Examination of stands should be frequent and salvage operations begun as soon as infestation is found.

189. Heller, R.C., J.H. Lowe, Jr., R.C. Aldrich and R.P. Weber. 1967. A test with large scale aerial photographs to sample balsam woolly aphid damage in the Northeast. Amer. J. For. 65:10-18.

A sampling technique for detecting and estimating Adelges piceae damage to Abies balsamea by photo-interpretation of large-scale color transparencies is described. Several scales and camera angles were tried before 1:1188 vertical scale was established as the best. Tree mortality as a result of heavy aphid attack on stems was estimated with > 95% accuracy. Terminal deformation on the tops of the crowns could not be detected > 75% of the time, but this level of accuracy was consistent from one year to the next. A proposed sampling scheme for estimating damage in Maine and Vermont consists in periodic photography (every 3-4 years) of the same sites, as a basis for establishing trends of mortality. The cost of such aerial sampling combined with ground checking, is estimated at only two-fifths of the cost of a ground survey.

190. Hesmer, H. 1936. (The forest of Germany V: the Fir.) Silva 24(17): 133-136. (G.).

Abies pectinata occupies about 300 000 ha, or 2.5% of the German forest area. It occurs mainly in a zone between the beech and the spruce zones, chiefly in eastern Bavaria and the Black Forest region of Wurttemberg and Baden. It requires sites free from late frosts, with considerable atmospheric humidity and fresh, fairly fertile soil, and does best on rather deep soil with high lime content. It has lost much territory formerly occupied as a result of clear-cutting and browsing by deer. During the last decade fir has suffered greatly from attacks of woolly aphids (Dreyfusia piceae and D. nusslini).

191. Hopewell, W.W. and D.G. Bryant. 1966. Tests of various insecticides for chemical control of the balsam woolly aphid in Newfoundland. Can. Dept. For. Bi-Mon. Prog. Rept. 22(2):1.

Eight insecticides were tested by spraying balsam firs, 25-35 ft. high, infested with Adelges piceae. Baygon, Diazinon, Menazon, and Sumithion appear to merit further testing, especially Baygon. The addition of a wetting agent (Invadine) appeared to improve the effectiveness of three of the compounds with which it was used.

192. Hopewell, W.W. and D.G. Bryant. 1969. Chemical control of Adelges picea (Homoptera: Adelgidae) in Newfoundland 1967. Can. Ent. 101: 1112-1114.

Five insecticides previously shown to have some effect on control of the balsam woolly aphid, A. piceae (Ratz.), on branches of Abies balsamea (L.) Mill., were tested more intensively. Individual trees were sprayed from the ground with 1.0, 0.5, or 0.25 ℓ of solution containing 5% active ingredient; (an approximate per acre dosage rate of 12 to 25 lb.). Dursban, Baygon, and Diazinon caused 85, 75, and 72% mortality respectively. Furadan and Menazon were less effective, causing 56 and 34% mortality.

193. Hudak, J. 1976. Microbial deterioration of balsam fir damaged by the balsam woolly aphid in western Newfoundland. Ph.D. Dissertation. Coll. Environ. Sci. Stat. Univ., New York.

Damage to merchantable trees caused by the balsam woolly aphid (Adelges piceae) in a stand of balsam fir (Abies balsamea) was classified for 8 years. Advanced saprot first occurred in trees dead for 3 years. The heartrot content was less than 5%, and did not vary with the extent of aphid damage. Bacteria and 58 species of fungi were isolated Polyporus abietinus was responsible for most of the advanced saprot. Wood moisture content in living trees decreased gradually with increasing aphid damage, with an abrupt decrease, levelling off to 40-50%, in dead trees. Aphid damage had little

effect on the density of normal wood, but redwood caused by the aphid increased the average wood density by 2-5%. The holocellulose and α-cellulose contents decreased from the 5th or 6th year after death, suggesting that trees dead for 5 years could be used for chemical pulping.

194. Hudak, J. and P. Singh. 1970. Incidence of Armillaria root rot in balsam fir infested by balsam woolly aphid. Can. Dept. Agric., Plant Dis. Serv., 50(3):99-101.

Studies in Newfoundland have shown that the incidence and intensity of Armillaria root rot in balsam fir (Abies balsamea) varies directly with the level of damage caused by the balsam woolly aphid (Adelges piceae). This damage appears to predispose trees to infection by Armillaria mellea.

195. Hudak, J. and R.E. Wells. 1974. Armillaria root rot in aphid-damaged balsam fir in Newfoundland. For. Chron. 50:74-76.

Compares the incidence and intensity of Armillaria mellea root rot in trees in different aphid-damage classes on representative Abies balsamea sites in western Newfoundland, and indicates how losses may be minimized. Site quality had no apparent effect on the presence or severity of the disease. Damage by Adelges piceae was the primary factor affecting the incidence and intensity of root-rot in the trees examined.

196. Hunt, K. 1968. Balsam woolly aphid infested Abies wood as a source of pulp fibre. Can. Dept. For. and Rural Devel. Inf. Rept. VP-X-39.

Describes the biology of Adelges piceae, the tree mortality caused and methods of control; Abies grandis is most, and A. lasiocarpa least resistant to infestation. The production of compression wood induced by the insect's feeding habit can lead to a reduction of up to 10% in pulp yield and 20-30% in its strength, depending on the pulping method. The over-all costs and other effects of the damage in Canada are estimated.

197. Jackson, M.D., T.J. Sheets and C.L. Moffett. 1974. Persistence and movement of BHC in a watershed, Mt. Mitchell State Park, North Carolina-1967-72. Pestic. Monit. J. 8:202-208.

An experimental area in Mount Mitchell State Park, North Carolina (USA), was sprayed with BHC (benzene hexachloride) at an average rate of 11.2 kg/ha to control the balsam woolly aphid (Adelges piceae). Residues were 31 and 5858 ppm in soil and litter, respectively, 1 month after spraying. Contamination of streams

draining the area was minimal. The residue level in surface soil reached a high of 58 ppm but dropped to 134 ppm in the litter 1.5 years after application. Residues in soil and litter were 32 and 27 ppm, respectively, 5 years after application. Concentrations of BHC in animals were unrelated to trapping locations.

198. Johnson, N.E. and K.H. Wright. 1957. The balsam woolly aphid problem in Oregon and Washington. U.S. Dept. Agric. For. Serv. Res. Paper PNW-18. 34 pp.

A biological description with illustrations is given of Adelges piceae, with an account of the present outbreak on Abies grandis, A. amabilis and A. lasiocarpa. Methods of control are discussed.

199. Johnson, N.E. and H.J. Keikkenen. 1958. A method for field studies of the balsam woolly aphid. J. Econ. Ent. 51:540-542.

Describes a method of setting up a binocular dissecting microscope (eyepiece x 9 1 mm coordinate grid; objective, X2), with flashlamp and locating bracket so that the development of up to 300 stationary wingless sistens of Chermes piceae on the bark of Abies amabilis can be accurately observed throughout the season, at mapped positions on a plot 0.5 x 0.5 cm.

200. Johnson, N.E., R.G. Mitchell and K.H. Wright. 1963. Mortality and damage to Pacific silver fir by the balsam woolly aphid in Southwestern Washington. Amer. J. For. 61:854-860.

Reports observations made on 15 plots of Abies amabilis from 1954 to 1959 in order to find methods of minimizing losses from Adelges piceae. Damage was greatest in dominants and codominants on the best sites. Site index was related to the number of trees with stem infestations, which in turn was related to the % of dead trees in the stand and the general crown condition. Gives details of an infestation rating system for stands, and recommends felling infested stands containing many dead or seriously weakened trees, stem infestations, or a predominance of overmature trees.

201. Johnson, N.E. and J.S. Zingg. 1968. The balsam woolly aphid on young Pacific silver fir in Washington, Weyerhaeuser For. Pap., Centralia, Wash. No. 13., 10 pp.

Young Abies amabilis trees, as well as older trees, are now being severely attacked by Adelges piceae. Height growth may be almost halted within 10 years of infestation. Extreme caution is advised in planting other susceptible species, e.g. A. grandis. So far, the aphid has not been found on A. procera, which still appears to be a reasonable substitute for A. amabilis at higher altitudes.

202. Kaltenbach, J.H. 1843. (A monograph of the family Pflanzenlause.) Teil. 1. Blatt. and Erdlause. Aachen (G.)

203. Karafiat, H. 1955. (New methods of analysing populations of bark inhabiting arthropods.) Mitt. biol. Bundersanst. Land-u. Forstw. Berl. No. 83:90-91 (G.).

Describes the comparison, over a period, of Adelges piceae populations on 3 rectangular patches on a stem, of which one was unprotected, another enclosed in a wire cage allowing the entry of other insects, and a third enclosed in an insect-proof wire cage, by (a) a series of Leica photographs, and (b) recording on a ruled sheet, with the help of a grid placed over the patch and a pair of binoculars on a stand, the position of each individual.

204. Karafiat, H. 1957. (A method of studying fluctuations in population of sessile arthropods.) Z. Pflkankh 64:663-676 (G.)

A full account, with detailed descriptions and illustrations of equipment used, of a method of studying development and survival of individuals of Adelges piceae on small plots of bark, by serial mapping, using a wire-gauze cage to exclude predators, binoculars and portable lighting and a pantograph for recording.

205. Karafiat, H. and J. Franz. 1956. (Studies on population fluctuations of the bark aphid (Adelges (Dreyfusia) piceae Ratz. (Heimpt. Adelgidae.) Zool. Jahrb. Abtg. Syst. Ockol. Geogr. 84:467-504. (G.).

Describes in detail quantitative studies of A. piceae on Abies alba.

206. Keen, F.P. 1952. Insect enemies of western forests. U.S. Dept. Agric. Misc. Pub. 273, (revised), pp. 59-60.

207. Kloft, W. 1953. (The role of some aphids and coccids in forest biocoenosis.) Mitt. biol. Zent. Anst. Berlin. No. 75:136-140 (G.)..

Injurious aphids such as Adelges piceae are not visited by ants.

208. Kloft, W. 1955. (A method for the cell-physiological investigation of the effect of aphid stabs on plant tissues.) Naturwissenschaften 43:10. (G.).

209. Kloft, W. 1955. (Studies on the bark of white fir (Abies pectinata) infested by Adelges piceae Ratz.) Z. angew. Ent. 37, 340-348. (G.).

Changes in the inner bark of 80-year-old trees infested to varying degrees were investigated by specific cytochemical methods. The cells on which the aphids feed (phellogen, phelloderm, the parenchyma of the medullary rays and annular layers, the neighbourhood of resin ducts and lenticels are favoured spots) are emptied of their proteins and polysaccharides, and after some time collapse completely. As a result of 2-3 years' feeding, all parenchymatous tissues to a depth of 3-4 mm collapse, causing pathological bark formation. This drying up of the food supply usually leads to collapse of the mass infestation without serious injury to the tree. The different reaction of the bark of A. balsamea which may account for the much greater seriousness of attacks, is discussed.

210. Kloft, W. 1955. (Investigation on Adelges piceae.) Waldhygiene 1:49-53. (G.).

A discussion of the effect of aphid feeding on the bark of Abies alba and A. balsamea and the role of their different reactions on aphid population fluctuations. The aphids are not visited by ants.

211. Kloft, W. 1956. (Investigations on plant-sucking insects and reactions of the tissue of the host plant.) Ber. d. Physik.-med. Ges. Wurzburg, 68: (G.).

212. Kloft, W. 1957. Further investigations concerning the inter-relationship between bark condition of Abies alba and infestations of Adelges piceae, typica. Z. angew Ent., 41:438-442.

Histological, cytological and metabolic-physiological investigations on 107 bark samples from 57 trees, ranging from non-infested to heavily infested, showed a clear relation between the protein content of the bark tissue and the degree of aphid infestation. The respiration rate of infested tissue at first increases with the infestation, owing to stimulation by the saliva of the aphids, then the outer tissue layers collapse, cutting off the aphids' food supply. This, together with the action of predators, ends the mass infestation.

213. Kloft, W. 1960. (Relations between plant-sucking insects and the tissues sucked. Part I). Z. angew. Ent. 45:337-381. (G.).

A general investigation of reciprocal physical and chemical responses between sucking insects and various hosts, including research on cyto-chemical and physiological changes in the bark of silver fir in connection with population fluctuations of Adelges piceae and A. nusslini. These changes, which include local accumulations of proteins and increases in the size of cell nuclei, are compared with gall formations.

214. Kloft, W. 1960. (Reactions between plant-sucking insects and the tissues sucked. Part II.) Z. angew. Ent. 46:42-70. (G.) (See Abstr. paper 213.)

215. Kotinsky, J. 1916. The European fir trunk louse apparently long established in the United States. Chermes (Dreyfusia) piceae, Ratz. Proc. Entomol. Soc. Washington 18:14-16.

216. Lambert, H.L. and W.M. Ciesla. 1967. Impact of summer cutting on the dispersal of the balsam woolly aphid. J. Econ. Ent. 60:613-614.

An evaluation of the effect of cutting Fraser fir, Abies fraseri (Pursh) Poir., infested by the balsam woolly aphid, Adelges piceae Ratzeburg, on the dispersal of the motile 1st instar nymph was conducted on Roan Mountain in Western North Carolina during 1965. Results indicate that cutting operations contribute to the dispersal and subsequent spread of this insect when motile 1st instar nymphs are present in large numbers on infested trees.

217. Lambert, H.L. and W.M. Ciesla. 1967. Status of the balsam woolly aphid in the Southern Appalachians 1966. U.S. Dept. Agric. For. Serv. Rept. SE-67-13, 15 pp.

A localized infestation of Adelges piceae on 27 trees in an Abies fraseri stand in N. Carolina was studied. Trapping of motile nymphs was done, (a) before felling, and (b) during and after felling of the infested trees. Although the number of nymphs collected was much greater in (b) than in (a), it is thought that, if infested trees are left standing throughout the growing season, the long-term effect on dispersal would be greater than if the trees were felled. It is therefore recommended that the infested trees be felled in isolated areas to slow down the rate of spread, but at a time when the proportion of eggs and motile nymphs is relatively low.

218. Lambert, H.L. and R.T. Franklin. 1967. Tanglefoot traps for detection of the balsam woolly aphid. J. Econ. Ent. 60:1525-1529.

Detection of local infestation of Adelges piceae, before widespread deaths of Abies fraseri occur, is desirable. The authors investigated the use of microscope slides and wire screens, both coated with a thin layer of 'Tree Tanglefoot' adhesive, for collecting wind-disperse nymphs in N. Carolina. The highest numbers of nymphs were collected by the traps in June and September; the results agreed with data already obtained on the life history of A. piceae in the southern Appalachians. More nymphs were collected on horizontal than on vertical screens.

219. Lambert, H.L. and E.T. Wilson. 1968. A device for examining large insect traps. J. Econ. Ent. 61:324-326.

Describes a home-made device for rapid microscope scanning of large numbers of screen traps 18 x 18 in. (used for detection of localized infestations of Adelges piceae).

220. MacAloney, H.J. 1935. The balsam woolly aphid in the Northeast. J. For. 33:481-484.

221. Marchal, P. 1906. (Contribution to the biology of Chermes piceae Ratz.) Bull. Soc. Zool. Fr. 31:111. (F.).

222. Marchal, P. 1909. (Contribution to the biology of Chermes. New observation for the Chermes group. C. piceae Ratz.) C.R. Seances Soc. Biol. 68:368. (F.).

223. Marchal, P. 1913. (Contribution to the study of the biology of Chermes.) Ann. Sci. Nat. Zool. 18:153385. (F.).

224. McAllan, J.W. and J.B. Adams. 1961. The significance of pectinase in plant penetration by aphids. Can. J. Zool. 39:305-310.

The feeding punctures of forms of 19 species of aphids (including a number attacking trees) were examined histologically. The types of penetration by the aphids' stylets were compared with the occurrence of pectinase in the saliva. It is suggested that pectinase aids intercellular penetration by its hydrolytic action, but is not necessary when the aphid penetrates directly through cells.

225. McAlpine, J.F. 1978. A new dipterous predator of balsam woolly aphid from Europe and Canada (Diptera: Chamaemyiidae). Entomologica Germ. 4:349-355.

Leucopis hennigrata, an important European chamaemyiid that has been released several times since 1958 for the control of Adelges piceae on Abies balsamea, A. alba and A. concolor in Canada, is described from Germany, Switzerland, Turkey, Greece, Yugoslavia and Canada. It has been reported formerly as L. griseola and L. melanopus.

226. McGugan, B.M. and H. C. Coppel. 1962. A review of the biological control attempts against insects and weeds in Canada. Part II. Biological control of forest insects 1905-68. Commonw. Inst. Biol. Control Tech. Comm. No. 2. 216 pp.

227. McIntyre, H.L. 1939. Report on forest pest problems in New York. J. For. 37:879-883.

Prevalence, damage and control of Adelges piceae is outlined with similar information for other pests.

228. McMullen, L.H. and J.P. Skovsgaard. 1972. Seasonal history of the balsam woolly aphid in coastal British Columbia. J. Entomol. Soc. British Columbia 69:33-40.

Studies of Adelges piceae at four locations in 1967-68 showed that there were basically two generations per year, although the second generation may be only partial at high altitudes and a partial third generation may occur at low altitudes in some years.

229. Merker, E. 1954. (Two dangerous fir aphids.) Pfl. schtztg. d. Biol. Budesanst. (G.).

230. Merker, E. 1958. (Determination of species and the genus Adelges by chromatography.) Naturwissenschaften 45:118-119 (G.).

Paper-chromatographical experiments show quite different patterns for A. piceae, A. nusslini and A. merkeri (all from Abies alba), A. prelli (from A. nordmanniana) and A. piceae (from A. grandis in the U.S.A.). It is concluded that these are 5 distinct species, and that the American species is not, as is generally believed, the ordinary European species introduced with transplants from Europe.

231. Merker, E. 1961. (What causes the injurious effect of forest fertilizing on insects?) Allg. Forst- u. Jagdztg. 132:73-82 (G.).

Discusses the mechanisms of the effects on injurious insects including Adelges.

232. Merker, E. 1962. (The biology and systematics of Central European silver fir aphids (genus Dreyfusia). Allg. Forst-u. Jagdztg. 133: 149-159 and 195-199. (G.).

Discusses Dreyfusia (Adelges) piceae, D. nusslini and D. merkeri, particularly their effects on Abies alba. When D. nusslini and D. merkeri suck on thin-barked shoots where their stylets (mean lengths 1.2 and 1.6 mm, respectively) penetrate to the cambium and beyond, their saliva causes swellings and breakdown of parenchyma cells, leading to a disruption of sap flow and hence to the death of shoots or whole young plants. The affected cells swell much more under attack by D. merkeri than by D nusslini, so that the former generally causes the worst damage. Bark killed on stems or older branches is usually shed, and the damage to trees from such attacks (despite considerable loss of assimilates) is rarely serious, but occasionally aphids penetrating cracks in the bark, caused by earlier attack, do serious damage to branches.

233. Merker, E. and O. Eichhorn. 1955. (The biology of dangerous fir aphids and their distinguishing characters in the field.) Allg. Forst-u. Jagdztg. 126:95-108. (G.).

The history and present state of infestation in S. Baden, the effect on the size and bionomics of Adelges nordmannianae and A. piceae of climatic factors, host species and plant part fed on the wax-wool exudations of the numerous autumnal third generation of A. piceae, and the appearance (illustrated) of damaged shoots. A. nordmannianae causes defoliation and death of shoots more rapidly, and the bark of shoots is not thickened. Chemical control is recommended chiefly for nurseries. E.605 (parathion), if sprayed repeatedly, gave satisfactory results. If infested trees are felled during the periods of aphid immobility, between December and March (starting somewhat later for A. piceae) they need not be burned, as the aphids will perish within about 4 weeks.

234. Merker, E. and O. Eichhorn. 1955. (On the biology of, and damage caused by, the two dangerous fir adelgids in central Europe.) Der Forstmann in Baden and Wurthemberg. 5(3):pp. 16. (G.) (Translation No. 113, Can. Dept. Fish. and For. 1967).

A comparative study of damage to Abies alba in central Europe by native Dreyfusia (Adelges) piceae and by D. (A.) nusslini, which has migrated from its original home east of the Black Sea. D. nusslini appears to be less destructive in central Europe than in N. America, where conditions seem to be more favourable to it. The egg-laying period for D. nusslini usually ended in August whereas for D. piceae it continued into December. The type of damage caused, the process of infestation, and possible control measures are discussed.

235. Merker, E. and O. Eichhorn. 1956. (Grouping in the genus Adelges.) Die Naturwissenschaften 43:453-454. (G.).

Counts of pores on the spinal plates showed the following groupings: (1) A. piceae typica, Canadian A. piceae from balsam fir, A. prelli and A. piceae Freiburg form. (2) A. nusslini f. typica and f. schneideri.

236. Merker, E., O. Eichhorn and I. Kleist. 1957. (The destructive effects of cold spells on fir aphids of the genus Adelges.) Z. angew. Ent. 41:333-352. (G.).

Overwintering aphids of Dreyfusia (Adelges) piceae and D. nusslini withstood -1925 hour-degrees (degrees below 0°C x hours) in February 1954, but unprotected aphids were almost completely annihilated by -6061 hour-degrees in February 1956. Wet, cold weather in the spring further reduces the numbers of winter sistents and eggs surviving.

237. Merker, E. and W. Berwig. 1962. (Has Abies alba any immunity against Adelges?) Naturwissenschaften 49:112-113. (G.).

Discusses briefly the relationship of attack to moisture and osmotic pressure, and presents tabulated data showing the low rate of attack on long-needled trees.

238. Mesnil, L.P. 1956. An analysis of the balsam woolly aphid problem in Europe. Proc. 10th. Int. Congr. Entomol.., Montreal, 1956, 4:777-779.

Provides a general review of Adelges piceae in Europe.

239. Mitchell, R.G. 1960. The biology of the balsam woolly aphid, Chermes piceae Ratz. in Oregon and Washington and the identification and evaluation of its native predators. Ph.D. Dissertation.

Presents the results of studies in 1957-59. The biology of the insect is described. Fourteen insects (10 Diptera, 3 Neuroptera and 1 Coleoptera) and 2 mites were found as predators, and 9 other species of arthropods that may be predaceous were collected. The most important predators were Cnemodon rita, Syrphus vitripennis, S. opinator and Metasyrphus lapponicus; Hemerobius neadelphus was also moderately abundant. Evaluation studies on two areas in Oregon showed that no significant predation was effected by the aggregate predator complex.

240. Mitchell, R.G. 1962. Balsam woolly aphid predators native to Oregon and Washington. Oregon Stat. Univ. Agric. Exp. Stat. Tech. Bull. 62. 63 pp. (See Abstr. of paper 239.)

241. Mitchell, R.G. 1966. Infestation characteristics of the balsam woolly aphid in the Pacific Northwest. U.S. Dept. Agric. Serv. Res. Pap. PNW-35. 18 pp.

Gives a general description of Adelges piceae and methods of recognition on its principal hosts. In order of increasing susceptibility these are Abies grandis, A. amabilis and A. lasiocarpa. The best policy at present is to encourage resistant species already on the site, Pseudotsuga taxifolia and Tsuga heterophylla below 3,500 ft., and Picea engelmannii, Pinus contorta, Tsuga mertensiana, A. procera, A. magnifica var. shastensis and A. amabilis at higher altitudes.

242. Mitchell, R.G. 1967. Translocation of dye in grand and subalpine firs infested by the balsam woolly aphid. U.S. Dept. Agric. For. Serv. Res. Note. PNW-46. 17 pp.

Tree-killing populations of Adelges piceae on the stems of Abies grandis and A. lasiocarpa cause traumatic xylem tissue resembling compression wood, and such damage from 3-4 years of infestation

might inhibit sap flow and thus significantly reduce tree vigour. Twenty infested and 20 non-infested trees were injected with acid fuchsin dye, and the path of the dye was traced in the stem. Dye patterns confirmed that stem-infesting aphid populations materially affected water-conducting tissue. Since more rings actively conduct water at the base than higher up a stem, aphid infestation at the base would be less damaging than the same infestation higher up. This may explain why A. grandis (in which infestation usually starts low down) is more tolerant of aphid attack than A. lasiocarpa (in which it is usually high on the stem).

243. Mitchell, R.G. 1967. Abnormal ray tissue in three true firs infested by the balsam woolly aphid. For. Sci. 13:327-332.

Investigation of 'Rotholz' (abnormally dense, reddish wood), characteristic of N. American Abies spp. infested by A. piceae, showed that rays in such wood from aphid-infested A. grandis, A. amabilis and A. lasiocarpa were 35-73% more numerous per sq. mm. of tangential surface and about 15-35% longer and wider, and occupied 150-180% more of the wood volume, than in normal wood. Reaction to aphid infestations seemed to be essentially the same in all three species.

244. Mitchell, R.G. 1975. Brevipalpus grandis a new species of false spider mite (Acarina: Tenuipalpidae) on grand fir. Ann. Entomol. Soc. Am. 68:4-6.

Describes the female, male and deutonymph of B. grandis, which was found infesting the bark of Abies grandis in Oregon. Mite numbers were greatest in association with stem populations of Adelges piceae. There was no evidence that the mites were harming the infested trees.

245. Mitchell, R.G., N.E. Johnson and J.A. Rudinsky. 1961. Seasonal history of the balsam woolly aphid (Adelges piceae) in the Pacific Northwest. Can. Ent. 93:794-798.

Wide variations were found in the aphid's seasonal history, depending on a variety of factors, e.g. altitude, weather, and location of host tree.

246. Mitchell, R.G. and K.H. Wright. 1967. Foreign predator introductions for control of the balsam woolly aphid in the Pacific Northwest. J. Econ. Ent. 60:140-147.

Of 23 species of predators introduced from seven countries throughout the world, 5 have been successfully established. Of these, Laricobius erichsonii is the most promising, followed by

Aphidoletes thompsoni. Pullus impexus, Cremifania nigrocellulata, Leucopis obscura do not seem promising.

247. Mitchell, R.G., G.D. Amman and W.E. Waters. 1970. Balsam woolly aphid. U.S. Dept. Agric. For. Serv. For. Pest Leaflet 118. 10 pp.

Gives information on Adelges piceae in N. America, its hosts (Abies spp.), symptoms and effects of attack, morphology and life history of the pest, and natural, biological, and chemical control measures.

248. Montmorency, W.H. 1966. The effect of woolly aphid (Adelges piceae) infestation on the pulping characteristics of balsam fir (Abies balsamea). Pulp Paper Mag. Can. 67:T 399-406.

Wood samples from A. balsamea trees, some of which were infested and some uninfested by A. piceae, were pulped mechanically and chemically by the Magnefite process. Test data were compared for (a) wood affected by A. piceae, (b) unaffected wood adjoining (a) from infested trees, and (c) wood from uninfested trees. Results showed that: (a) was much denser than (b) and (c); groundwood pulps from (a) contained fewer long fibres, were weaker (particularly in tear resistance), and less bright than those from (b) and (c); and chemical pulps from (a) were 20-30% weaker, and less bright, and gave about 10% lower yield than those from (b) and (c).

249. Morris, R. F. 1958. A review of the important insects affecting the spruce-fir forests in the Maritime provinces. For. Chron. 34:159-189.

The hosts, outbreak history, epidemiology and control of the following insects are discussed: Choristoneura fumiferana, Adelges piceae, Dendroctonus piceaperda, Diprion hercyniae, Acleris variana, Lambdina fiscellaria.

250. Mueller, F.P. 1976. (Keys for the identification of Polish invertebrates: Vol. 2, Aphids-plant pests. A regional key for identification.) Panstwowe Wydawnictwo Naukowe: Warsaw, Poland. Paper Pr. zl. 32. (P.).

Keys for determining the family, subfamily, genus and species of aphids (Lachnidae, Chaitophoridae, Callaphididae, Aphididae, Thelaxidae, Pemphigidae, Adelgidae and Phylloxeridae) are presented. External anatomical structure, ecology, and the collection and preservation of specimens are also discussed.

251. Mullick, D.B. 1969. Reddish purple pigments in the secondary periderm tissues of Western North American conifers. Phytochem. 8:2205-2211.

A new class of non-anthocyanic reddish-purple pigments of phlobaphenes has been found by thin-layer chromatographic, microtechnique. The

pigments, not yet identified, varied between the species analysed (Thuja plicata, Abies amabilis and Tsuga heterophylla). They did not occur in normal primary periderm. The study was undertaken in connection with an investigation of interactions between Adelges piceae and its host, which result in reddish-purple pigments in the corky layers surrounding feeding sites.

252. Mullick, D.B. 1971. Natural pigment differences distinguish first and sequent periderms of conifers through a cryofixation and chemical techniques. Can. J. Bot. 49:1703-1711.

Distinct differences in the natural pigmentation of the first and sequent periderms noted in the field were subsequently studied in detail in Abies amabilis, A. grandis, Thuja plicata and Tsuga heterophylla. Preliminary studies were also made of 36 conifer species (13 genera). The distinctions were confirmed by cryofixation and chemical techniques in the four species studied in detail. The first periderm was dark-brown. Two types of pigmentation were observed in subsequent periderms: one, reddish in colour, invariably replaced the brown periderm and abutted on the rhytidome; the other, which was brownish, never abutted on the rhytidome and was not normally present below the reddish periderm. Colour photomicrographs of the various types of pigmentation are given and the observations and chemical studies are discussed.

253. Mullick, D.B. 1975. A new tissue essential to necrophylactic periderm formation in the bark of four conifers. Can. J. Bot. 53:2443-2457.

A study was made of methods for initiating and detecting non-suberized impervious tissue (NIT) in Abies grandis, A. amabilis, Tsuga heterophylla and Thuja plicata. NIT developed within 3 to 4 weeks in summer at healed injuries regardless of the cause, at abscission scars, and at old resin blisters and rhytidome. Histochemical tests showed that neither suberin nor callose was responsible for the imperviousness to water of NIT, which could be detected by a test based on the penetration of 2% $FeCl_3$ followed by 4% $K_3Fe(CN)_6$. The formation of NIT in the absence or presence of Adelges piceae or fungal pathogens injuries suggests that its production may be the physiological basis of the host defence mechanism in the bark of conifers. It is concluded that NIT precedes the formation of wound periderm, that it may provide the environment necessary for the formation of wound periderm in tissues internally abutting NIT, and that it is a marker for distinguishing wound periderm from exophylactic periderms.

254. Mullick, D.B. 1977. The non-specific nature of defense in bark and wood during wounding insect and pathogen attack. In: Recent Advances in Phytochemistry Vol. II. Ed. F.A. Loewus and V.C. Runeckles. Plenum Press. New York. pp. 395-441.

255. Mullick, D.B. and G.D. Jensen. 1976. Rates of non-suberized impervious tissue development after wounding at different times of the year in three conifer species. Can. J. Bot. 54:881-892.

One of the three species examined was Abies amabilis that had rates consistently faster on resistant than on the susceptible A. amabilis heavily infested with balsam woolly aphid, Adelges piceae Ratz. Possible causes of these variations and implications of the findings, in relation to process of NIT formation as a basic physiological host component in pathogenic interactions of bark, are discussed.

256. Murtha, P.A. and J.W.E. Harris. 1970. Airphoto interpretation for balsam woolly aphid damage. J. Remote Sensing 1:3-5.

257. Nigam, P.C. 1972. Summary of toxicity of insecticides and chemical control studies against balsam woolly aphid, Ottawa. Can. For. Serv., Inf. Rept. CC-X-26. 7 pp.

258. Nigam, P.C. 1976. Summary of chemical control studies against balsam woolly aphid in British Columbia, 1973-74. Can. For. Serv. Inf. Rept. CC-X-123. 6 pp.

259. Nusslin, O. 1903. (The biology of Chermes piceae Ratz.) Naturwissenschaft Zeit. Land-und For. 1:25-35, and 59-67. (G.).

260. Nusslin, O. 1908. (The biology of Chermes piceae Ratz.) Verk. Dtsch. Zool. Ges., 18:205-224. (G.).

261. Oechssler, von G. 1962. (Sucking injuries to the tissues of native and exotic firs caused by central European fir aphids.) Z. angew. Ent. 50:408-454. (G.). (Transl. Can. Dept. For. No. 57, 1966.)

Chiefly a histological study of the sucking of Dreyfusia (Adelges) merkeri and D. nusslini on needles, shoots, and stems of Abies alba, supplemented by observations on other Abies species and some of D. piceae f. typica on A. alba. Preliminary experiments with artificial fine wounds and/or treatment with IAA compared to aphid wounds differed in some important respects; while no change in cell content took place in artificial wounds, the starch content of sucked cells decreased and their protein content increased. Feeding on young shoots by both shoot-sucking species caused similar symptoms for the first 60 days but, after a year, increase in cell size was much more marked for D. merkeri. Macroscopic and microscopic observations on 3- to 5-year-old A. grandis, A. lasiocarpa, A. nobilis, A. nordmanniana, and A. numidica are described, showing considerable differences in host reactions and general susceptibility. Changes in cell sizes after 60 days were least for A. grandis (both aphids); A. numidica and A. nordmanniana reacted more strongly to D. merkeri, A. lasiocarpa to D. nusslini; A. nobilis was highly reactive to both.

262. Page, G. 1973. Impact of balsam woolly aphid damage on fir stands in Newfoundland. Can. For. Serv. Inf. Rept. N-X-94. 35 pp.

263. Page, G. 1975. The impact of balsam woolly aphid damage on balsam fir stands in Newfoundland. Can. J. For. Res. 5, 195-209.

This paper presents data on the effects of balsam woolly aphid damage mensurational characteristics of balsam fir trees and stands, and quantitative estimates of changes in merchantable volumes that result from alterations in these characteristics. Average volume losses in damaged semi-mature and mature stands ranged from 2 to 6%, but were as high as 80% or more in a few highly susceptible stands. Strong and consistent relationships were recorded between the incidence and severity of aphid damage and a number of site and stand characteristics, including elevation, soil-moisture regime, stand height and age, balsam fir content and total balsam fir basal area of affected stands, and length of time damage had been present. These relationships were utilized to construct a hazard-rating system for use by forest managers in identifying sites and stands highly susceptible to severe damage, and in scheduling silvicultural control measures.

264. Page, G. 1976. The impact of balsam woolly aphid (Adelges piceae) damage on balsam fir. (Abies balsamea) stands in Newfoundland: Reply. Can. J. For. Res. 6:558-559. (See Abstr. of paper #82).

265. Page, G., H.O. Schooley and J. Hudak. 1970. Effect of balsam woolly aphid attack on balsam fir tree volume relationships in western Newfoundland. Can. For. Serv. Inf. Rept. N-X-57. 20 pp.

266. Parent, B. 1969. (Effect of climatic factors on arthropod pests of crops.) Phytoprotection 50:95-119 (F.).

A review of world literature, dealing mainly with pests of field and orchard crops, but including also a section on forest insect pests important in Quebec (Choristoneura fumiferana, Neodiprion spp., Dendroctonus spp., Coleophora laricella, Croesia semi-purpurana, and Adelges piceae).

267. Patch, E. 1909. Chermes of Maine Conifer. Maine Agric. Exper. Stat. Bull. No. 173.

268. Peirson, H.B. and A.M. Gillespie. 1934. Some observations on the balsam woolly aphid in Maine. J. Econ. Ent. 27:340-341.

269. Perem, E. 1965. The structure and properties of reaction wood formed in trees infested by balsam woolly aphid. Can. Dept. For. Inf. Rept. OP-X-3. 28 pp.

270. Phelps, V.H. 1967. Will balsam woolly aphid infestations spread in B.C.? Can. Dept. For., British Columbia Timber Talks, #30.

271. Pimentel, David. 1966. Population ecology of insect invaders of the Maritime Provinces. Can. Ent. 98:887-894.

From a study of the ecology of the insect invasions occurring in the Maritime Provinces the following generalizations are made: (1) The Maritimes have served as a focal point of many invasions because they have several international ports that are surrounded by diverse human modified environments. (2) Plant and animal communities of the Maritimes are relatively simple, which makes invasions easier and more successful. (3) The lack of evolved homeostasis between the invader and its adopted community may have been one of the prime reasons for outbreaks in the species populations newly introduced. (4) Both native and introduced parasites and predators have provided effective control of introduced pests.

272. Pope, R.B. 1957. The role of aerial photography in the current balsam woolly aphid outbreak. For. Chron. 33:263-264.

Makes suggestions for increased use of aerial photography in locating outbreaks, assessing their intensity, estimating amount of timber killed and damaged, tracing trends of outbreaks, and determining the types of stand attacked.

273. Pope, R.B. 1958. Cooperative survey of Chermes damage, Mount St. Helens, Wash., U.S. Dept. Agric. For. Serv. PNW Rept. 25 pp.

274. Prebble, M.L. and J.E. Bies. 1954. The situation with respect to forest entomology and pathology in Canada, 1943 to 1953. For. Chron. 30:25-29.

275. Pschorn-Walcher, H. 1956. Climatic and biocoenotic aspects for the collection of predators of Adelges piceae Ratz. (Hemiptera: Adelgidae) in Europe. Proc. 10th Int. Congr. of Entomol., Montreal, 1956 4:801-805.

Summarizes current consideration of climate biocoenotics when collecting predators for introduction to other geographic areas.

276. Pschorn-Walcher, H. 1960. (The present state of the Adelges problem in forestry.) Forstwiss. Centralbl. 79:129-139. (G.).

A general article with particular reference to Germany and Austria, distinguishing A. piceae, A. nusslini and A. merkeri, describing their life history and habits, and discussing methods of preventing damage and of control.

277. Pschorn-Walcher, H. 1964. Comparison of some Dreyfusia (Adelges) infestations in Eurasia and North America. Commonw. Inst. Biol. Tech. Bull. No. 4:1-23.

A comparative review of all the Dreyfusia spp. of the N. hemisphere recorded to date, with the exception of D. joshii (not known to the author personally). Subjects covered are taxonomy, reproductive cycles, and biological control.

278. Pschorn-Walcher, H. and M. Kraus. 1956. Notes on the predators of Dreyfusia (Adelges) piceae and D. nusslini in Sweden. Proc. 10th Int. Congr. of Entomol., Montreal 1956. 4:797-799.

279. Pschorn-Walcher, H. and H. Zwolfer. 1956. (Recent investigations on fir aphids of the genus Dreyfusia and their predator and parasite complex.). Anz. Schadlingsk. 29:116-122. (G.).

Describes central European Dreyfusia species, their ecology, population dynamics and predator and parasite complex.

280. Pschorn-Walcher, H. and H. Zwolfer. 1956. The predator complex of the white-fir woolly aphids. (Dreyfusia: Adelgidae). Z. angew. Ent. 39:63-75.

Proposes a provisional subdivision of the species on ecological grounds, classifies predators by importance, host specificity, stages attacked etc. and discusses the interaction of factors in the collapse of outbreaks.

281. Pschorn-Walcher, H. and H. Zwolfer. 1958. Preliminary investigations on the Dreyfusia (Adelges) populations, living on the trunk of silver fir. Z. angew. Ent. 42:240-277.

Reports on studies of endemic populations of D. piceae, f. typica and D. nusslini f. schneideri on the stems of silver fir in 27 pure and mixed stands in Switzerland, France (Vosges) and Germany (Black Forest). Light, open, dry stands had generally smaller populations per tree and fewer infested trees than dense, moist stands. Infestation trials in cages generally led to increased populations except where a tree had had a mass infestation. Protection against the weather and prevention of dispersal appeared to favour increases in cages. Egg clusters of endemic populations tended to be smaller than those of mass populations. The virtual destruction of the aphids on mass-infested trees by the 1956 frost are described. Factors causing decline of mass infestations, including the weather, overcrowding, bark exhaustion, and physiological regression are discussed. The validity of the

methods and some of the findings of Karafiat and Franz, particularly regarding the role of predators, is questioned. Mass infestations appeared to be less frequent in mixed stands than in pure coniferous stands.

282. Pschorn-Walcher, H. and H. Zwolfer. 1960. Further observations on European Dreyfusia (Adelges) populations. Z. angew. Ent. 46: 260-273.

A further contribution to the controversy with Karafiat and Franz on mortality factors, briefly summarizing the authors' investigations and predator collections in Switzerland, S. Sweden, Germany and Slovakia. In discussing systematics, they report the presence of D. merkeri in S. Sweden. Predator complexes were found to be very uniform for each Adelges species within the natural range of silver fir, but much poorer in species outside. The authors conclude that the differences in observations may be due partly to differences in species (Karafiat and Franz agree, in a postscript, that the population observed was D. merkeri), habitat, and intensity of infestation.

283. Pschorn-Walcher, H., D. Schroder, and O. Eichhorn. 1968. Biological control of some forest insect pests in Canada. Proc. 9th. Commonw. For. Conf. New Delhi. 21 pp.

Reviews work on the biological control of Operophtera brumata, Neodiprion sertifer, Pristiphora erichsonii, Rhyacionia buoliana, and Adelges piceae.

284. Pschorn-Walcher, H., D. Schroder and O Eichhorn. 1969. Recent attempts at biological control of some Canadian forest insect pests. Commonw. Inst. Biol. Control Tech. Bull. No. 11:1-18.

Summarizes experiments in the biological control of five major forest pests. Of these, Operophtera brumata has been controlled very satisfactorily after a comparatively short time; results in control of Pristiphora erichsonii are now beginning to look promising. For Rhyacionia buoliana and Neodiprion sertifer the possibilities appear somewhat less. For Adelges piceae, it would seem, from the nature of the reproductive and developmental cycles of the pest and the effects of predators on population dynamics in Europe, that possibilities of biological control are slight.

285. Puritch, G.S. 1971. Water permeability of the wood of grand fir (Abies grandis (Doug.) Lindl.) in relation to infestation by the balsam woolly aphid, Adelges piceae (Ratz.). J. Exp. Bot. 22:936-945.

By measuring the rate of flow of water through plugs of wood of standard dimensions and under constant suction, it was ascertained that in normal trees growing near Aberdeen, permeability of the wood was less in the inner than in the outer sapwood, and that this difference was correlated with a greater void space (gas-filled tracheids) in the inner sapwood. The permeability of the heartwood was < 5% of that of the sapwood. Aphid infestation reduced the permeability of the outer sapwood to about the same value as that of normal heartwood. The infested wood had a high % of void space, and again permeability was negatively correlated with void space. For a given amount of void space, however, the infested wood had a much lower permeability than normal wood. This suggests that there is a factor additional to the air in the tracheids, that contributes to the low permeability of infested wood.

286. Puritch, G.S. 1973. Effect of water stress on photosynthesis, respiration and transpiration of four Abies species. Can. J. For. Res. 3:293-298.

Data on photosynthesis, respiration and transpiration were obtained from growth-chamber experiments in British Columbia with potted 5-year-old seedlings of A. amabilis (a), A. grandis (b) and A. lasiocarpa (c), and 3-year-old seedlings of A. balsamea (d). The results, presented in graphs, show that the photosynthesis of (d) is reduced most, and that of (b) least, by water stress. It has been reported that on the west coast (b) is more resistant to damage and mortality caused by Adelges piceae than are (a) and (c), and on the east coast (d) is known to succumb rapidly to aphid infestation. These factors, together with the results of the present experiments, lend support to the hypothesis that mortality due to aphid infestation results from the initiation of physiological drought conditions within the tree.

287. Puritch, G.S. 1975. The toxic effects of fatty acids and their salts on the balsam woolly aphid, Adelges piceae (Ratz.). Can. J. For. Res. 5:515-522.

Describes laboratory and field tests in British Columbia to determine the toxicity of these compounds to different life stages of A. piceae on Abies grandis. The most effective fatty acids for killing aphids were in two major groups, one centred on capric and caprylic acids within the shorter-chain fatty-acid series, and the other on oleic acid within the unsaturated 18-C fatty-acid series. The K soaps were more effective than the corresponding acids; the soaps of caprylic, capric, oleic and linoleic acids were the most effective. Eggs were less sensitive to the soaps than later stages of the aphid, and there was a large variation in their response to soap treatments. The practical implications of these results are discussed.

288. Puritch, G.S. 1977. Distribution and phenolic composition of sapwood and heartwood in Abies grandis and effects of the balsam woolly aphid. Can. J. For. Res. 7:54-62.

The heartwood and sapwood were studied in discs taken from 3 heights on healthy trees and on trees infested with Adelges piceae. In non-infested trees, there was a significant regression between percentage heartwood by age and disc age and between percentage heartwood by area and disc area. Aphid infestation increased both the number of annual rings of heartwood, and the heartwood area. The amount of heartwood in infested trees varied with the degree of aphid infestation. The phenolic composition of A. grandis was similar to that of Tsuga heterophylla: the heartwood contained matairesinol, hydroxymatairesinol, conidendrin, and an unknown phenolic glucoside; and the sapwood contained several leucoanthocyanidins. Aphid infestation did not alter the phenolic composition of the heartwood but caused the occurrence of a new phenolic in the sapwood. The possible causes of the increased amounts of heartwood in infested trees are discussed.

289. Puritch, G.S. and J.A. Petty. 1971. Effect of balsam woolly aphid Adelges piceae (Ratz.) infestation on the xylem of Abies grandis (Doug.) Lindl. J. Exp. Bot. 22:946-952.

Studies of sapwood of aphid-attacked A. grandis growing near Aberdeen showed that the infestation by A. piceae did not cause 'Rotholz', the abnormal xylem usually produced in response to aphid attack. The tracheid length, annual ring width, and % late-wood per annual ring were not significantly different between the wood of infested and non-infested trees. Gas permeability, in combination with a modified Adzumi equation, was used to determine the total number and size of the conducting pit-membrane pores and tracheid lumina. In infested and non-infested sapwood dried by solvent exchange, the average pore radius of the pit membrane was calculated as about 0.1 μm. The radius of the pit pore, and the tracheid lumina and the number of conducting tracheid lumina were not significantly different in the infested and non-infested wood. Infestation reduced the number of pit pores per conducting tracheid in the wood by a factor of about 3. The reduced number of conducting pit pores may have lowered the permeability of the infested wood by directly reducing the number of available flow channels.

290. Puritch, G.S. and R.P.C. Johnson. 1971. Effects of infestation by balsam woolly aphid, Adelges piceae (Ratz.) on the ultrastructure of bordered-pit membranes of grand fir, Abies grandis (Doug.) Lindl. J. Exp. Bot. 22:953-958.

In sapwood of non-infested trees the membranes of early-wood pits were well perforated, whereas those of the late-wood pits were either heavily incrusted or incompletely developed, and showed few perforations. In the heartwood, pit membranes from both early and late wood were heavily incrusted. In aphid-infested trees all the pit membranes from the sapwood were incrusted and resembled those of heartwood of non-infested trees. These incrustations reduced the number of pores in the margo of pit membranes, and could account for the reduced permeability to water reported for sapwood of trees attacked by the aphid. It is suggested that the incrustation of pit membranes in sapwood of A. grandis infested with A. piceae occurs because these aphids cause heartwood to form prematurely.

291. Puritch, G.S. and M. Talmon-de L'Armee. 1971. Effect of balsam woolly aphid, Adelges piceae, infestation on the food reserves of grand fir, Abies grandis. Can. J. Bot. 49:1219-1223.

Effects of infestation by this aphid on the concentration of carbohydrates soluble and insoluble in ethanol were studied in four age classes of needles and six age classes of twigs in A. grandis before and after bud-break. In March, before bud-break, sugars made up about 2/3 of the total carbohydrate content of the foliage. Infestation did not affect the concentration of sugars in the needles, but reduced starch content by 28%. In twigs, sugar concentrations were lower in infested trees, but starch concentrations were unaffected. Older needles and twigs contained higher concentration of starch than younger ones. In June, after bud-break, starch increased and accounts for 65% of the total carbohydrate in non-infested foliage and 53% in infested foliage. Infestation significantly increased the sugar concentration of the foliage by 6% but decreased the starch concentration by 36%. Infestation did not affect the sugar concentration in twigs, but reduced the starch concentration by 18%.

292. Puritch, G.S. and W.W. Nijholt. 1974. Occurrence of juvabione-related compounds in grand fir and Pacific silver fir infested by balsam woolly aphid. Can. J. Bot. 52:585-587.

Analyses of stem sections from healthy trees of Abies grandis and A. amabilis and from trees infested by Adelges piceae (varying in age and height) from two sites on Vancouver Island, indicated the presence of (+)-todomatuic acid and dehydrotodomatuic acid in wood from infested trees but not from healthy trees; (+)-todomatuic acid occurred only in areas adjacent to aphid infestation, regardless of height within the tree, and was

localized in certain annual rings. Reasons for this variable distribution are not understood, but indicate that hubabione-related compounds are not normal constituents of the trees but are produced in response to aphid infestation or some other stress situation.

293. Puritch, G.S. and M. Talmon-de L'Armee. 1974. Biocidal effect of fatty acids and soaps on balsam woolly aphid. Can. For. Serv. Bi-Mon. Res. Notes 30:35-36.

Reports promising results of tests of soaps and fatty acids, notably the unsaturated oleic and linoleic acids, as insecticides for the control of Adelges piceae on Abies spp., and points out that these compounds (which are natural constituents of plants and animals) are relatively cheap, biodegradable and low in phyto-toxicity.

294. Puritch, G.S. and D.B. Mullick. 1975. Effect of water stress on the rate of non-suberized impervious tissue (NIT) formation following wound healing in Abies grandis. J. Exp. Bot. 26: 903-910.

The formation of non-suberized impervious tissue (NIT) injuries is an integral part of the process of periderm formation. Water stress such as that associated with Adelges piceae infestation greatly retards the rate of NIT formation.

295. Randall, A.P., W.W. Hopewell and P.C. Nigam. 1967. Chemical control studies on the balsam woolly aphid (Adelges piceae (Ratz.). Dept. For. Can. Bi-Mon. Res. Notes 23:18-19.

Extensive laboratory and field tests of insecticidal foliage sprays indicated that NIA-10242, Baygon, Bidrin, Diazinon, and Matacil were promising materials.

296. Rao, V.P. 1965. Surveys for natural enemies of Adelges spp. attacking silver fir and spruce in the Himalayas. Commonw. Inst. Biol. Control, Bangalore, India, Final Rept. 85 pp.

297. Rao, V.P. 1971. Studies of the population dynamics of the predators of balsam woolly aphid on silver fir and spruce in the Himalayas. Commonw. Inst. Biol. Control, Bangalore, India. Final Tech. Rept. 66 pp.

298. Ratzeburg, J.T. 1844. (Forest Insects.) Nicolaische Buchhandlung 3:195-205 Berlin. (G.).

299. Retnakaran, A., T. Ennis, L. Jobin and J. Granett. 1979. Scanning electron microscopic study of wax distribution on the balsam woolly aphid, Adelges piceae (Homoptera: Adelgidae). Can. Ent. 111:67-72

Scanning electron micrographs of balsam woolly aphid, A. piceae Ratz. (a serious pest of true fir), show ribbon-like wax secretion in the dorso-median, marginal and inter-tergal regions. Longitudinal grooves in the ribbons indicate that secretions from a row of cells fuse together to form bands of wax. Most of the ribbons appear as extensions of the tergal sclerities. Post-notal plates are conspicuous in the dormant 1st instar and in the adults characteristic wax plates with crater-like pits are evident. The chemistry of wax in related species and a rationale for control using juvenile hormone analogs are discussed.

300. Ruzicka, Jaroslav. 1937. (The problem of Dreyfusia on fir from the forester's viewpoint.) Lesnicka Prace. 16:123-144. (Hun.)

Komarek's assertion that Dreyfusia nusslini, not freezing, causes the death of fir, is refuted by the fact that there is no D. nusslini on many of the old firs that die, but that their crowns and wood show evidence of severe freezing. Only the weaker trees under about 23 years old are attacked by the insect, which is comparatively rare in Bohemia. D. piceae, which is relatively abundant, is harmless.

301. Saigo, R. 1969. Anatomical changes in the secondary phloem of grand fir induced by balsam woolly aphid. (Adelges piceae Ratz.). Ph.D. Dissertation. Univ. British Columbia. 101 pp.

Describes the cortex, cambial zone, secondary phloem and part of the xylem of infested and healthy trees and those attacked and then abandoned.

302. Saigo, R. 1976. Anatomical changes in the secondary phloem of grand fir (Abies grandis) induced by the balsam woolly aphid. Can. J. Bot. 54:1903-1910.

The microscopic anatomy and seasonal changes of the secondary phloem, cambium and a portion of the xylem of grand fir trees: (A. grandis (Dougl.) Lindl.) infested with the balsam woolly aphid (Adelges picea Ratz.) are compared with tissues of non-infested trees. The reactivation of the vascular cambium and production of astrosclereids and resin cells are about the same in infested and non-infested trees. The infested trees exhibit sieve cells that are shorter in length, having a tangential dimension about the same as normal cells, and produce more

tangential bands of phloem parenchyma cells, more fiber sclereids, biseriate rays and lipoidal-filled ray cells, abnormally shaped ray parenchyma cell nuclei, giant cortical parenchyma cells and traumatic resin ducts in the xylem.

303. Schneider-Orelli, O. 1945. (Further investigations on Dreyfusia). Mitt. Schweiz. Anst. forstl. Vers. 24:105-132. (G.).

To facilitate a survey by forest officers of the distribution of Dreyfusia nusslini on silver fir in Switzerland, the paper reviews the generic characters of Pineus, Dreyfusia, Adelges, Sacaphantes, Cholodkovskya and Gilletteella and gives a method of separating, macroscopically and microscopically, mixed infestations of D. nusslini and D. piceae. Dusting and spraying have limited control possibilities infestation can be checked but rarely completely controlled by such measures.

304. Schooley, H.O. 1975. Cone production of balsam fir damaged by balsam woolly aphid. For. Chron. 51:105-107.

The effect of Adelges piceae damage on cone production by Abies balsamea in Newfoundland was studied on 49 trees classified into six aphid-damage classes. The results revealed no appreciable effect until damage exceeded the 'moderate' category. Cone production, on trees in the 'moderate-to-severe' and 'severe' damage categories was seriously reduced but, since advanced damage is not reached by all trees simultaneously, it is concluded that adequate seed should be available for stand replacement.

305. Schooley, H.O. 1976. Effect of balsam woolly aphid on cone and seed production by balsam fir. For. Chron. 52:237-239.

Sample trees of Abies balsamea in Newfoundland, 47 years old and infested for 10 years with Adelges piceae, were classified according to degree of damage by A. piceae and examined for cone and seed characteristics. There was no apparent damage to cones as a result of aphid infestation of the shoots; the cones were free of aphids. Aphid damage was unrelated to damage by other pests (chalcids, cone maggots and cone worms) and had no effect on seed yield and quality, unless severe (a condition found only in scattered trees). Results are discussed in relation to the reported decrease in cone production in A. fraseri infected with A. piceae. It is concluded that infestation with A. piceae is not a threat to the regeneration of A. balsamea.

306. Schooley, H.O. 1976. Recovery of young balsam fir trees damaged by balsam woolly aphid. For. Chron. 52:143-144.

An 18-year-old Abies balsamea stand in SW Newfoundland was examined 5-8 years after severe infestation with Adelges piceae. The original leader had resumed growth on 60% of the sample (moderate to moderate-severe damage) and height loss was equivalent to 2 years' increment. In the remaining 40%, re-orientated branches had replaced dead leaders (severe damage) and height loss was equivalent to 1-4 years. The relatively small loss of height increment, and the lack of stem deformities show that the single infestation (of relatively short duration) had little adverse effect on the stand studied.

307. Schooley, H.O. 1978. The effect of balsam woolly aphid attack on the development of young balsam fir stands. I: Methods and plot description. Can. For. Serv. Inf. Rept. N-X-147. 25 pp.

Permanent plots have been selected in second-growth regeneration, 5-yr-old and 15-yr-old stands of Abies balsamea with symptoms of initial attack by Adelges piceae in western Newfoundland. Details are given of the methods that will be used for annual and periodic measurements of tree characteristics, aphid populations and decay and cull. A classification is presented for the severity of aphid damage during separate cycles of attack.

308. Schooley, H.O. 1978. Abnormal wood formation in the tops of aphid-damaged balsam fir. Can. For. Serv. Bi-Mon. Res. Notes 34:5.

309. Schooley, H.O. 1979. Introduction, spread and occasional resurgence of the balsam woolly aphid in Newfoundland. Proc. of Int. Union of For. Res. Org. Groups S2-07.05 and .06. Conf. on Dispersal of Forest Insects.

310. Schooley, H.O. and L. Oldford. 1969. Effect of balsam woolly aphid damage on the reproductive potential of balsam fir. Can. For. Serv. Inf. Rept. N-X-35. 21 pp.

311. Schooley, H.O. and L. Oldford. 1974. Damage caused by the balsam woolly aphid in young balsam fir stands. Can. For. Serv. Inf. Rept. N-X-115. 19 pp.

Describes a study of 23 young stands of Abies balsamea in western Newfoundland, showing that the magnitude of damage by Adelges piceae is highly variable, ranging from 0 to > 90%, and that the intensity of damage in a stand increases with increasing incidence of damaged trees. Most young A. balsamea stands in this area appear at present to be not seriously affected by A. piceae, mainly because mortality has been insignificant; most of the damage has been light or moderate, and > 1/3 of the damaged trees have recovered. However, since recovery is less common among dominant trees, stand quality will probably be reduced at merchantable age if aphid damage persists.

312. Schooley, H.O. and L. Oldford. 1975. Balsam woolly aphid damage to the crowns of balsam fir trees. Can. For. Serv., Inf. Rept. N-X-121. 27 pp.

Describes the distribution of damage by Adelges piceae in the crowns of Abies balsamea trees 32-70 years old in western Newfoundland, and the effect of such damage on crown development. Data from all six damage classes distinguished showed that 'gout' - i.e. swelling of the nodes - was distributed throughout the apical part of the crown (in the study, the section formed during the last 11 years) early in the cycle of damage. The area of intense 'gout' was confined to the vicinity of 5-year-old branches on trees in the light damage class, but occupied half, three-quarters and nearly all of the apical part of the crowns of trees in the moderate, moderate-to-severe and severe damage classes respectively. With increasing severity of damage the development of tree height, the number of branches and the length of annual branch increments were progressively reduced, so that while the volume of living crown in healthy trees was 130 ft^3, that of severely damaged trees was only 25 ft^3. However, although the evidence is inconclusive, it is tentatively concluded that unless attack by A. piceae is moderately severe or severe, the volume of wood eventually produced by damaged merchantable trees is unlikely to be seriously affected.

313. Schooley, H.O. and D.G. Bryant. 1978. The balsam woolly aphid in Newfoundland. Can. For. Serv. Inf. Rept. N-X-160. 72 pp.

The balsam woolly aphid, Adelges piceae (Ratz.), a serious introduced insect pest of balsam fir, Abies balsamea (L.) Mill., is expected to be a persistent problem of all susceptible forests in Newfoundland. Research information on the biology of the pest and the effect of infestation on individual trees and stands have been collected and integrated into a unified source of information. A damage hazard rating system based on site and stand parameters is provided and management procedures that may reduce losses from infestations are recommended.

314. Schooley, H.O. and G.J. Laflamme. 1979. Stem decay in balsam fir damaged by balsam woolly aphid. Can. For. Serv. Bi-Mon. Res. Notes 35:13-14.

The aphid-killed leaders of young fir are usually not susceptible to decay.

315. Schremmer, F. 1956. (An outbreak of A. piceae in the Viennese forests and its natural enemies.) Pfl. Sch. Ber. 16:49-69. (G.).

Presents the results of observations on the biology of the pest, the cause of the attack, and 18 different predators, with preliminary notes on a parasitic fungus, as yet unidentified, found on preserved material.

316. Sedlaczek, W. 1938. (Thoughts for the control and prevention of damage by fir aphids (Dreyfusia sp.)) Centralbl. Forstw. 64(7/8):194-199. (G.)

As Dreyfusia requires considerable light, biological control depends on dense stands. The best spp. to plant in mixture are spruce and pine, rather than broadleaf spp. Fir stands should be regenerated under the shade of the old stand. Maintenance of a flora rich in spp. favors abundance of Dreyfusia parasites, especially along the borders of the stand.

317. Sellars-St. Clare, E. 1969. Woolly aphids (Adelges spp. and Pineus spp.) on conifers in British Columbia. Can. For. Serv. For. Pest Leafl. No. 19, 6 pp.

Deals briefly with 6 Adelges spp. and 7 Pineus spp.

318. Shea, K.R., N.E. Johnson and S. McKee. 1962. Deterioration of Pacific silver fir killed by balsam woolly aphid. Amer. J. For. 60:104-108.

Abies amabilis trees, dead for various lengths of time up to 5 years provided data for planning salvage operations. Insects encountered included ambrosia and bark beetles, cerambycids and horntails. Decay fungi most frequently identified were Fomes pinicola, Polyporus abietinus, Stereum chaillettii, and Armillaria mellea, in order of decreasing importance. Deterioration averaged 13% of merchantable volume per year, to a cumulative total of 53% in 3-5 years. Pronounced changes were found in the physical and chemical properties of pulp from trees dead 3 years compared with that from wood of living trees; wood dead 3-5 years, if it formed the major portion of the wood supply, would not produce an acceptable bleached pulp. The results show that A. amabilis killed by Adelges piceae should be salvaged soon after death, preferably within 3 years.

319. Silver, G.T. 1959. The balsam woolly aphid, Adelges picea (Ratz.), in British Columbia. Can. Dept. For. Bi-Mon. Progr. Rept. 15(1):3.

The first authentic record of this aphid in British Columbia was reported in 1958 on Abies amabilis at 1400-3500 ft. alt. The infestation is believed to be about 8 years old and several infested trees are dead.

320. Silver, G.T., D.H. Ruppel and S.J. Allen. 1962. The balsam woolly aphid in British Columbia, 1960. Can. Dept. For. Bi-Mon. Progr. Rept. 18(3):3-4.

Adelges piceae was first discovered in British Columbia in 1958, and this report summarizes the extent of the infestation, mainly on Abies amabilis, and the current programme of research and control.

321. Sisson, W.E., Jr. 1971. Effects of the balsam woolly aphid (Adelges piceae (Ratz.)) on the cambial activity of grand fir. (Abies grandis (Dougl.) Lindl.) and subalpine fir (Abies lasiocarpa (Hook.) Nutt.) Ph.D. Dissertation, Oreg. State Univ. 49 pp.

322. Smirnoff, W.A. 1967. (Preliminary information on cryptogamic diseases of Adelges piceae in the Gaspe Peninsula and research into methods of dissemination.) Can. Fed. Advance Sci. Ann. 1966/67 34:123.(F.).

Parasitic cryptogams of A. piceae, found in the Gaspe region of Quebec in Oct. 1966, were isolated and cultured. Investigations are being made of the dissemination of the pathogens by means of spraying and dusting, and by introducing entomophagous Acarina (Trombidiidae) dusted with fungus spores.

323. Smirnoff, W.A. 1970. Fungus disease affecting Adelges piceae in the fir forest of the Gaspe Peninsula, Quebec. Can. Ent. 102:799-805.

The following fungi were isolated from A. piceae in 1966-67: Fusarium larvarum, Cephalosporium coccorum, Entomophthora sp., Aspergillus fumigatus, A. nigra, Penicillium thomii, Penicillium sp., Cladosporium sp., Isaria farinosa and Beauveria sp. Only F. larvarum gave evidence of pathogenicity, and it was most frequently found in A. piceae populations of average density; C. coccorum was considered a facultative pathogen. The Aspergillus spp., Penicillium spp. and Cladosporium sp. were saprophytic. There were insufficient data to determine the function of the remaining species. Pathogenicity tests with F. larvarum and C. coccorum were not successful in defining their degree of virulence as pathogens.

324. Smirnoff, W.A. 1970. The fungus diseases of Adelges piceae and their possible use for the control of this species. Proc. 4th. Int. Colloq. Insect Path. College Park, Maryland, U.S.A. pp 80-83.

Gives details of fungal species isolated from A. piceae in studies made in Europe and North America. Fusarium larvarum was the most widespread parasitic species isolated, and in field trials in Canada and Germany, treatment with combinations of cultures of the fungus and sublethal doses of chemical insecticides showed promise for the control of A. piceae.

325. Smirnoff, W.A. and O. Eichhorn. 1970. Diseases affecting predators of Adelges spp. on fir trees in Germany, Switzerland and Turkey. J. Invert. Path. 15:6-9.

In a survey made in 1968, Beauveria bassiana and Isaria farinosa were found to be the most likely causes of mortality in larvae and pupae of predators of Adelges spp. These diseases must be taken into account when studying the population dynamics of Adelges spp.

326. Smith, B.C. 1956. Predators of the balsam woolly aphid, Adelges piceae (Ratz.) (Homoptera: Phylloxeridae) recently introduced into Canada. Proc. 10th. Int. Congr. Entomol. Montreal 1956. 819-821.

327. Smith, B.C. 1958. Response to light and influences of light and temperature on locomotion of the crawler of balsam woolly aphid, Adelges piceae (Ratz.) and of insect predators of this species. Can. Ent. 90:193-201.

In field tests, the feeding, last-instar, larvae of Aphidecta obliterata and Pullus impexus covered greater areas of bark than those of Cremifania nigrocellulata and Laricobius erichsonii, and the locomotor activities of the species were not greatly affected by changes in air temperatures. Adults of C. nigrocellulata and Neoleucopis obscura made short flights to areas of sunlight at 15 to 25°C, whereas adults of A. obliterata, L. erichsonii and P. impexus did not fly, but remained stationery or walked on the bark surface. These species walked at temperatures ranging from 8 to 25°. The probable sequence of the species in descending order of tolerance of adults to light, on the basis of field observations and laboratory tests, is N. obscura, C. nigrocellulata, A. obliterata, P. impexus, and L. erichsonii. In laboratory tests, adults, except those of A. obliterata, were active from about 3 to 22°. The number of times they ceased movement was greater at high intensity than at low for all species except N. obscura, and frequency of path-crossing was greater for these 4 species at low light intensity than at high. The walking rate of A. piceae in the laboratory was greater at high light intensity than at low, and at the higher test temperatures.

328. Smith, B.C. 1958. Development, feeding habits, and predator-prey relations of insect predators of the balsam woolly aphid, Adelges piceae Ratz. recently introduced into Canada. Can. Ent. 90:441-449.

Investigations on insect predators at Fredericton, New Brunswick, indicated that the development of Aphidecta obliterata, Cremifania nigrocellulata, Laricobius erichsonii and Pullus impexus on A. piceae is generally similar to that in Europe. A. obliterata attacked Mindarus abietinus on the twigs of balsam fir. Larvae of C. nigrocellulata, L. erichsonii and P. impexus did not attack Myzus persicae or Pseudococcus spp., and the prey of these predators are probably confined to the genus Adelges. The value of the predators in control of A. piceae is limited, because few of their stages attacked the crawler or the sessile first-instar larva. In cage studies in the field, the larvae of the predators reduced the numbers of A. piceae appreciably when present before the first-instar larvae became abundant.

329. Smith, B.C. and H.C. Coppel. 1957. Releases in North America and reviews of bionomics in Europe of insect predators of the balsam woolly aphid, Adelges piceae (Ratz.). Can. Ent. 89:410-420.

From 1933 to 1955, 11 species of insect predators of A. piceae were introduced from Europe into E. Canada. Times, location and numbers of predators released are tablulated for each species and their life histories, habits and natural enemies in Europe reviewed. Of 6 species from England, only Neoleucopis obscura has become established in New Brunswick, Nova Scotia and Prince Edward Island. Three of the 6 species from Switzerland and Germany are established in the Fredericton, N.B. area: Cremifania nigrocellulata, Laricobius erichsonii and Pullus impexus.

330. Smith, F.H. 1967. Effects of balsam woolly aphid (Adelges piceae) infestation on cambial activity in Abies grandis. Am. J. Bot. 54:1215-1223.

Salivary secretions injected into the cortex or outer phloem by A. piceae caused a type of growth characterized by increased periclinal and anticlinal divisions of fusiform initials, increased production of new ray initials from fusiform initials and from anticlinal divisions of existing ray initials, and a decline of numerous fusiform initials and the termination of many tiers by maturation. This results in increased frequency of ray fusion and separation by decline or intrusion of adjacent fusiform initial. There was a marked increase in size and number of rays and number of parenchyma strands, both of which also distinguish aphid-affected wood from compression wood, with which it has frequently been compared.

331. Smith, R.K. 1964. Fraser fir stands threatened. Forest Farmer 23:8-10.

Balsam woolly aphid recognized as a pest.

332. Speers, C.F. 1958. The balsam woolly aphid in the Southeast. Am. J. For. 56:515-516.

Records the discovery of an infestation of Fraser fir by Adelges piceae on Mt. Mitchell, N.C., mentioning also A. nusslini on the same species near Luray, Va.

333. Speers, C.F. 1962. A study to determine the effectiveness of insecticidal control of the balsam woolly aphid in Mt. Mitchell State Park in 1961. U.S. Dept. Agric. For. Serv. Rept. SE For. Expt. Stat. 6 pp.

334. Speers, C.F. 1975. Experimental planting in cutover spruce-fir in the southern Appalachians: 50-year results. U.S. Dept. Agric. For. Serv. Res. Note SE-219. 5 pp.

The native stands of Picea rubens and Abies fraseri have regenerated poorly after large-scale clear fellings. Planting trials with these and 18 exotic conifer species were made in 1923-31 on 77 plots (of 0.1 acre) at 5500 ft. alt. on Clingman's Peak, North Carolina. Performance data, including stem form and vigour, are tabulated for 38 plots measured in 1973. The two native species showed the best over-all performance. Several exotics also did well, especially Picea abies, but Pinus resinosa was only exotic regenerating naturally. Since P. resinosa has proved very susceptible to Dendroctonus frontalis and A. fraseri has been severely damaged by Adelges piceae, the only species that can be recommended with certainty is Picea rubens.

335. Stebbing, E.P. 1903. On the acquisition of alar appendages by the spruce form of Chermes abietis-piceae M.S. in N.W. Himalayas. Jour. Asiatic Soc. Bengal, N.S. 72:57-60.

336. Stebbing, E.P. 1904. Life history of Chermes abietis-piceae Stebb. Jour. Asiatic Soc. Bengal, N.S. 72:229-235.

337. Talmon-de L'Armee, M. 1972. A tree platform for crown sampling. Can. J. For. Res. 2:166-167.

In the course of investigation of balsam woolly aphid (Adelges piceae) infestation, a device was developed for convenient twig and foliage sampling of trees 100-150 ft. in height. The apparatus can be conveniently installed in 4 to 6 hrs by 2 men, using a rope and pulley. This device is free of hazard, both to the user and the tree, and is inexpensive to fabricate.

338. Thomas, H.A. 1968. Distribution of the balsam woolly aphid predator Leucopic obscure, in Maine. Ann. Entomol. Soc. Amer. 6a:1344-1346.

Gives a map showing the present distribution of L. obscura in Maine. The insect, introduced in 1933-34, is now established throughout the area occupied by its major known host, Adelges piceae.

339. Tunnock, A. and J.A. Rudinsky. 1959. Observations on the life-cycle of the balsam woolly aphid, Adelges piceae (Ratz.) in the Willasnette Valley of Oregon. Can. Ent. 91:208-212.

The method of following successive generations is described. A. piceae overwintered as a first instar and development started early in February. By October the aphid had gone through four generations. The insects development was correlated with temperature and precipitation.

340. Varty, I.W. 1956. Adelges insects of silver firs. For. Comm., Edinburgh, Bull. 26. 75 pp.

Replaces Bulletin No. 7, long out of print, and contains the following chapters: (1) Taxonomy (including a note on the application of paper chromatography to taxonomy). (2) Life histories of A. nusslini and A. piceae. (3) The reaction of the tree to attack by A. nusslini and A. piceae. (4) Forest relations (forest status and distribution in Britain of the Adelges of silver fir, and silvicultural aspects). The appendices deal with meteorological data, estimation of chlorophyll content in leaves of Abies alba attacked by progredients of A. nusslini, technique of sugar estimation, technique of N estimation for leaves of A. alba, and measurement of pH in Abies spp.

341. Vyse, A.H. 1971. The potential impact of the balsam woolly aphid on forest in British Columbia. Can. For. Serv. Inf. Rept. B-C-X-61.

Describes the main features of a deterministic spatial-diffusion model for forecasting the spread and establishment of Adelges piceae and the resulting mortality of Abies amabilis and financial losses over the period 1968-1987. Maps are presented showing the range of infestation in 1971, the maximum possible spread by 1987, and the long-term hazard zones in British Columbia. Data are given on the progress and intensity of other infestations of A. piceae on Abies spp. in N. America, especially Washington and Oregon.

342. Warren, G.L., W.C. Parrott and S.G. Cochran. 1967. Balsam woolly aphid dispersal and damage in balsam fir stands in Newfoundland. Can. For. Serv. Inf. Rept. N-X-15. 64 pp.

343. Waters, W.E. 1954. Forest insect conditions in the Northeast. U.S. Dept. Agric. For. Serv. Paper NE-76. 22 pp.

344. Waters, W.E. and R.V. Mook. 1958. Forest insect and disease conditions in the Northeast. U.S. Dept. Agric. For. Serv. Paper NE-107. 31 pp.

345. Whiteside, J.M. 1958. Forest insect conditions in the Pacific Northwest during 1957. U.S. Dept. Agric. For. Serv. Rept. PNW-16. 49 pp.

346. Williamson, G.D. 1968. Insect liberations in Canada: Parasites and predators 1968. Can. Dept. Agric. Res. Inst. Belleville, Liberation Bull. No. 32. 19 pp.

A summary of predators and parasites shipments made in Canada in 1968. Includes predators introduced against balsam woolly aphid.

347. Wimmer, E. 1938. (Notes on silver fir aphids.) Forstwiss. Centralbl. 60:118-125. (G.).

Notes on the biology of Dreyfusia spp. on Abies pectinata.

348. Witter, J.A. 1969. Laboratory studies on the development period and feeding behavior of Aphidecta obliterata (L.) (Coleoptera: Coccinellidae), an introduced predator of the balsam woolly aphid. Ann. Entomol. Soc. Amer. 62:1004-1008.

A. obliterata completed its developmental period (egg through pupal stage) in 53 days at 15°C and 75% relative humidity. Feeding studies showed that a straight-line relationship existed between length of larvae and the number of balsam woolly aphid, Adelges piceae (Ratz.), eggs consumed per capita per day. The average number of aphid eggs consumed per capita during larval development was 1853, with a range from 1579 to 2456. In the 4th stage, larvae consumed more eggs per capita than they did in the 1st 3 stages combined. The consumption of prey was reduced when predator density increased.

349. Witter, J.A. and G.D. Amman. 1969. Field identification and sex determination of Aphidecta obliterata, an introduced predator of Adelges piceae. Ann. Entomol. Soc. Amer. 62:718-721.

Description of stages of A. obliterata (L.) (Coleoptera: Coccinellidae) are given. Size was of limited value in differentiating Aphidecta from native predators, Mulsantina spp. in the field, but helpful in identification of early instars. Sex was identified correctly in 93% of A. obliterata adults by observing differences in head colour markings, and in 100% of adults by observing both head markings and length.

350. Wood, R.O. 1968. First occurrence of balsam woolly aphid in the interior of British Columbia. J. Entomol. Soc. British Columbia, 65:13-14.

Adelges piceae was discovered near Vancouver in 1958 and in the interior of British Columbia in 1967. Three planted Abies alba and two A. concolor were found to be infested in the Okanagan Valley. No aphids were found on native A. lasiocarpa.

351. Woods, T.A.D. 1967. The balsam woolly aphid on Christmas trees. Can. Dept. For. and Rural Devel. Bi-Mon. Res. Notes 23:34.

The dormant Adelges piceae were transported on Abies amabilis Christmas trees without risk of spreading the pest. A. piceae taken indoors on the trees died quickly, whereas those on branches and trees thrown outside remained dormant, constituting a possible source of infestation. It is therefore considered advisable to burn unsold trees.

352. Woods, T.A.D. and M.D. Atkins. 1967. A study of the dispersal of balsam woolly aphid crawlers by small animals. Can. Dept. For. and Rural Devel., Bi-Mon. Res. Notes 23:44.

To determine whether the motile stage of Adelges piceae was dispersed by phoresy (i.e. by attachment to other animals), 'fall-traps' were sunk in the forest litter in aphid-infested stand of Abies grandis and A. amabilis. Sticky cards were placed on the trap covers for estimating the number of aphids dropping in the vicinity of the traps. Results showed that the crawlers do not initiate the phoresy.

353. Wylie, H.G. 1958. Observations on Aphidecta obliterata (L.) (Coleoptera: Coccinellidae), a predator of conifer-infesting Aphidoidea. Can. Ent. 90:518-522.

A. obliterata (L.), a predator of Adelges nusslini (Borner), has 1 generation each year in eastern France. The gravid female lays up to about 300 eggs on the bark and needles of infested trees, and the larvae hatch in about 7 days and feed on all stages of A. nusslini except the sessile neosistens. Pupae form on the bark and needles and adults emerge in about a week, i.e., usually late in June. The adults soon mate and disperse from the infested trees and do not return until the following spring. The population of A. obliterata was not appreciably affected by other predators with which it was associated but over half of the pupae were parasitized by the phorid Phalacrotophora berolinensis Schmitz and a smaller proportion by a mermithid of the genus Hexamermis.

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APPENDICES

APPENDIX I. UNPUBLISHED REPORTS

Balch, R.E. 1963. The morphology and host relationships of Adelgids on fir in North America. Can. Dept. For., For. Ent. and Path. Br., Fredericton, N.B.

Balch, R.E. and L.S. Hawboldt. 1943. Report of forest insect conditions in Nova Scotia in 1942. Rept. Dept. Lands For. Nova Scotia.

Balch, R.E. and L.S. Hawboldt. 1943. Report of forest insects in New Brunswick, 1942. Rept. Dept. Lands and Mines, New Brunswick, p. 116-118.

Bajzak, D. 1965. Detection and appraisal of damage by balsam woolly aphid on Abies balsamea (L.) Mill. by means of aerial photography. Can. Dept. For. and Rural Devel., For. Res. Lab., Nfld. Intern. Rept. N-3. 141 pp.

Bowaters Nfld. Pulp & Paper Mills. 1955. Results of grinding woolly aphid infected wood, Special Rept. 1008 R.M.

Brown, N.R., R.C. Clark, and B.C. Smith. 1953. Studies of Adelges piceae and its predators. Can. Dept. Agric. For. Biol. Lab., Fredericton, N.B. Intern. Rept. 17 pp.

Bryant, D.G. 1959. Studies of Adelges piceae (Ratz.) in Newfoundland. Can. Dept. Agric., For. Bio. Lab., Nfld. Interim Rept. 72 pp.

Bryant, D.G. 1963. Adelges piceae (Ratz.). Studies in Newfoundland: Review of associated predators introduced and native, from 1952-1962. Can. Dept. For., For. Res. Lab., Nfld. Interim Rept. 56 pp.

Bryant, D.G. 1972. Sampling balsam woolly aphid populations: 1. Description of pest and host, and problems of sampling. Can. For. Serv., Nfld. For. Res. Cent., Interim Rept. N-49. 25 pp.

Bryant, D.G., H.O. Schooley and J. Hudak. 1973. The effect of balsam woolly aphid attack on the development of young balsam fir stands: Analytical method. Can. For. Serv., Nfld. File Rept. Study 3-1 (72-73B), 24 pp.

Carroll, W.J. 1955. Investigations on the spruce budworm, balsam woolly aphid and hemlock looper. Can. Dept. Agric., For. Biol. Lab., Corner Brook, Nfld. Interim Rept. 24 pp.

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APPENDIX II REFERENCE ON ADELGID SPECIES RELATED TO BALSAM WOOLLY APHID

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