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R. Lavallée

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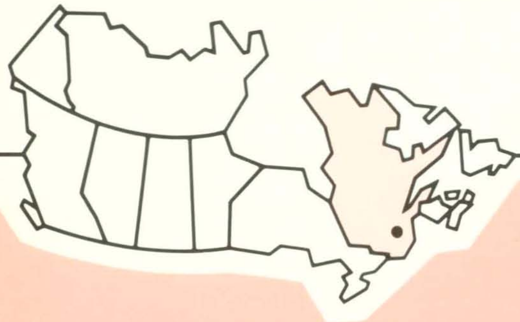

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RÉSUMÉ

Le peuplier faux-tremble (*Populus tremuloides* Mich.) est l'hôte primaire du puceron, *Pachypappa tremulae* (L.). À l'instar de nombreuses autres espèces de pucerons, une partie de son cycle vital s'effectuera sur un hôte alterne non apparenté taxonomiquement à l'hôte primaire. C'est ainsi que *P. tremulae* accomplira une partie de son cycle sur des racines d'épinettes. D'autre part, si on a peu souvent fait mention de cet insecte sur les racines de conifères en milieu naturel, *P. tremulae* semble s'accomoder particulièrement bien des conditions qui lui sont offertes sur les racines des semis croissant en récipients. Le présent document a pour but de rassembler les connaissances actuelles sur *P. tremulae*.

ABSTRACT

Aspen (*Populus tremuloides* Mich.) is the primary host of the aphid *Pachypappa tremulae* (L.). As with many other aphid species, part of its life cycle takes place on an alternate host unrelated taxonomically to the primary host. Thus, *P. tremulae* lives part of its cycle on spruce roots. Although there has been infrequent mention of this insect on conifer roots in the natural environment, *P. tremulae* seems particularly well adapted to the conditions offered by the roots of seedlings growing in containers. This document seeks to gather together current knowledge of *P. tremulae*.

INTRODUCTION

Pachypappa tremulae (L.), an aphid of the subfamily *Pemphiginae*, carries out part of its life cycle on aspen (*Populus tremuloides* Michx.) branches and continues it on roots of spruce (*Picea* spp.) or other resinous varieties such as pine (*Pinus* spp.) and larch (*Larix* sp.) (Theobald 1929; Smith 1969). North America has eight species and two subspecies of *Pemphiginae* associated with conifer roots (Smith 1969).

Except for mention by Zak (1965), *P. tremulae* has been rarely observed on conifer roots in the natural environment. In nurseries, however, it has been frequently reported on roots of containerized seedlings (Theobald 1929; Smith 1969; Sutherland and Van Eerden 1980; Wong 1982). During the past few years, there have been numerous reports of this aphid in Quebec nurseries (Lachance et al. 1984, 1985). Observations made of this aphid encourage the belief that seedlings in containers offer a favorable environment for its proliferation (Jacobi 1905; Hottes 1960).

Aphids of closely related species are well known in agriculture for their harmful effects on the production of turnips, sugar beets, and cabbages (Harper 1961; Harding 1971). Thus, considering the reforestation effort currently under way in Quebec, as well as this insect's preference for roots of certain conifers, there is reason to focus on *P. tremulae*. Although Hartig described *P. tremulae* in 1857, little is known of its biology or of its relationship with its hosts. Therefore, this report has two objectives: one, to gather the available information on *P. tremulae* and, two, to identify the gaps that should be filled by research.

TAXONOMIC POSITION

In 1761, Linnaeus first introduced *P. tremulae* (L.) into taxonomy under the name, *Aphis tremulae* L. (Smith and Parron 1978). His observation must refer to the aphid on the foliage of *Populus tremulae* L. In 1857, Hartig described a spruce root aphid and gave it the name, *Rhizomaria picea* Hartig (Hottes 1960; Smith 1969; Stroyan 1975). In 1909, Tullgren considered that *Rhizomaria picea* Hartig represented the underground generations of a galligenous species of Pemphigus, but could not make a precise identification and suggested *Pemphigus picea* (Hartig).

In 1929, Theobald considered that *Pemphigus picea* (Hartig) was not a true *Pemphigus* and placed it in the genus *Pachypappella* (Baker) (Hottes 1960; Smith 1969), thus *Pachypappella picea* (T. Hartig) (Stroyan 1975). In 1932, Börner and Schilder placed *Rhizomaria picea* Hartig in the genus *Pachypappa* (Hottes 1960; Stroyan 1975).

In 1934, Maxon gave the term *Asiphum rosettei* Maxon for the aphid he found on aspen in Colorado, however this was *Pachypappa tremulae* (L.) (Smith and Parron 1978). In 1972, Stroyan proved that the species *Rhizomaria picea* Hartig of England was the form of *Asiphum tremulae* (L.) present on the secondary host (Smith 1974). Then, in 1972, Stroyan changed the name of *Pachypappella picea* (T. Hartig) to *Asiphum tremulae* (L.) (Stroyan 1975).

Finally, in 1975, Stroyan placed *Asiphum* Koch as a synonym of *Pachypappa* Koch and considered that the true name of *Aphis tremulae* (L.) was *Pachypappa tremulae* (L.).

DISTRIBUTION AND HOSTS

In Europe, *Pachypappa tremulae* is widespread: its distribution area stretches from Great Britain to Russia, including Denmark, Sweden, Norway, and Finland (Heie 1980). In England, its growing presence would probably follow the increase in planting spruce (Stroyan 1975). In North America, on the other hand, its presence would be the result of introduction (Hottes 1960).

In Canada, *P. tremulae* has been reported in British Columbia, Manitoba, Nova Scotia (Smith and Parron 1978), Alberta (Wong 1982), and Quebec. Since aspen is also a host for *P. tremulae*, it is thought that the latter occupies most of the aspen's distribution area (Rose and Lindquist 1982).

In addition to being observed in Quebec on white spruce (*Picea glauca* (Moench) Voss) and black spruce (*Picea mariana* (Mill.) B.S.P.), *P. tremulae* has also been noted on numerous other conifers (Table 1). But the preference of *P. tremulae* for a given host also seems to be a function of the type of mycorrhizae associated with the roots of the host. Zak (1965) showed that the aphid is common on different types of mycorrhizae of *Pseudotsuga meziessii* (Mirb.) Franco var *menziessii* though it has never been observed when the fungus *Rhizopogon vinicolor* A.H. Smith was present.

MORPHOLOGICAL DESCRIPTION

The morphology of *Pachypappa tremulae* varies considerably during the different stages of its biological cycle. One will find a complex system of alternating generations including apterous, alate, parthenogenetic, and sexed aphids. In the present document, summary descriptions are given of the fundatrixes, fundatrigeniae, alienicolae, and sexuparae. To know more about the aphid's morphology, however, it will be necessary to consult the work of Smith (1969), Stroyan (1975), and Heie (1980).

Fundatrix. Very large, apterous, globular viviparous females (5 to 6.6 mm long) (Figure 1A); in life, brownish yellow (Stroyan 1975) or reddish brown; bodies densely covered by long hairs (Heie 1980); 5-segmented antennae; head and body without wax gland plates; cornicles absent; short legs (1.6 to 2 mm) almost black (Stroyan 1975).

Fundatrigenia. Alate viviparous females (Figure 1B) also called migrant; body length from 3.2 to 4.4 mm; in life orange yellow with a black head and pterothorax; 6-segmented antennae; gland plates absent from the head but present on thorax and abdomen; pores of the cornicles on the sixth abdominal tergite; on the forewing, a bifurcated median vein is observed (Figure 2A); bodies covered by a layer of whitish wax flocculence (Stroyan 1975).

Alienicola. Apterous viviparous female living on roots of the secondary host (Stroyan 1975); from 1.4 to 1.9 mm long (Smith 1969) at maturity (Figures 3A and 5); in life, pale yellow (Stroyan 1975); eyes composed of three facets; 5-segmented dark antennae. The pale thorax may be dark on the flanks; legs are also dark. Numerous wax gland plates on the pale abdomen (Smith 1969). Abdominal dorsum plates produce whitish, flocculent ribbon-like wax which extends a certain distance. Abdomen devoid of cornicles (Hottes 1960).

Sexupara. Alate viviparous females bigger than alienicolae, measure 1.8 to 2.4 mm long (Smith 1969) (Figure 3B); in life, yellowish with the abdomen suffused dorsally with dark green (Stroyan 1975); head dark without wax gland plates; 6-segmented dark antennae. Wax gland plates are observed on the thorax and abdomen (Smith 1969; Heie 1980). Cornicles are absent (Stroyan 1975). The median vein of the forewing is single (Smith 1969) (Figure 2B).

Table 1. Resinous hosts of *Pachypappa tremulae* (L.)

HOST	DATE GATHERED	PLACE	REFERENCE
Picea abies (L.) Karst.	20-10-1951	England	Smith, 1969
Picea sitchensis (Bong.) Carr.	13-09-1967	England	Smith, 1969
Picea sitchensis (Bong.) Carr.	-	British Columbia (Canada)	Sutherland and Van Eerden, 1980
Picea sp.	29-09-1966	Utah (U.S.)	Smith, 1969
Picea pungens Engelm.	-	Colorado (U.S.)	Smith, 1969
Pseudotsuga menziesii (Mirb.) Franco	-	Oregon (U.S.)	Smith, 1969
Pseudotsuga menziesii (Mirb.)	-	British Columbia (Canada)	Sutherland and Van Eerden, 1980
Picea glauca (Moench) Voss	18-06-1957	New Brunswick (Canada)	Smith, 1969
Pinus sp.	-	-	Theobald, 1929
Larix sp.	-	-	Theobald, 1929
Tsuga heterophylla (Raf.) Sarg.	-	British Columbia (Canada)	Sutherland and Van Eerden, 1980
Tsuga heterophylla (Raf.) Sarg.	-	Oregon (U.S.)	Zak, 1965
Picea glauca (Moench) Voss	-	Quebec (Canada)	Lachance et al., 1985
Picea mariana (Mill.) B.S.P.	-	Quebec (Canada)	Lachance et al., 1985
Pinus banksiana Lamb.	-	Quebec (Canada)	Lachance et al., 1985

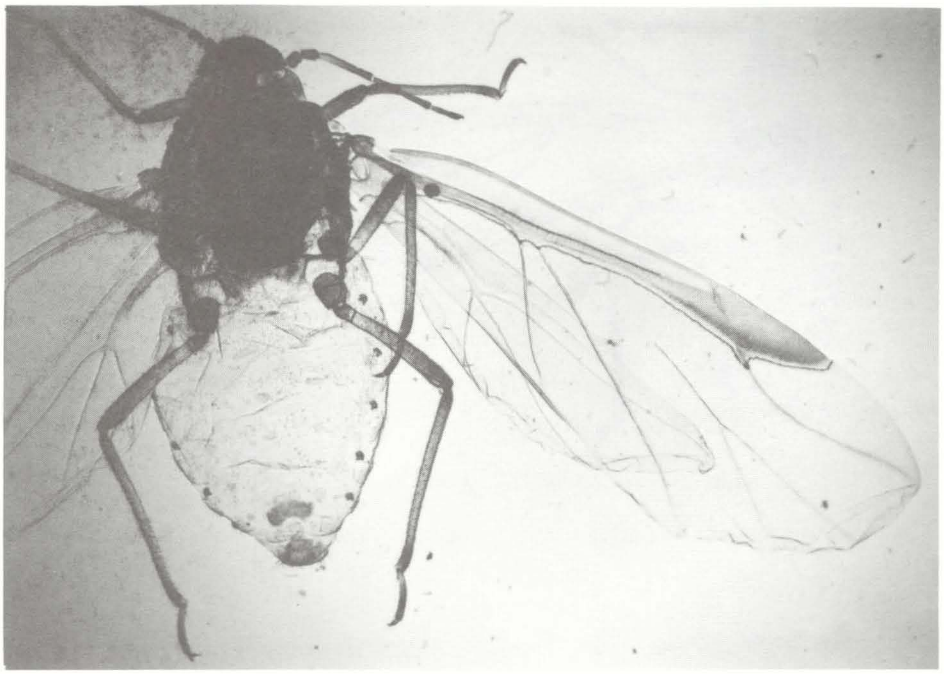


Figure 1. A) Fundatrix, *Pachypappa tremulae* (L.) (Photo: J. Morissette).

B) Fundatrigeniae, *Pachypappa tremulae* (L.) (Photo: J. Morissette).

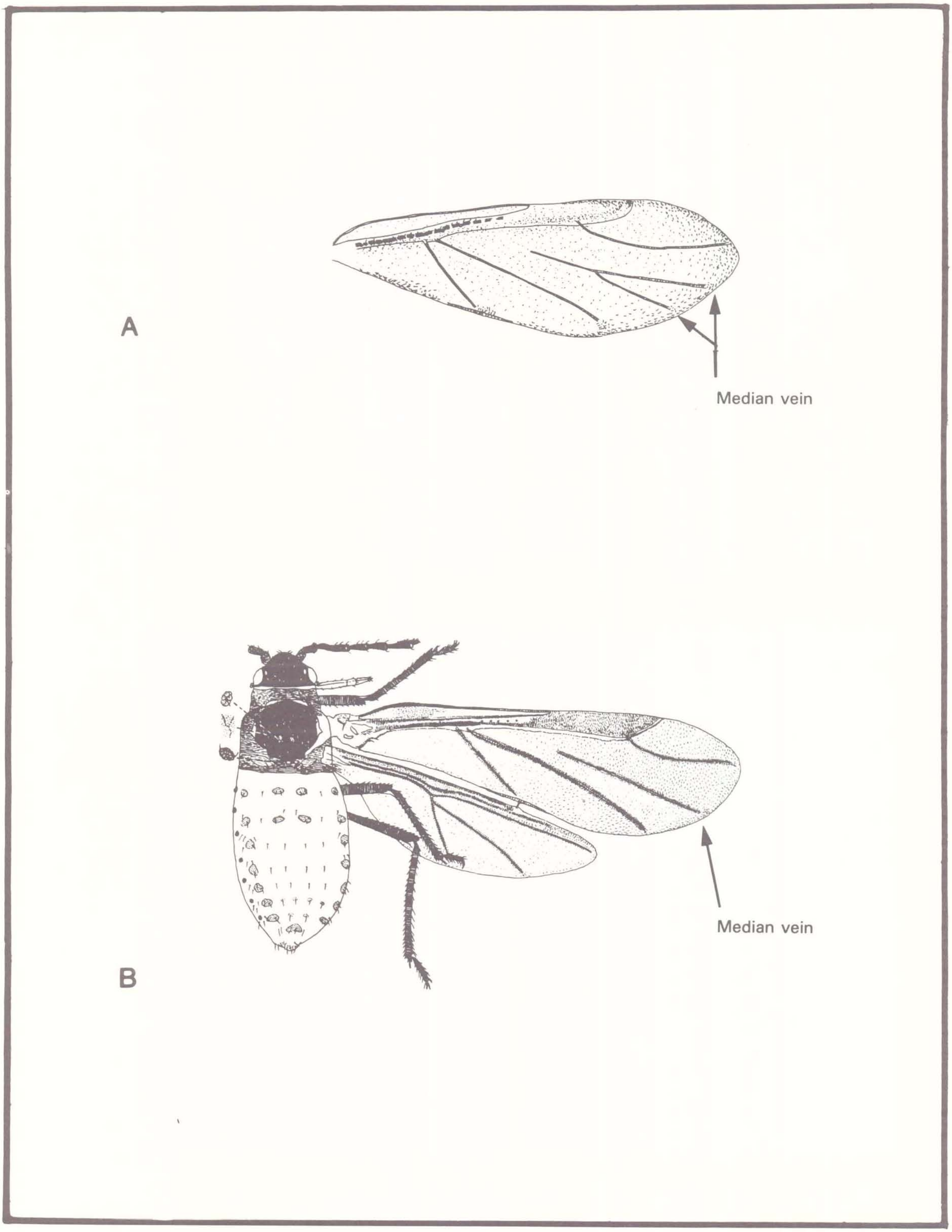


Figure 2. Forewing of a fundatrigeniae (A) and a sexupara (B) (Drawing B: F.W. Quednau).

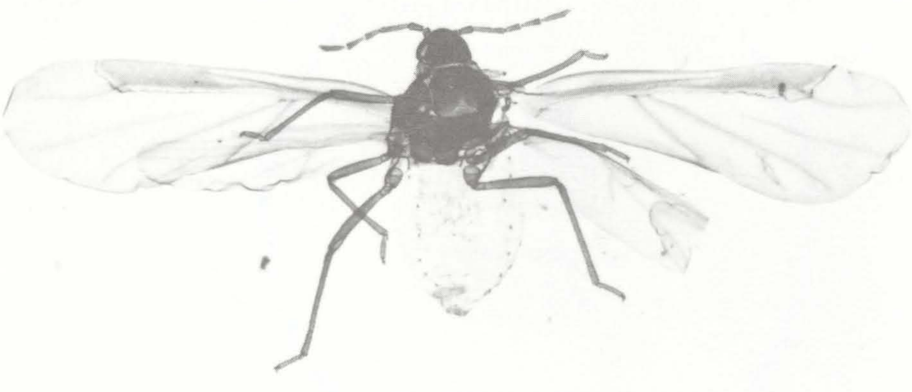


Figure 3. A) Alienicola, *Pachypappa tremulae* (L.) (Photo: J. Morissette).

B) Sexupara, *Pachypappa tremulae* (L.) (Photo: J. Morissette).

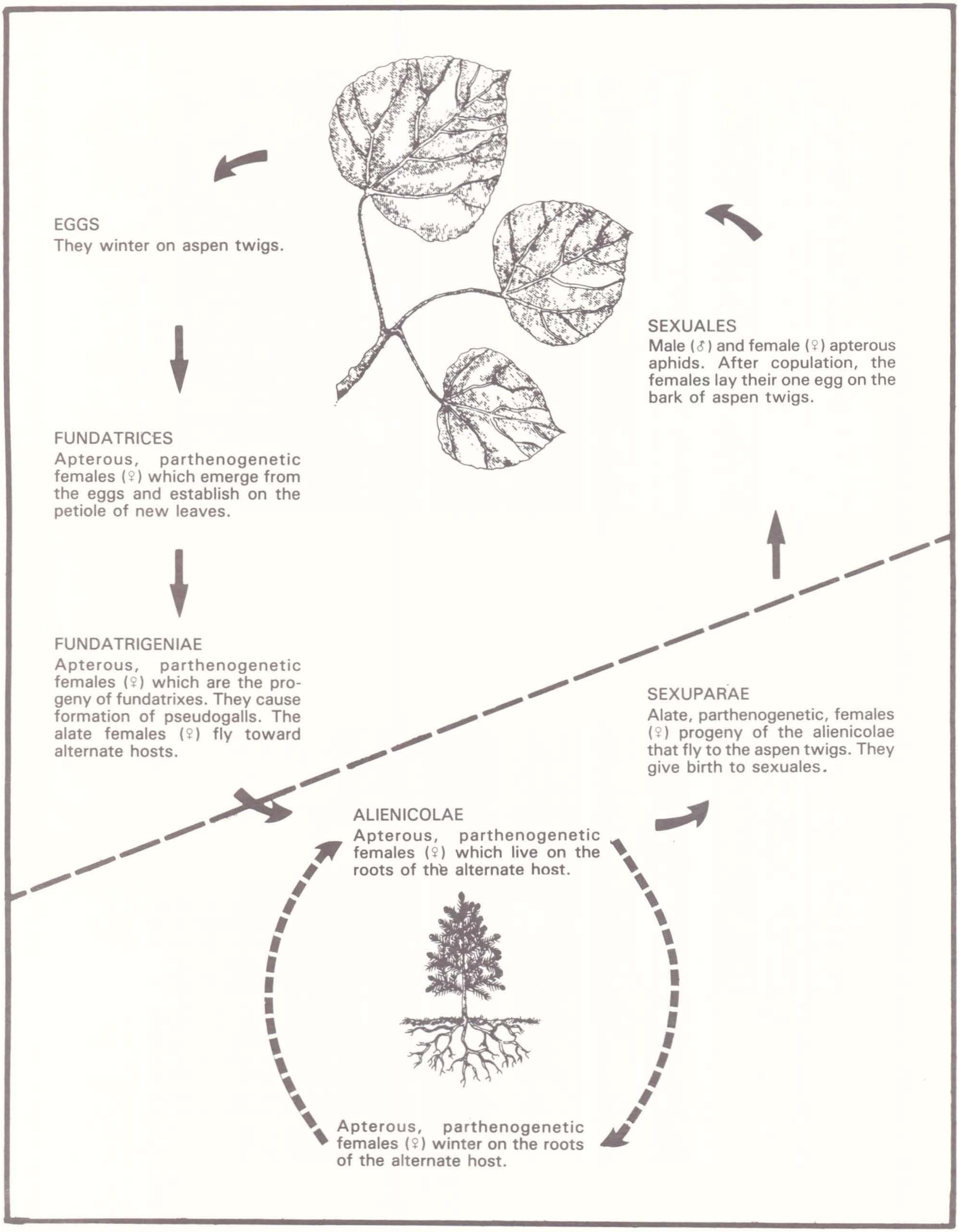
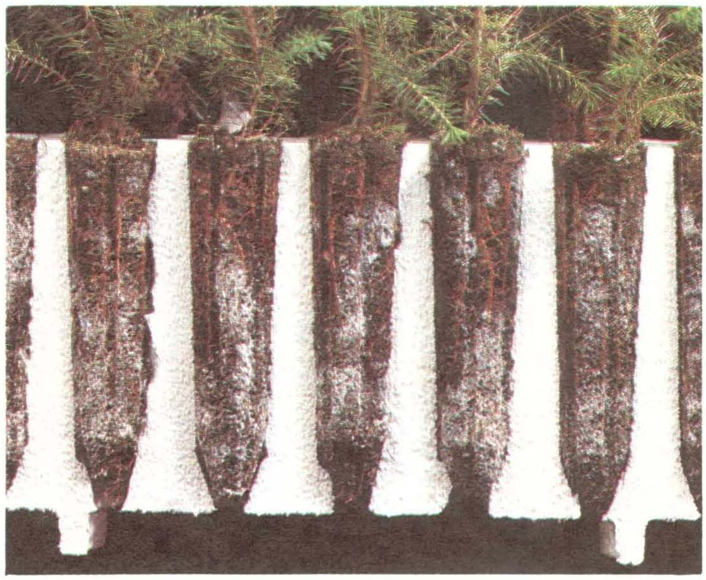


Figure 4. Biological cycle of *Pachypappa tremulae* (L.).

Figure 5. Alienicolae feeding on the mycorrhizal portion of the root (Photo: C. Moffet).

Figure 6. Black spruce seedlings (2-0) infected by *Pachypappa tremulae* (L.) (Photo: C. Moffet).



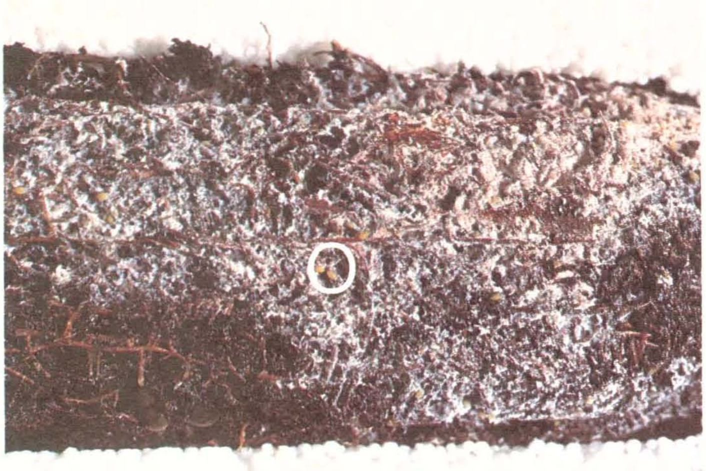


Figure 7. White flocculent wax produced by *Pachypappa tremulae* (L): two aphids can be seen in the circle (Photo: C. Moffet).

Figure 8. Aspen shoots damaged by *Pachypappa tremulae* (L.) (Photo: J. Morissette).

BIOLOGICAL CYCLE

Pachypappa tremulae is heteroecious like several other species of aphids. This means that its life cycle develops on two plant-hosts that are unrelated taxonomically (Dedryver 1982). The plant where eggs are laid is the primary host and the others are secondary (Chararas 1972) or alternate hosts.

The life cycle of *P. tremulae* lasts one year (Figure 4). In the spring, after the eggs hatch the first individuals to appear are the apterous, viviparous females called fundatrices. These are then found on the bark of the short twigs of the aspen (Heie 1980), and sometimes far from the twigs (Tullgren 1909). The young larvae make their way toward the petioles of new foliage. By sucking the sap, they cause the petiole to curve (Tullgren 1909; Smith 1974). The leaves will grow closer together without being deformed (Heie 1980) and form a pseudogall (Alleyne and Morrison 1978). At maturity, the fundatrices will give birth to fundatrigeniae or virgins, which are also parthenogenetic, viviparous females. The aphids will inhabit aspen leaves during June and July (Tullgren 1909; Rose and Linquist 1982).

After a certain number of generations, alate individuals will be born and fly to the secondary hosts. According to

Heie (1980), the new generation born in the upper part of the alternate host will migrate to the roots. The aphids living on the roots, called alienicolae, feed at the level of the mycroohizal portion of the root (Zak 1965) (Figures 5, 6, and 7).

Aphids are easily noticed on the root system because the alienicolae produce an abundance of whitish, flocculent wax (Hottes 1960). As with Jacobi's (1905) observations, we noted that young individuals are highly active by comparison with adults in gestation which remain motionless on roots. The latter stay in small cavities or in crevices of the soil, where they line the walls with waxy filaments. On the contrary, young larvae travel easily and rapidly and can even leave the plant-host.

Finally, the cycle is complete with the arrival of alate individuals. These sexuparae will fly from the roots to the branches of aspens (Heie 1980) where the females will produce sexed, apterous individuals (sexuales). After mating, the females lay their only egg on the bark of aspen branches (Stroyan 1975) where it will spend the winter before hatching to begin the cycle again the following spring.

In certain aphid species, only a portion of the sexuparae are produced in the fall. The remainder continue to reproduce parthenogenetically (Dedryver 1982). This is also true of *P. tremulae*. Some aptera spend the winter on spruce roots (Heie 1980) where they may even survive the entire year (Jacobi 1905; Smith 1969).

DAMAGE

Damage to spruce seedlings by *Pachypappa tremulae* has at times been very severe. Jacobi (1905) mentioned that in infestation centers in nurseries, aphids would attack healthy good growing plants and then leave them when they were severely affected. The main symptoms of an attack were a gradual yellowing of needles followed on occasion by withering and needles falling. Zak (1965) observed that *P. tremulae* infestations left seedlings stunted and faded.

Currently there is very little or no damage caused by *P. tremulae* (Sutherland and Van Eerden 1980; Wong 1982). However, there are reasons to pay close attention to the aphid's influence on the plant. Aphids feed on sap which contains amino acids, minerals, and other nourishing substances. On occasion, the importance of their feeding can be seen by the great quantity of honeydew they produce. But the host-insect relationship can be more complex, and even be modified to the insect's advantage. Heie (1980) pointed out that adaptation by aphids sometimes involves changes in the physiological condition of the plant-host so that the needs of it will be better served. Dixon (1973) also reported this in the black bean aphid (*Aphis fabae* Scop.). As yet, however, there is no evidence of this phenomenon with *P. tremulae*.

Presently, several questions go unanswered. Given its mode of feeding, is *P. tremulae* a vector for viral diseases (Zak 1965; Chararas 1972)? How does the root system react after the stylet is inserted? Are the development and functioning of the mycorrhizae altered by the secretion of honeydew in the rhizosphere (Zak 1965)? What influence has the type of mycorrhizal fungus on the aphid? As Zak (1971) indicates, can certain species of fungi play a protective role for the root?

Damage is less important on aspen, the primary host of *P. tremulae*, because this tree species is in less demand. However, aphid feeding causes a weakness at the junction of the leaf and the petiole, giving the leaves a withered appearance (Smith 1974) (Figure 8).

CONTROL

To date, no method has been developed for combatting *Pachypappa tremulae*. For chemical control of this insect, we can consult the work on root aphids harmful to farm crops. However, the first approach to be encouraged is the insect's natural control by biotic and abiotic factors.

Aphids living on roots are not free of predators. *Thaumatomyia glabra* (Mg.), a diptera of the *Chloropidae* family, is recognized as an important natural predator of aphids of the sugar beet root (Swan and Papp 1972). Any chemical control of aphids should take predators into consideration. Harper (1961) showed that insecticides had an adverse effect on *T. glabra* and, to a certain extent, fostered the development of the aphids.

Since the environment where aphids live is a preferred location for entomopathogenic fungi, significant control could be exercised by certain *Metarrhizium* and *Entomophthorales* fungi (Desmoras and Champ 1982). Harper (1961) reported that beet root aphids could be severely affected by *Entomophthora aphidis* Hoff. Therefore, the use of fungicides in the nursery soil will undoubtedly hamper the natural control exercised by entomopathogenic fungi.

The spread of root aphids may also be controlled by modifying the physical environment. A certain humidity level in the soil can foster the growth of fungi harmful to the aphids (Harper 1958). Hottes (1960) revealed that *P. tremulae* does not tolerate a soil which retains water. This was also reported by Davidson and Peairs (1966) for *Pemphigus populivenae* Fitch. It would be advantageous, then, to plant in humid soil.

Though there are no recent studies on the chemical control of *P. tremulae*, we can examine the control of root aphids in certain farm crops. In 1961, Harper attempted to control *Pemphigus betae* Doane on sugar beet roots, but, even with very effective products such as dieldrin, endrin, and heptachlor protection lasted no longer than a month. However, aldrin, lindane, and parathion provided protection for more than two months.

In 1969, Chalfant used other insecticides against *Pemphigus populitransversus* Riley on turnip roots. The most effective were diazinon in granular and liquid form, as well as liquid oxydemetonmethyl applied to the foliage. In 1971, Harding carried out tests to control this same aphid on the roots of cabbage. Disulfoton, aldicarb, and carbofuran were among the most effective granular products. Liquid insecticides applied to the foliage gave better results. Among these, the most effective were carbofuran, dimethoate, and oxydemetonmethyl.

CONCLUSION

Though the taxonomic position of *P. tremulae* appears settled, the studies of its biology, damage, and means of control are still incomplete. As spruce reforestation will be more and more intensive in Quebec and as container culture becomes more and more popular, the situation could greatly promote the spread of *P. tremulae*. We now know the insect is present without knowing what conditions favor its presence or if it is harmful; this is an uncertain situation.

Although some attempts at chemical control of other root aphids species were effective, it was apparent that these kinds of aphids are difficult to eradicate. Therefore, I believe it is necessary to determine an acceptable threshold of tolerance of *P. tremulae*.

Several research projects must be undertaken to increase our knowledge of this aphid. First, to determine its real impact on the growth of seedlings and then, to improve our knowledge of its biology. Questions that we should attempt to answer are: What are the aphid's secondary hosts? What is this aphid's importance in the natural environment? What relationship exists between the aphid and the mycorrhizae? Finally, if necessary, effective and practical control methods would have to be developed. It would have to be determined if natural control can be sufficient. How can this be encouraged? Can chemical control be harmful to natural control? Would the use of entomopathogenic fungi be an interesting approach to the control of root aphids?

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