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STUDIES ON THE SUSCEPTIBILITY OF PEAR TREES TO PEAR PSYLLA, PSYLLA PYRICOLA FOERSTER (HOMOPTERA: PSYLLIDAE)

By

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THE EARTH DOES NOT BELONG TO MEN
MEN BELONG TO THE EARTH

Quotation from 'Man and His Environment',
Spokane World's Fair, Washington State,
Native's People Pavilion, 1974.

Dedicated to my tireless, generous and understanding parents

Alfredo and Irene

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ABSTRACT

STUDIES ON THE SUSCEPTIBILITY OF PEAR TREES TO PEAR PSYLLA, PSYLLA PYRICOLA FOERSTER (HOMOPTERA: PSYLLIDAE).

Juan F. F. Chang

Under the supervision of Dr. Bernard J. R. Philogéne.

Development and behaviour of the pear psylla, _Psylla pyricola_ Foerster, were observed under field and laboratory conditions. Bioassay chambers were used in the laboratory to determine the susceptibility of different taxa of pear to pear psylla attack. The selected plant material and the insects were collected from the field, at the Jordan Experimental Farm, Jordan Station, Ontario.

Psylla behaviour in the chambers was compared to field observations and in both cases most adult pear psylla migrated to the leaves of pear by early evening.

Pear psylla tested on different plant species and different cultivars of pear did not show significant differences in the relative number of insects per plant species or cultivar. _Psylla_ produced frass in a consistent and reproducible manner on the different taxa tested. Frass deposition was also accompanied by egg laying in the majority of cases. Results indicate that pear psylla fed differentially on the different plants tested.

Pear psylla development in the field after 21 days was also observed

and the data recorded from it paralleled the data obtained for the same plants tested under bioassay conditions in the laboratory.

A cursory analysis of lipid and polar soluble phenolic compounds was performed. The ratio of the common number over the total number of different polar phenolics between the two taxa compared shows a grouping trend among the taxa tested, which is similar to the results from the bioassays and the field study.

According to the results obtained in the field, in bioassays, and two-dimensional chromatography of phenolic compounds in the plants tested, these plants can be arranged in three categories: 1) most preferred hosts for *Psylla pyricola* (Bosc and Old Home), 2) intermediate hosts (Bartlett, Kieffer, and d'Anjou), and 3) least preferred hosts (Clapp, *P. ussuriensis*, and quince).

The present work indicates that pear psylla, tested on the Niagara Peninsula, is a specific pest of the pear crop, but it could feed on quince under unfavorable conditions. The analysis of phenolic compounds indicates that there is a definite number of phenolic compounds associated with the susceptibility of the plant successfully attacked by *Psylla pyricola*.

RESUME

ETUDES SUR LA SUSCEPTIBILITE DU POIRIER AU PSYLLE DU POIRIER, PSYLLA PYRICOLA FOERSTER (HOMOPTERE: PSYLLIDAE)

Juan F. F. Chang

Sous la supervision du Dr. Bernard J. R. Philogène

Le développement et le comportement du psylle du poirier, Psylla pyricola Foerster, ont été observés en conditions de laboratoire et sur le terrain. Des chambres d'essais biologiques ont été utilisées dans le laboratoire pour déterminer la susceptibilité de différents taxa du poirier envers le psylle. Les plantes choisies et les insectes provenaient de la Ferme Expérimentale de Jordan dans la Péninsule du Niagara, Ontario.

Le comportement du psylle du poirier dans les chambres a été comparé avec les observations sur le terrain. On a observé que la plupart des psylles sont allés vers les feuilles du poirier le soir. Il n'y a pas de différence significative dans le nombre relatif de psylles du poirier mis en présence de différentes espèces de plantes et différentes varietés de poirier. Le psylle a produit de l'excrément de façon constante et reproductible sur les différentes plantes.

Le développement du psylle du poirier après 21 jours a aussi été étudié et les résultats ont été parallèles à ceux obtenus pour les mêmes plantes étudiées dans le laboratoire.

Une analyse des composés phénoliques solubles dans les solvents organiques et dans l'eau a été faite. A partir des rapports entre le nombre

commun et le nombre total des differents composés phénoliques, solubles dans l'eau, pour les deux spécimens comparés, on peut voir la tendance des plantes à se grouper, ce qui est similaire aux résultats obtenus dans les expériences en laboratoire et sur le terrain.

Ce travail indique que le psylle du poirier étudié dans la Péninsule du Niagara est un déprédateur spécifique du poirier, mais le psylle peu se nourrir sur le cognassier dans des conditions non favorables. L'analyse des composés phénoliques montre qu'il y en a un nombre determiné associé à la susceptibilité des plantes attaquées avec succès par le psylle.

I.- INTRODUCTION

Pear psylla, Psylla pyricola Foerster (Homoptera; Psyllidae), is regarded as one of the most injurious pests to pear trees in North America. It is known colloquially as the pear sucker or jumping louse, and it is generally believed to be native of southern Europe and western Asia, where its preferred host Pyrus communis is found. Psylla pyricola was first reported in North America in 1848, and it was probably introduced on pear stock brought from Europe to Massachussetts or Connecticut in 1832 (Harris, 1972). It populated the northeastern part of the North American continent fairly quickly, appearing in Ontario in 1894, and in Nova Scotia in 1916. There was no report on the occurrence of pear psylla west of the Mississippi River until 1939, when it was found in the Spokane Valley in Washington State. By 1942 this insect had spread northwards to British Columbia and by 1953 it was reported in California (Nichols et al., 1965; Wilde and Watson, 1963).

Pear cultivars grafted on Pyrus communis rootstocks can tolerate moderate infestations of pear psylla, while the ones grafted on P. ussuriensis cannot (Hartmann et al., 1963; Higdon and Westwood, 1964; Westwood, 1968). The presence of pear psylla on pear trees is associated with leaf curl and a condition known as "Pear decline" which is generally explained as the result of a toxin injected by the insect. However, on the west coast of North America and Czechoslovakia pear psylla has been proven to be a vector of a mycoplasma-like organism which also causes pear decline (Blattny and Vana, 1974; Hibino and Schneider, 1970). While the pear psylla is currently controlled satisfactorily by insecticides, it has a marked capability to develop resistance to certain chemicals. Resistance to chlorinated hydrocarbons and organophosphorous compounds is presently widespread in pear psylla populations in the Pacific Northwest. The necessity for using the most recently developed, and hence, more expensive kinds of insecticides has increased cost of control greatly. An understanding of the relationship between the pear psylla and the pear trees could lead to the development of pear trees which are resistant to this insect, and to a decrease in the use of pesticides for its control. Pear psylla has been reported to exhibit a certain degree of preference to different P. communis cvs. and this preference is manifested in various ways (Harris and Lamb, 1973; Westigard et al., 1970; Williams et al., 1963). This work is an attempt to understand this host plant specificity. Some of the behavioural and physiological parameters involved in host plant specificity were investigated under laboratory and field conditions.

Studies on insect-plant relationships and specificity are necessary to gain an understanding of the interaction between the insect and its host plant, which in turn could lead to more effective method of biological control. Consequently, there would be a reduction in 1) the cost of pear production, and 2) food contamination and pollution of the environment by pesticides.

II.- LITERATURE REVIEW

Pear Psylla Bionomics

1.- Description of the Insect

Pear psylla, *Psylla pyricola* Foerster, belongs to the Order: Homoptera, Family: Psyllidae. Being a hemimetabolous insect, it passes through three distinct stages during its development: eggs, nymphs, and adults (Burts, 1970).

The egg is elongated, and creamy white when deposited, changing to yellow before hatching. It is firmly cemented to the underside of the leaves of the host plant during egg deposition (Bonnemaison, 1964; Burts, 1970).

As reported by Burts (1970) *P. pyricola* nymphs pass through five instars, each ended by a moult. The first instar is creamy yellow, elongated, and slightly flattened, with conspicuous red eyes, and a pair of black tipped antennae. The nymphs cover themselves with a syrupy honeydew excreted soon after they begin feeding. The second and third instars resemble the first instar in shape and color, but are larger, flatter, and oval. The fourth is more ovoid than the previous stages, and may appear bluish green to brown in color, with well developed wing pads. The fifth instar or hard shell nymph, does not produce as much honeydew as the younger forms, and is often seen without the honeydew surrounding it. This nymph has been reported to have a light to dark brown, rather heavily sclerotized integument, with dark bluish-green showing through the translucent sutures, and well developed wing pads.

The adults are very active small insects, jumping and taking short flights when disturbed (Borror and DeLong, 1966; Burts, 1970; Comstock, 1966). Both sexes are winged, and have large thickened forewings held, roof-like, over the abdomen, and smaller hind wings underneath (Comstock, 1966; Wong and Madsen, 1967). There are two types of generations: 1) A single large winter generation which measures 3.3 to 4.0 mm long (from head to the end of the folded wings) the insects being dark brown to black; and 2) five summer generations with adults measuring from 2.1 to 2.8 mm in length and with individuals light orange to reddish brown with dark markings (Burts, 1970; Comstock; 1966).

Pear psylla resembles winged aphids (Comstock 1966; Little, 1972), but differs from them by having a firmer body texture; stouter legs, jumping hindlegs, and ten-jointed antennae with a dark terminal abdominal segment bearing 2 thick setae of unequal length (Comstock, 1966). Other authors (Borror and DeLong, 1966; Burts, 1970; Imms, 1964; Metcalf et al., 1967) note a superficial resemblance between pear psylla and cicadas, although the latter are much larger.

2.- Life Cycle of the Insect

Pear psylla adults overwinter under rough bark on the trunk and main limbs of pear trees, under grass leaves or rubbish near the host, in wasp nests, and under bark scales of adjacent apple trees (Burts and Kelly, 1966; Burts, 1970; Wilde and Watson, 1963). The overwintering adults become active during the first warm days of spring. At this time, the gravid, negatively phototactic females migrate to the shaded side of pear limbs where they remain until the weather becomes sufficiently warm to commence egg laying. Once egg laying begins, it continues until all the petals from the pear blossoms have fallen, after which, it ceases. The number of eggs per female varies from 200 to 400 (Burts, 1970; Rasmy and MacPhee, 1970, Ross, 1918; Wilde and Watson, 1963).

Egg eclosion usually occurs when the buds are beginning to break. This first summer generation takes from 41 to 47 days to develop, but in greenhouse situations, development takes an average of 29 days (Wilde and Watson, 1963).

Summer generation psyllids are found only on pear trees. The first and second generation are negatively phototactic, lay their eggs along the mid-vein on the underside of the leaves, preferentially on develpping leaves. Summer adults seem to be more prolific than the overwintering ones. They lay from 500 to 700 eggs per female, and overall development takes approximately four weeks as compared to the overwintering ones (Ross, 1918, Wilde and Watson, 1963).

As the leaves become increasingly damaged by the honeydew secretion and sap extraction by feeding psyllid, the pattern of egg laying changes for the third and fourth generations, and oviposition takes place in any undamaged portion of the leaves that remain on the tree (Ross 1918; Wilde and Watson, 1963).

3.- Pear Psylla Control

The fight against this insect in North America has been reported since 1896, when 'whale oil soap' was used as a general insecticide; in 1899 the use of kerosene was recommended as an ovicide. In addition to these compounds, cultural methods such as spacing between trees, use of wind barriers as well as mechanical control such as rasping the bark of the pear trees and pruning, were used but it was not possible to eradicate the insect pest

(Ross, 1918).

Botanical compounds like nicotine were used to kill the adult insect, but were not adequate because of the rapid dispersal of this pest, and the development of resistance. Inorganic salts like lead arsenate ($Pb_3(As\ O_4)_2$) were also used, but persistence in the soil and phytotoxicity restricted their use. Some fungicides such as lime-sulphur, and zinc-sulphate gave some control in the egg stage, but problems of cultural methods in the orchards, lack of synchronization in pesticide application, and the solubility of the compounds in rain water hindered the control of the pear psylla (Ross, 1918; Wilde and Watson, 1963). Chlorinated hydrocarbon compounds have been used since the second world war to control pear psylla. DDT, Dieldrin, Endrin, Methoxychlor were used often and extensively, but are persistent and breakdown very slowly, and pear psylla has developed resistance to these compounds. Although most of these insecticides have low to medium toxicity to mammals, they are a hazard to the environment because they can accumulate in the food chain, becoming more concentrated biologically (Burts 1968).

Organophosphates and carbamates are used because of their short residual effect, but some of these compounds are very toxic to mammals, and some have a phytotoxic effect which interferes with the plant metabolism. Parathion, Malathion, Ethion, Phosdrin, Metasystox. Sevin, Perthane, Zolone, etc., are being used, but are not achieving the expected results, and the insect has developed a resistance to these substances. All chemical insecticides affect biological control by predators and parasites, resulting in the increase of other insect pests, such as the Codling moth (Carpocapsa pomonella) (Burts, 1968; Westigard and Zwick, 1972; Wilde and

Watson, 1963). Therefore, the major problem in the use of chemicals is the development of a resistance by the insects to these compounds, thus rendering them ineffective.

Biological control by predators such as Anthocoris melanocerus, A. antevolens, A. nemoralis (Order: Hemiptera, Family: Anthocoridae), Chrysopa oculata, C. carnea, C. ploribunda (Order: Neuroptera, Family: Chrysopidae) (Burts, 1970; McMullen and Jong, 1967), and some chalcidoid parasites such as Trechnites insidiosus, T. psyllae, Psyllephagus sp. (Order: Hymenoptera, Family: Chalcidoidea) (Burts, 1970; Georgala, 1957; Lal, 1934; McMullen and Jong, 1967; Rasmy and McPhee, 1970; Westigard and Zwick, 1972) has been tried, but this is difficult because the effect is limited by migration range, diapause, and Psylla population density. It has also been reported that anthocorid larvae are antagonistic to chrysopid larvae, and the parasitic wasps also parasitize the chrysopids. Most predators are able to consume the larval stages of the pear psylla, but few of them feed on the adult (Burts, 1971; Fields and Beirne, 1973; McMullen and Jong, 1967; Rasmy and McPhee, 1970; Wilde and Watson, 1963).

Pear psylla is controllable when the trees are in the dormant stage, but this requires an extensive campaign, and orchards where insecticides have been used previously usually present a problem of very low control. These orchards then serve as primary infestation centers for other ones.

4.- Pear Psylla Hosts

The only crop of economic importance attacked by this insect is the pear tree. Most commercial cultivars belong to the species Pyrus communis L. and their order of susceptibility, ranging from very susceptible to tolerant is as follows: d'Anjou, Clapp, Bartlett, Winter Nelis, Old Home, and Flemish Beauty. The degree of susceptibility was evaluated according to the degree of acceptability as a host and susceptibility to injury (Williams _et al_., 1963). Grafting of commercial cultivars on oriental species affects the response of the pear trees to the attack of the insect (Burts and Kelly, 1966; Hartmann _et al_., 1963; Higdon and Westwood, 1964; Rasmy and MacPhee, 1970; Wilde and McIntosh, 1964; Williams _et al_..

Williams _et al_. (1963), measured the susceptibility of some pear species to injury from pear psylla on the leaf petioles (by staining the phloem tissue with phloroglucinol under acid conditions that react with the pentosans released from the injured cells). _Pyrus communis_ L. cultivars, which had a heavy psylla population per leaf unit suffered light phloem injury; some _P. ussuriensis_ and _P. serotina_ cvs. had light to medium infestation per leaf unit, but suffered heavy phloem injury. However, the Chieh li (_P. ussuriensis_) and Japanese Golden Russet (_P. serotina_) cvs. had a medium infestation per leaf unit and suffered very low phloem injury. The species _P. calleryana_ and _P. betulaefolia_ had large masses of eggs in many of the leaves, but few of them produced nymphs. Dead nymphs were found in some of the leaves and it appeared that they were unable to find a suitable feeding site. Therefore, up to now these appear to be the only species resistant to psylla infestation.

Although pear trees are the only host for the summer generations of pear psylla, it has been reported that Quince (_Cydonia oblonga_ L.) (Smith, 1941) and Downy chess grass (_Bromus tectorum_ L.) are reservoir hosts for the pear psylla. There is a correlation between the degree of psylla infestation and the presence of Downy chess grass in the pear orchards (Wilde _et al_., 1963).

5.- Pear Decline

Pear psylla is reported in most of the pear growing areas of the world. In Canada, Czechoslovakia, Germany, Israel, Italy, and the United States it has been noticed to cause a destructive condition known as Pear decline. During the past two decades it has killed many producing trees in orchards from countries already listed (Baldacci et al., 1949; Blattny and Vana, 1974; Hibino and Schneider, 1970; Kegler, 1965; Swirski, 1954). Causal factors in the pear decline syndrome are poorly understood, and it has been differentiated into two types of symptoms: 1) Slow decline, a condition of reduced growth and loss of vigor over a period of two or more years; and 2) Quick decline, or sudden wilting of the foliage prematurely. Affected trees may defoliate prematurely or foliage may become abnormally red in the fall (Blattny and Vana, 1974; Nichols et al, 1965; Shalla et al., 1963). Roots in diseased trees are low in starch, and the phloem at the union of scion and rootstock degenerate (Higdon and Westwood, 1964; Shalla et al, 1963; Westwood, 1968).

Pear psylla toxins are shown to induce pear decline symptoms, and oriental pear species which are used in commercial propagation are most sensitive to them. Pear psylla per se suppresses plant vigor by: 1) reduction of root growth, which is proportional to psylla infestation, 2) the honeydew excreted by the nymphs which reduces the rate of photosynthesis (because of poor light absorption and gas exchange), and 3) reduction of tree vitality by the feeding of a dense psylla population. This loss of vigor increases the susceptibility of the tree to winter kill (Burts et al., 1966; Burts, 1970; Griggs et al., 1967; Wilde and McIntosh, 1964). However, in Czechoslovakia and in California there is evidence that the decline is graft transmissible, and it is attributed to a mycoplasma-like

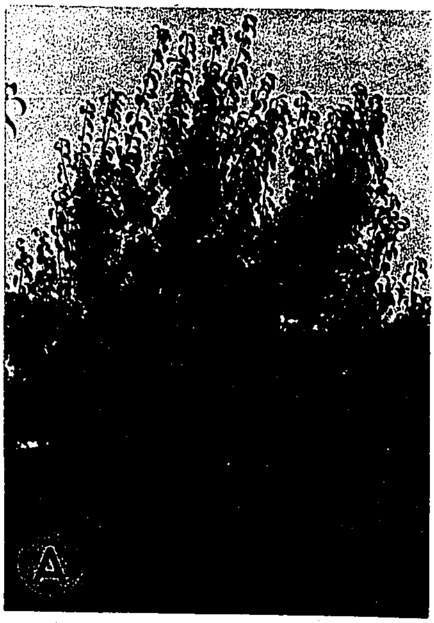
PLATE 1. Healthy and _Psylla pyricola_ Damaged Pear Trees.

A.- Cultivated d'Anjou pear tree, during mid summer where pear psylla population was kept under control.

B.- Pear psylla early damage. Fungal development and necrotic spots.

C.- Pear psylla subsequent damage. Defoliation of terminal branches.

D.- Wild growing Kieffer pear tree, early in the summer, where the pear psylla population was left unchecked.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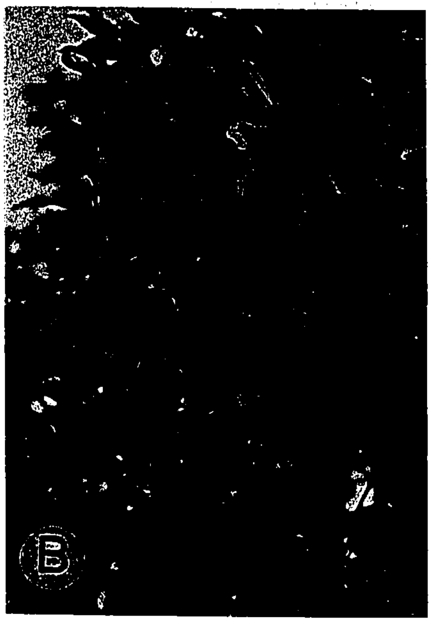
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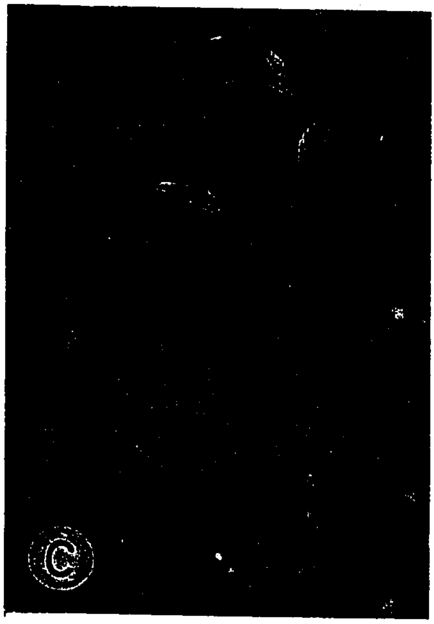
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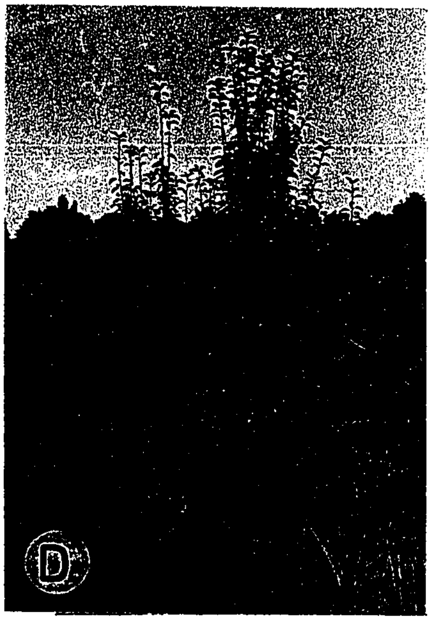
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organism injected by pear psylla (Blattny and Vana 1974; Hibino and Schneider, 1970). The insect has also been reported to be a vector for Erwinia amylovora, which produces the bacterial disease known as Fireblight (Wilde, 1963).

6.- Pear Psylla Status in Canada

Pear psylla occurs in most of the important pear growing areas of Canada, from the west coast, where it is the most destructive and hard to control insect attacking pear orchards, to the east coast where only one type of decline (slow decline) occurs.

In British Columbia, the pear psylla was introduced from Washington State around 1942 in the Oliver-Osoyoos area, but did not cause serious concern until 1958. In the southern interior of British Columbia the annual return from the pear crop exceeds two million dollars. The cultivars in this province, in order of susceptibility are: d'Anjou, Bartlett, and Flemish beauty (Wilde et al., 1963). In 1971, pear psylla occurred in the Lower Fraser Valley, Vancouver Island, and the Kootenay Valley where the damage was from two to five per cent of the total crop; the infestation was light, averaging five eggs and nymphs per leaf. However, in orchards where resistance to the insecticide Perthane was developed, infestation averaged from five to fifty eggs and nymphs per leaf, and the injury to the crop went from thirty to one hundred per cent (Creelman, 1971).

In the province of Ontario, the pear psylla is believed to have been introduced in 1894, from the Burlington area to the Niagara River, causing concern since 1918 (Ross, 1918). In 1971 the Niagara peninsula of Ontario suffered a high infestation of pear psylla, but several chemicals gave excellent control, although, slight miscalculations in the timing of the spray resulted in poor control in some cases (Creelman, 1971).

Pear psylla also appears in the south-west of Quebec, in the Franklin district, where it caused severe damage in 1971 (Creelman, 1971). In the province of Nova Scotia, it occurs in the Coldbrook area, on Clapp and Bartlett cultivars (Rasmy _et al_., 1970), but it was not a problem in the 1971 season (Creelman, 1971).

Kelleher in 1973 and 1975 reports that pear psylla is still the major pest of pear trees in Canada.

INTERACTION BETWEEN INSECTS AND PLANTS

1.- Host-Plant Relationships

A good understanding of insect-plant interactions is necessary when developing resistant crop plants for use in pest management system, because insects show the most outstanding plasticity, the most rigid restrictions and the greatest diversity of diets (Beck, 1974, Dethier, 1953). A plant feeding insect, in the presence of the plant located through its own foraging or otherwise, either does or does not feed. If it does not feed, and its locomotion power is inadequate for seeking food elsewhere, it will die of starvation. On the other hand, if the insect is sufficiently mobile, it has the alternative of foraging in search of a more suitable plant. Indeed, alate insects may also abandon their preferred food-plant after a period of feeding activity (Thorsteinson, 1960).

Phytophagous insect species are more or less selective in their choice of food plants, and they can be classified as polyphagous or oligophagous insects. In the first case many plant species from different families are eaten, while in the latter case only some species, usually belonging to one or a few related families are selected by the insect (Schoonhoven, 1968). Fraenkel (1969) stated that all plants are more or less nutritious and could serve equally as food provided no adverse chemical factors are operating. Most, if not all, plant species may satisfy the food requirements of certain insects. Some insects will thrive on several plant species which may be unrelated botanically, while others have a more limited appetite and relish only a few related species of plants or even one single species (Schoonhoven, 1972). To indicate that a plant is preferred by an insect species is to imply in the broadest sense that it will support a population of insects and permit their propagation. "From the point of view of an individual insect, however, a preferred plant may be one that is for some reason more acceptable, even though nutritionally inadequate or highly toxic" (Dethier, 1953).

Species making up the class Insecta do not differ greatly in their fundamental qualitative requirements for biochemical nutrients, but differences and specializations do occur. The nutritional quality of some tissues has been shown in some instances to influence their utilization by insects. Although different species of green plants may not differ in their qualitative content of nutrients required by insects, they may differ in the quantitative sense. Modern studies have shown that phytophagous insects do not vary widely in the biochemical nutrients required and that the needed chemicals are present in almost any green plant. Nevertheless, it has been known for many years that plant species vary in their adequacy as hosts for even the most polyphagous insects. Nutrition and metabolism are not isolated processes, they occur in conjunction with the behavioural and chemosensory facets of the biology of the phytophagous insects (Beck and Reese, 1976).

Beck (1974) suggested that the host plant must meet the insect's requirements with respect to both behavioural and general dietetics, and he classifies food plants into the following types: 1) acceptable or preferred hosts (which are very attractive, offer good feeding and orientation stimuli, and are both nutritious and non toxic); 2) non preferred hosts (which are suitable for growth and survival of the insect, but to which the insect responds negatively); 3) resistant hosts (which are inadequate for normal larval growth and survival, but meet the behavioural requirements of the insect); and 4) non hosts or immune species (those that are unattractive, repellent, physically unmanageable, and/or toxic). Most plants to which the insect is adapted contain phenols, flavonoids, alkaloids, terpenoids, and various glycosides that are deleterious and which must be degraded metabolically. The insect's ability to metabolize such plant components constitutes an important aspect of its adaptation to a particular plant host (Krieger, _et al_., 1971; Self _et al_., 1964). Most herbivores attack a few species of food plants from the many available, yet almost all plants are attacked by some insects. Herbivores have evidently evolved a means of detoxifying most of the toxic materials in plants, but not all of them are detoxified by any one species. A specialist (oligophagous) insect presumably gains an advantage by restricting its detoxifying energies to one or a few potentially harmful substrates, whereas a polyphagous species must spend more of its energy and nutrients maintaining mechanisms of detoxification for a wide range of chemically defended plants (Whittaker and Feeny, 1971).

In respect to the evolution of defenses against insect depredation, plant evolution tends to be in the general direction of the non-host type, while insect evolution is towards the successful utilization of the plants, by means of adaptations that enable the incorporation of that plant into the preferred type of hosts (Beck, 1974). The development of a typical chemical by a plant results generally in a protection against insects and other organisms. Some insect species, however, become resistant and even develop a predilection for the substance. This could lead to an intimate relationship between a plant species and its commensals, from which, in general both partners benefit. In some cases the insects not only became adapted to the presence of certain toxins in their food, but even exploited them by accumulating them in specialized tissues, which protect the insects against predators (Brower _et_ _al_., 1967; Eisner _et_ _al_., 1974; Reichstein _et_ _al_., 1968).

The first requirement of a host-plant is that it be located by the insect. Also it must evoke an appropriate orientation response, provide the insect with a suitable physical environment, and a nutritional substrate that is adequate, non toxic, and utilizable from the standpoint of digestion, assimilation, and conversion into insect tissue. Vision, phototaxis, geotaxis, and hydrotaxis undoubtedly play a part in directing insects to the proper environment for oviposition and feeding, the ultimate forces working at close range and operating in the final recognition of a preferred host plant are largely chemical (Dethier, 1953, Martin, 1958).

At a behavioural level, the greatest proportion of host plant specificity is a function of the ovipositing females. Orientation of a gravid insect to a prospective plant may involve visual as well as chemical stimuli (Beck, 1974). The approach appears to be based on visual clues, and the landing is in response to olfactory stimuli. Odours from non hosts may fail to evoke any orientation response, or they may elicit a negative response, in which case the insect moves away from the odour source (De Wilde et al., 1969, Maxwell et al., 1966). Basically host plants may be encountered during the course of random undirected locomotory activity, in such cases the insect tends to resume locomotion after encountering a non host, but to remain or display a behavioural change upon contacting an acceptable host (Beck, 1974; Martin, 1958).

Phytophagous insects are usually specialized as to the parts of the host utilized, although the range of specificities is much larger than the number of species available. As an insect develops, its feeding behaviour may be different from one stage to the next, and the food of the adult of a given species may bear little resemblance to that of the larva. The insect's requirements and behaviour may change during development, but developmental changes in the plant may exert considerable influence on its suitability as a host. Therefore, the synchronization of the two becomes an important factor in the insect-plant relationships. The developing insect lives in a microenvironment that is unstable, being determined by the developmental and phenotypic state of the plant, which in turn is an expression not only of the genotype, but also the effect of the environment in which the plant is growing. In consequence, geographical variability of both plant and insect pose important problems to those who would develop and employ resistant crop plants (Beck, 1974).

The study of the chemosensory relationship between an insect and its food plant involves three types of experimental procedures: 1) analysis of feeding behaviour to localize the particular receptor involved; 2) observation of feeding reaction when the isolated plant substances are offered either alone or in combination; and 3) examination of olfactory and gustatory processes by analyzing the physiology of the receptors (Schoonhoven, 1968).

Differences in the susceptibility or resistance of various plants to an insect are determined by physiological factors that influence the establishment of a larger or smaller population of an insect on them. These factors may be arranged in six main categories according to the six chief phases of its establishment, each phase involving interaction of two types of factors; the responses to plants and various characteristics of the plants. The responses of an insect and the plant characteristics are: 1) orientation in response to attractance or repellence of plants determined by their physical or chemical characters; 2) feeding activity resulting in food intake according to the ingestibility of plants as determined by their physical and chemical characters; 3) metabolism of ingested food resulting in its assimilation according to the nutritive value of the plant; 4) growth of the insect determined by food intake and nutritive value of ingested food; 5) survival and egg production in the adult stage determined by food intake and the nutritive value of the food, and 6) oviposition determined by physical and chemical characters of the plants (Saxena, 1969).

Oligophagous insects are excellent subjects for investigations of insect plant relationships, because of their high degree of host specificty. A satisfactory plant for an oligophagous insect can be regarded as one that provides all the positive chemical stimuli needed to fulfill the sensory requirements of the insect, and is devoid of negative chemical stimuli. Any alteration in the chemical composition of a suitable host plant leading to negative responses would make it unsuitable for that insect. In studying the host specificity of oligophagous insects, considerations must be given to chemical and nutritional factors that favourably or unfavourably influence behavioural responses and physiological processes of insects (Hsiao, 1969). Therefore, recognition of the host plant and the initiation of biting and feeding require the presence of host specific stimulants.

The pear psylla is an oligophagous insect which is very specific in the selection of its host, especially the summer generations. It attacks most _Pyrus_ species, but it has been reported that when pear psylla fed upon _Pyrus_ _calleryana_, _P._ _betulaefolia_ or _P._ _ussuriensis_ the eggs produced few nymphs, which died, apparently because they could not find a suitable place on the plant to feed (Harris, 1972; Westigard _et_ _al_., Williams _et_ _al_., 1963). Therefore, pear psylla is a good candidate for the kind of studies reviewed above.

2.- Host-Plant Recognition

The capability to recognize the presence of various chemicals in a plant resides primarily in the insect chemoreceptors, which have been localized on the antennae, the legs, and various mouthparts (Dethier, 1963, Schoonhoven, 1972). The response of an insect to its chemical environment assumes two forms: delayed and immediate reactions. Delayed reactions include symptoms of toxicity, growth. Chemicals eliciting delayed responses in insects are insecticides or nutrients which elicit a response over a long period of time. Immediate reactions comprise the many behavioural manifestations of the interactions of chemicals with exteroreceptive sense organs.

Chemicals eliciting immediate response in insects may be categorized as: attractants (chemicals that cause insects to make oriented movements towards the source), arrestants (chemicals that cause insects to aggregate), stimulants (chemicals that elicit a biological activity), repellents (chemicals that cause insects to move away from the source), and deterrents (chemicals that inhibit feeding or oviposition). The action of this latter group of chemicals is most commonly associated with some link in the chain of behaviour leading to oviposition or ingestion (Dethier, 1970).

Host selection is primarily made by the ovipositing female. Oviposition involves a series of behavioural events which are regulated by different chemical stimuli. In some insect species initial orientation of a gravid female to a prospective host plant is influenced by olfactory stimuli originating from the prospective plant (Jermy, 1958; Wilde et al., 1969). Insect oviposition is not usually indiscriminant, but is typically confined to selected plant parts. Specific oviposition sites are selected in response to physical and chemical stimuli, which may vary with leaf maturity and the physiological state of the plant (Goeden and Norris, 1965; Gara et al., 1971; Miller and Hibbs, 1963). Tactile and proprioreceptive stimuli also influence oviposition, physical plant barriers to insect oviposition have an antibiosis effect and illustrate the necessity of considering both behavioural and survival parameters of the effect of plant characteristics on plant specificity. Proprioreceptive stimuli associated with specific oviposition sites are important in releasing egg deposition behaviour in many species (Beck, 1974). Chemoreception by the maxillae include both olfactory and gustatory receptors. Information from these receptors as well as from other sense organs feed into the central nervous system, from which motor control of behaviour emerges. Experimental alteration of either the plant or the insect might be expected to alter the specificity of the insect's behaviour. Removal of the maxillary sense organs from feeding larvae of some insect species, has been shown to cause changes in the feeding behaviour, the usual effect being a reduction in host plant specificity (Beck, 1974).

Extirpation of the chemosensorial maxilla from the tobacco hornworm (Manduca sexta), allows the insect to feed on other plant species on which feeding is unusual (Schoonhoven et al., 1966; Waldbauer et al., 1961; Waldbauer et al., 1961; Waldbauer, 1962; Yamamoto, 1974). This indicates that the chemosensory receptors of the maxilla are tuned against some feeding deterrents or repellents (Beck et al., 1976; Dethier, 1970; Fraenkel, 1969; Jermy, 1971; Mothes, 1976; Philogène, 1974; Schoonhoven, 1972; Martin, 1958; Thorsteinson, 1960; Whittaker et al., 1971.

The feeding process can be divided into 5 behavioural components: 1) host plants perception, 2) initiation of biting, 3) feeding action or swallowing (observed in some insects), 4) continuous feeding, and 5) cessation of feeding. Biting of the leaf surface is initated as soon as the larvae comes in contact with the plant, the biting action may be initiated by a variety of external stimuli and be affected by internal physiological conditions too (Hsiao, 1969).

The feeding responses of the larva are regulated by the presence of feeding stimulants and repellents. In the presence of deterrents, food ingestion does not occur despite the presence of feeding stimulants. Continuous feeding on the plant requires an adequate supply of phagostimulants and cofactors, and the absence of deterrents and toxicants (Hsiao, 1969).

Repellents and attractive materials seem equally important in nature. The degree of acceptability of a plant based upon the presence of taste stimuli can be measured by the appearance of biting damage, the amount of tissue consumed, the amount of excreta (frass) produced, or the relative periods of time spent by the insect in eating, resting, and wandering (Beck and Reese, 1976).

Unfortunately when plant chemistry has been studied in detail it has usually been in connection with plants of economic importance; and through some irony of nature the pests of these plants are generally small and do not lend themselves readily to neurological and physiological analysis (Dethier, 1970).

The overwintering pear psylla has to fly to reach the pear tree, at least to the growing tips. Therefore, the insect finds its host either by random movements or by mean of its olfactory sense, which is usually located in the antennae. Not much is known about this aspect of psylla/pear relationship.

3.- Attractants and Antifeedants

Plant biochemical characteristics affecting metabolism and thereby insect survival and development are at least as important as those affecting behaviour in determining host specificity. Host plant tissues may vary in their concentration of secondary chemicals, depending on the developmental stage of the tissue as well as on the plant organ. Such variability may influence the feeding activity and developmental success of the insect. Therefore, the effects may be partly nutritional and partly the reflection of developmental differences in tissue concentration of deleterious substances

(Bongers, 1970; Cibula, 1967).

The insect must not only ingest the tissue of its host, but the material ingested must also be suitable for conversion into energy and structural substances required for insect development. The nutritional requirements of plant feeding insects varies with the insect species, and plant nutrient ratios may also influence feeding behaviour and they are almost certain to influence the efficiency of conversion of food ingested. Host plant specificity is determined by both positive (acceptance-evoking) and negative (rejection-evoking) stimuli. However, the problem of host plant specificity becomes even more complex, as it is now known that the plant produces a multiplicity of stimuli to which the insect might be sensitive, and its behaviour must represent a central nervous system integration of the stimuli received. The relative strength of each of the several stimuli is variable depending on the anatomical and physiological state of the plant, and the effect of the complex signals on the insect's behaviour will also be variable, depending on the growth stage and the physiological condition of the insect (Beck, 1974). Up to now studies show that phytophagous insects can be conditioned to artificial diets that lack secondary plant substances as stimulants. However, in nature most oligophagous insects require attractants for host finding. Insects show a high degree of chemosensory specificity to their host plant chemicals, although this behaviour can be influenced by physiological stresses, such as starvation, thirst, reproduction and physical activity. The presence of chemosensory receptors in insects and their mode of action when exposed to attractants and/or deterrents in each insect species points to the needs for a more comprehensive study of the insect-host plant relationship (Beck et al., 1976; Dethier, 1970; Fraenkel, 1969; Jermy, 1971; Mothes, 1976; Philogène, 1974; Schoonhoven, 1972; Thorsteinson, 1960; Whittaker and Feeny, 1971).

Feeding specificities have been associated with specific chemical stimuli in a number of cases. The distinction between factors that induce feeding (feeding-incitant), and continued feeding after exploratory bite (phagostimulant) is not always clear, although many substances have both effects. Some phagostimulants have been shown to be host substances, but others have proved to be common chemicals of universal botanical distribution (Beck and Hanec, 1958: Gothilf & Beck, 1967; Thorsteinson, 1960). A series of plant species may all contain similar arrays of attractants and stimulants. Host specificities of insects utilizing members of the plant group may then be determined by repellents and deterrents present in some of the plants, that is since feeding deterrents may play a part in the feeding behaviour of even the most polyphagous insects (Beck, 1974).

Many secondary plant substances have been shown to be specific attractants which can be classified as gustatory, olfactory, and oviposition substances based on the behavioural response exhibited by the insect.

Mustard oil glycosides such as sinigrin are an example of gustatory stimulants for insects feeding on species of Brassicaceae (David & Gardiner, 1966, Klingauf et al., 1972; Matsumoto, 1970; Nault & Styer, 1972; Nayar and Fraenkel, 1963; Schoonhoven, 1967; Thorsteinson, 1953, Verschaffelt, 1910). Hexanol, cis-hex-2-en-1-ol, and cis-hex-3-en-1-ol have been shown to be phagostimulants for Epilachna fulvosignata (Murray et al., 1972; Stride, 1965), gossypol for insects feeding on cotton plants (Hedin et al., 1976; Maxwell et al., 1966), cucurbitacin for insects feeding on cucurbit species

(Chambliss et al., 1966; Sinha et al., 1969), morin for the silkworm (Hamamura et al., 1962; Hamamura, 1970; Ishikawa et al., 1969), hypericin for Chrysomela brunswicensis (Rees, 1969), phenolic compounds for several insect species (Baker, 1968; Meisner and Ascher, 1974; Meyer and Norris 1967; Meyer & Norris 1974), oryzanone (Munakata et al., 1970; Saito & Munakata, 1970) and many others.

Among the olfactory attractants are: volatile terpenes for Blastophagous piniperda (Kangas et al., 1967), frontalin for the bark beetle Dendroctonus pseudosugae (Baker et al., 1973; Bedard et al., 1969; Pitman et al., 1970), grass odours for grasshoppers (Kennedy and Moorhouse, 1969), etc..

Some of the oviposition attractants (those compounds eliciting egg deposition) are: allyl isothiocyanate for Plutella maculipennis feeding on cruciferous species (Gupta and Thorsteinson, 1960; Nayar and Fraenkel, 1963), α-farnesene for Laspeyresia pomonella (Sutherland et al., 1974; Wearing & Hutchins 1973), trans-2-hexenal for Polyphemus moths (Riddiford, 1967), etc.

Many secondary plant substances are antifeedants, chemicals that inhibit feeding but do not kill the insects directly; therefore, the insect remains on the leaves and dies through starvation. This is evident in some insect species, mainly polyphagous. However, the silkworm (Bombyx mori), which has been claimed to be a highly monophagous insect for mulberry (Morus sps.), is also capable of feeding on other plants of the Moraceae and several Asteraceae species. Therefore, the amount of feeding and its effect on growth and survival in Bombyx is limited by the simultaneous presence of repellent or toxicant substances (Ishikawa and Hirao, 1966; Ishikawa et al., 1969; Hamamura, 1970; Nayar & Fraenkel, 1962). Among the phagodeterrents are phenolic compounds (Beck and Reese, 1976; Chawla *et al.*, 1974; Ishikawa, 1966; Isogai *et al.*, 1973; Reese and Beck., 1976; Todd *et al.*, 1971), azadirachtin (Butterworth & Morgan, 1968; Gill and Lewis, 1971; McMillian *et al.*, 1969), and saponins (Applebaum *et al.*, 1965; Horber, 1972, Horber *et al.*, 1974). The list of specific compounds inhibiting insect feeding is increasing with the recent advances in chemical methodology. Some plants have been found to contain analogs of the insect's hormones (ecdysone and juvenile hormones) and in some cases feeding deterrency has been related to high concentrations of ecdysones (Heftman, 1970; Soo Hoo and Fraenkel, 1964; Wei Chun, 1969).

Catlin and Olsson (1966), and Williams *et al.*, (1963), reported an antibiosis factor present in Asian *Pyrus* species towards pear psylla. Westigard *et al.*, (1970), show that those *Pyrus* species could be used in pear breeding programs as indicated by the survival ratio between nymphs and eggs but, among those Asian pears, *P. ussuriensis* was the most valuable in breeding programs, because of the fruit size. Harris and Lamb (1973) have shown that the *P. ussuriensis* resistance factor is genetically transmissible into *P. communis* cvs., and is not linked to the poor horticultural characteristics for fruit quality and tree vigor inherent to the oriental species. They also indicated that pruning and fertilization practices did not affect host resistance in the hybrids, and that resistance against pear psylla is independent of resistance to fireblight, for which the experimental trees were originally planted.

4.- Secondary Plant Substances

Higher plants synthesize two main groups of compounds: 1) primary metabolites such as sugars, amino acids, oils, nucleic acids, nitrogen bases, which are used either to generate energy for other metabolic reactions or as structural components for the different types of plant cells; and 2) secondary metabolites such as, alkaloids, isoprenoid and aromatic compounds, mustard oils and glycosides, cyanogenic glycosides, and others. The function of many of these compounds is unknown, and many appear to be metabolic by-products, which because of the lack of appropriate excretory organs were dumped inside the plant at certain places, such as vacuoles or cell walls (Salisbury and Ross, 1969; Schoonhoven, 1972). Secondary plant substances may be conveniently grouped as saponins, tannins, alkaloids, terpenoids, phenylpropanoids, acetogenins, and their glycosides. Their occurrence is sporadic but may be specific for families, subfamilies, genera, and sometimes species and subspecies (Fraenkel, 1959).

The term secondary plant substances is hard to delimit, expecially with the development of new technology and techniques in chemistry, which speed isolation and identification of new plant compounds; nevertheless, most of their anabolic and catabolic pathways have not as yet been identified. The use of tracers, such as ^{14}C and ^{15}N, has unravelled several of these pathways, but alternative pathways are present (Beck et al., 1976; Geissman 1962; Haskins et al; 1961; Hess, 1968; Kaufmann et al., 1974; Leete, 1965; Luckner, 1972; Pridham, 1963; Robinson 1974).

Secondary metabolites are responsible for certain qualitative characteristics. The number, type, and concentration of these can help identify the plants taxonomically, since their presence will characterize individuals of the same family or in some cases to the genera. The coevolution of plants and animals developed in certain cases close relationships, making the animals very specialized, and narrowing the number of host plants utilized by them. Studies on mono- and oligo-phytophagous organisms indicate that some secondary metabolites are responsible for these close plant-animal relationships (Schoonhoven, 1972).

Phenolic compounds present in higher plants are quite numerous and diverse, since they are able to form complexes with different sugars as glycosides or esters, or to polymerize into more complex structures such as tannins or lignins (Ribereau, 1972). Some phenolic compounds are widely distributed among different plant families; universal among Angiosperms are p-hydroxybenzoic, protocatechuic, vanillic, and syringic acids (Harborne, 1973).

Studies on Schizaphis graminum L. (greenbug), have shown that certain phenolic compounds (catechol, tannic acid, quercetin, chlorogenic acid, and protocatechuic acid) were detrimental to its growth. Other phenolics were more specific in their effect since cis-caffeic acid caused drastic reductions in growth and reproduction, whereas, trans-caffeic acid caused some reduction in weight gain, but had no effect on reproduction (Hedin et al., 1974; Todd et al., 1971). Phenolics such as coumarins have been demonstrated as olfactory attractants in the case of the beetles Sitona cylindricollis (Thorsteinson, 1960), and Listroderes costirostris (Matsumoto, 1962). Although, coumarin is undoubtedly a significant cue in food-plant recognition, the amount of food ingested is conditioned by sugars, up to certain threshold limit, and their interaction is synergistic (Beck, 1974; Dethier, 1970; Thorsteinson, 1960).

Members of the Rosaceae family are known to have a high phenol content, apples and pears containing each one no fewer than three rare substances that show systematic correlation in distribution. They are dihydro-chalcone, phloretin, its 3-hydroxiderivative, and arbutin (a hydroquinone glucoside). Phloretin is of general occurrence in the genus Malus, while arbutin is characteristic of the genus Pyrus (Alston and Turner, 1963; Harborne, 1964).

Westigard et al., 1970, report 21 Pyrus species, from which P. communis Linnaeus, P. ussuriensis Maximowicz, P. serotina Rehder, P. calleryana Dcne., and P. betulaefolia Bge. are often used as rootstocks. Each species presents in their leaves arbutin, chlorogenic and iso-chlorogenic acids as chief phenolic compounds (Alston et al., 1963; Grisdale et al., 1960; Mosel et al., 1974; Ranadive et al., 1971). However, it has been found that P. Calleryana on which most psylla nymphs could not find a suitable place for feeding, has very low amounts of the glycoside arbutin. Besides, each species present some phenolic compounds which are in low concentrations or are lacking in the other species (Catlin, 1966).

III.- MATERIALS AND METHODS.

1.1- Insect Studies in the Lab

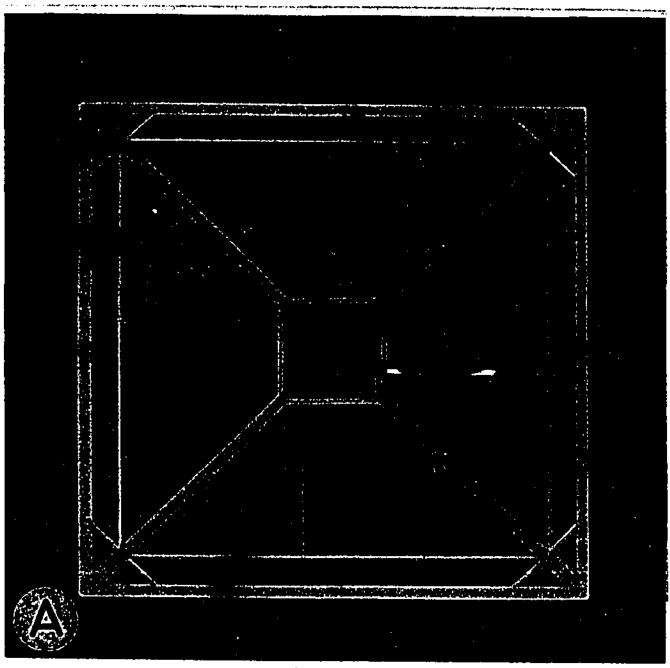
Bioassay chambers.- All the experimental work concerning the behaviour of pear psylla was carried out in bioassay chambers (Plate 2). The walls and the cover of the chamber were made of plexiglass 5 mm thick. Each side was 250 mm long by 100 mm high, the cover was 260 by 260 mm, with a hole (37 mm in diameter) in the center, through which the insect was released. The walls of the central cell were made of plexiglass 2.5 mm thick, each side was 50 mm wide by 100 mm high. The bottom of each chamber was made of glass to avoid static charges which accumulated on plexiglass and, as shown by preliminary studies, interfered with the movement of the insects. Each chamber consisted of four large independent cells, communicating with the central smaller cell by a 6.5 mm hole. Each large cell had a 13 mm hole in the external wall through which a leaf of a test plant was inserted.

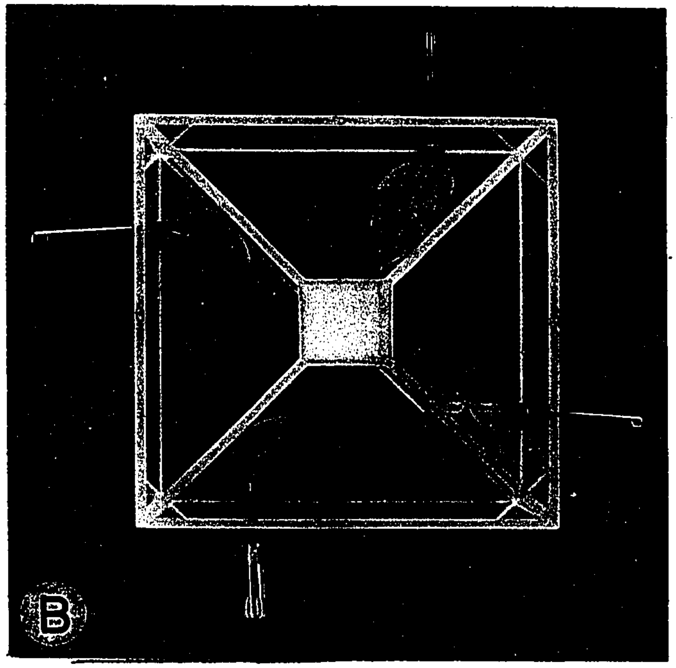
Frass collection.- The frass (excretus) in all bioassays was collected on fine 'Xerox' triangular acetate sheets (10 by 10 by 14 cm). At the end of each assay the insects were removed and the chambers were left overnight in a cool place. The next morning the frass was weighed on a Sartorius semimicroanalytical balance. Frass deposited on the acetate sheets was weighed and the weight of the sheet subtracted from the total weight, thus giving the net frass weight. Due to the size of the samples and the sensitivity of the scale, the acetate sheets with and without the frass were weighed 8 times. Each time the sheets were removed from the scale plate and repositioned on the plate to eliminate the position factor of the acetate sheet on the balance plate. A single stroke of a moist paper towel was used to remove the frass deposited on the acetate sheets, since it was found that

PLATE 2. Bioassay Chambers.

A.- Chamber without leaves showing the acetate sheets (with frass) for frass collection.

B.- Chamber showing the leaves and the test tubes assembly on it.


A


B

rubbing motions produced static charges which ultimately altered the sensitivity of the balance.

Experimental design.- The experiments were carried out under a Randomized Complete-Block Design (Calzada, 1964). The results for *Psylla* frass deposition, as well as the number of insects on the leaf were analyzed with a Two Way Analysis of Variance. The response of the insect by frass deposition or its number on each test leaf (as Treatments), and the uniformity of the testing material or number of insects on the leaves of the different days of testing and handling techniques (as Replications) were examined by the 'F' test of the analysis of variance (Steel and Torrie, 1960). If the Calculated 'F' was significantly different from the Tabulated 'F' at 5% significance level, then the data were compared according to the Duncan Multiple Range Test, and the results tabulated. The results for the relative number of insects per cell were analyzed with a One Way Analysis of Variance, in which we measure the relative number of pear psylla among the different test plant chamber cells. The results of the bioassays were normalized accordingly: a) the frass average (8 repetitions) weight was transformed into frass produced per insect, and b) the total number of insect per cell was transformed into the relative number in percentage for each replication.

1.2.- Insect Study in the Field

Sections of nylon screen (29 strands per inch) 40 cm squares were cut and sewed into sleeves with polyethylene thread. One end was closed with a 13 cm diameter circle, cut from the same material. A sleeve was placed on 5 different terminal branches of four cultivars of *Pyrus communis* in the mature pear orchard of the Jordan Experimental Farm, Jordan, Ontario. Each sleeve enclosed 12 terminal leaves. Prior to enclosure the leaves were gently rubbed with a wet sponge to eliminate other psylla instars, other organisms, and dust from the leaf surface and the stem. Below the 12th leaf, 15 cm of the stem was stripped of leaves, cleaned and washed, then a sleeve was slid into position and its bottom end was sewn together so as to fit tightly around the cleared part of the stem. A hole 10 mm in diameter was made to insert the 12 recently moulted couples of pear psylla, and it was plugged with small cork stoppers cut to fit.

2.- Insect Material

Adult pear psylla, Psylla pyricola Foerster, were collectéd in small aspirator bottles. From the 20th of June until July 7th, 1975, the insects were collected daily at three different times of the day (6:00, 10:00, and 15:00 hours), while from July the 8th until August 8th, the insects were collected during the morning (6:00 to 9:00 hours), from the mature pear orchard at the Jordan Experimental Farm. Approximately 27 insects per cell of the bioassay chamber were collected. From the 17th of June to the 23rd of August 1976 the insects were collected during the morning (7:00 to 10:00) from an abandoned orchard (Skull's Farm) located 9 miles south southwest from the Experimental Farm. Approximately 120 insects per chamber were collected in that year. The insects collected during early morning, when they were abundant and the male/female ratio was nearly one to one, were stored in a portable cage. Three sides of the cage were built with transparent nylon screen, which were supported by 5 mm thick plexiglass frames (20 by 36 cm), while the top and the bottom (20 by 20 cm), and the sliding door (19.5 by 36 cm) were made of plexiglass 2.5 mm thick. Pear cuttings were placed inside the cage, then the insects were released inside until they were required for testing. For the bioassays the insects were collected and released into the central cell of the bioassay chamber. Bioassays were carried out under dark conditions to avoid the positive phototactic responses of the pear psylla noted in preliminary tests. Counting of the insects in the various cells of the bioassay chambers was carried out under red light (provided by a red 25 Watt incandescent lamp) to which insects are reported to be insensitive. However, it was noted that pear psylla under these conditions reacted to red light from a 40 Watt lamp or to sudden movement of the light from the 25 Watt lamp.

3.- Plant Material Used in the Experimental Work.

a) *Pyrus communis* Linnaeus cultivars.

Old Home-	Leaves were taken from a single tree in the nursery plot at the Jordan Experimental Farm (this cv, is most recommended as a rootstock, in areas infested with pear psylla).
Bartlett Bosc d'Anjou Kieffer	One tree of each scion grafted on commercial *P. communis* was used and were planted in the mature orchard at the Jordan Experimental Farm. But the leaves of Bartlett and d'Anjou used in the comparisons with the rootstocks were collected from the nursery plot.
Clapp	One tree, grafted onto unknown *P. communis* rootstock, growing west of the mature sweet cherry orchard at the Jordan Experimental Farm.
Bartlett d'Anjou Lawson	Young trees grafted on commercial *P. communis* rootstocks, purchased from a commercial nursery of the Niagara district and grown in pots in the greenhouse at the University of Ottawa.

b) P. ussuriensis Maximowicz. One tree from the nursery plot at the Jordan Experimental Farm (this species is an oriental species widely used as a rootstock in the west coast of North America).

c) Quince (Cydonia oblonga Linnaeus) one of the trees growing in the mature pear orchard at the Jordan Experimental Farm.

d) Apple (Malus silvestris Linnaeus cv. Golden Delicious) the tree planted on the south end of the Golden Delicious row in the mature apple orchard at the Jordan Experimental Farm. This tree was selected because it was the only one on which adult psylla was found.

e) Cherry (Prunus cerasus L.) and peach (Prunus persica L.) from the virus free plant material orchard at the Jordan Experimental farm.

f) Nightshade (Solanum nigrum L.) growing weed underneath the trees of the mature pear orchard.

Mature leaves of approximately the same size with petioles at least 30 mm long and approximately same position from the tip of the branches were selected. The petiole of each harvested leaf was immediately immersed in water, and in the lab all leaves were rinsed in water. Excess water was gently removed and a rubber stopper size 00 fitted around the petiole near its base. Fitting of the stopper was facilitated by drilling a 2 mm hole through its center, then cutting open one side. The leaf blade was placed in one of the large cells of the bioassay chamber, and the petiole inserted through the 13 mm hole in the external wall. The rubber stopper surrounding the petiole was fitted into the hole and carefully adjusted so as to hold the leaf firmly in place without crushing the petiole tissues. The protruding end of the petiole was placed in a 5 ml test tube filled with water. To avoid air blocks in the xylem, a few millimeters were snipped from the tip with curved scissors before the test tube was attached to the smaller end of the rubber stopper. The fitted leaf was then left to dry for more than one hour before placing the cover on the chamber.

4.- Leaf Extracts

The extracts were made following the methods described by Harborne (1973) and Ribereau (1972). Leaf material for the extracts were obtained from two sources: 1) pear trees growing under greenhouse conditions (Bartlett, d'Anjou, and Lawson), and 2) the trees (Bosc, Clapp, Kieffer, and P. ussuriensis) and quince growing at the Jordan Experimental Farm. Twenty grams of mature leaves from each tree were collected and immersed in 260 ml of boiling methanol (in 500 ml ointment jars) to prevent enzymic oxidation of phenolic compounds (Harborne, 1973). After cooling, 130 ml of distilled water was added to prevent esterification, and the jar was sealed. The leaves were macerated in a Waring blender, and the extract filtered through a Buchner funnel with Whatman paper # 1. The residual was rinsed twice with methanol. The filtrate was concentrated under vacuum in a Buchi rotavapor 'R' at 30°C, until all the methanol was evaporated. About 50 ml of water and about 80 ml of hexane was then added and mixed well before transferring to a separatory funnel. The flask was rinsed first with water and then with hexane, the rinsings being added to the funnel. The two layers were separated into two separatory funnels and each layer at least washed twice: water with hexane, hexane with water. The water fraction (polar) was concentrated under vacuum, at 50°C, to 15 ml volume, and the hexane soluble fraction at 30°C to near dryness. Absolute ethanol was then added to the hexane soluble fraction and evaporation continued at 35°C to remove all traces of hexane. The fraction was finally dissolved in absolute ethanol and concentrated to 15 ml volume (lipid fraction). All extracts were kept under refrigeration and were not exposed to direct sunlight.

Chromatographic analysis.- As an attempt to a more comprehensive understanding of the differential attack of pear psylla on the different specimens of pear and quince available, a cursory analysis of phenolics for each one was performed. Undigested extract aliquots, as used in the bioassays, were chromatographed two dimensionally on Whatman 3 mm chromatography paper. Paper sheets were cut according to the tanks available, 20 by 27 cm, for ascending chromatography. The first run was carried out on the long side of the sheet of paper, and the second run on the short side. The polar fraction was first run with n-butanol saturated water: water: acetic acid (49:49:2), and in the second run with 5% acetic acid. The lipid fraction was run in the first direction with acetone: hexane (1:3 v/v), and in the second with 5% acetic acid. The chromatograms were dried out for 30 minutes, and then inspected by visible light and ultraviolet radiation, where the shape of the spots were outlined. After the spots were localized, the chromatographs were placed into an ammonia chamber for 20 minutes, then the spots were checked again under UV, and the position of the spots which were not visible or differentiated (bathochromic shift) prior to the ammonia treatment were marked (Harborne, 1973; Li and Hsiao, 1974). Once the localization of the spots was completed the second run was started, and the chromatograms were examined following the same procedures as for the first run in both fractions.

The chromatograms were sprayed with Folin-Ciocalteau reagent with which most phenols gave a blue colour. Catechins and leucoanthocyanidins however do not react to Folin-Ciocalteau reagent; therefore, for these compounds, Vanillin-HCl (10% vanillin in concentrated hydrochloric acid) reagent was used (Ranadive and Haard, 1971; Ribereau, 1972).

IV.- RESULTS

1.0.- Observations on the Life Cycle of Pear Psylla.

Pear psylla adults were found on the trees from late April to the beginning of May. Recently laid eggs were whitish, turning to yellow, with tiny red eye spots before hatching. They were attached to the leaf surface by a short peduncule, which made it difficult to remove them without damage. (Plate 3 A). If one managed to remove the egg from its original position successfully, the nymphs developing inside failed to emerge once ready to do so, indicating that attachment is crucial to successful hatching.

The early first instar is translucent, light yellow, with a very short abdomen, without wing pads, and its antennae are stubby with black tips (Plate 3 B). Before these nymphs moult they turn to a dark yellowish colour.

Second and early third instars are difficult to differentiate, since in both of these stages the protrusion for the wing pads begin to show (Plate 3 C). Both stages have a small roundish abdomen, but before moulting the second instar changes to dark yellowish, while the third instar (Plate 3 D), apart from its size (as observed under the microscope) is characterized by certain dorsal areas which take a light beige tinge and the wing pads are larger.

Early fourth instar show wing pads, are light yellow, translucent, and the dark-tipped antennae are longer than in the third instar prior to moulting. They turn to a whitish yellow colour, and before moulting, the wing pads, the sides of the head, certain dorsal areas of the thorax, and certain parts of the dorsal abdominal segments are darkened to brown (Plate 4 A).

PLATE 3. Pear Psylla Development. Early Instars.

A.- Egg showing pedicel (p) and the filament (f), x 85.

B.- First instar nymph (short abdomen and no wing pads), x 120.

C.- Second instar nymph (small abdomen and widening of the prothorax with wing pads development), x 75.

D.- Third instar with small wing pads, x 65.

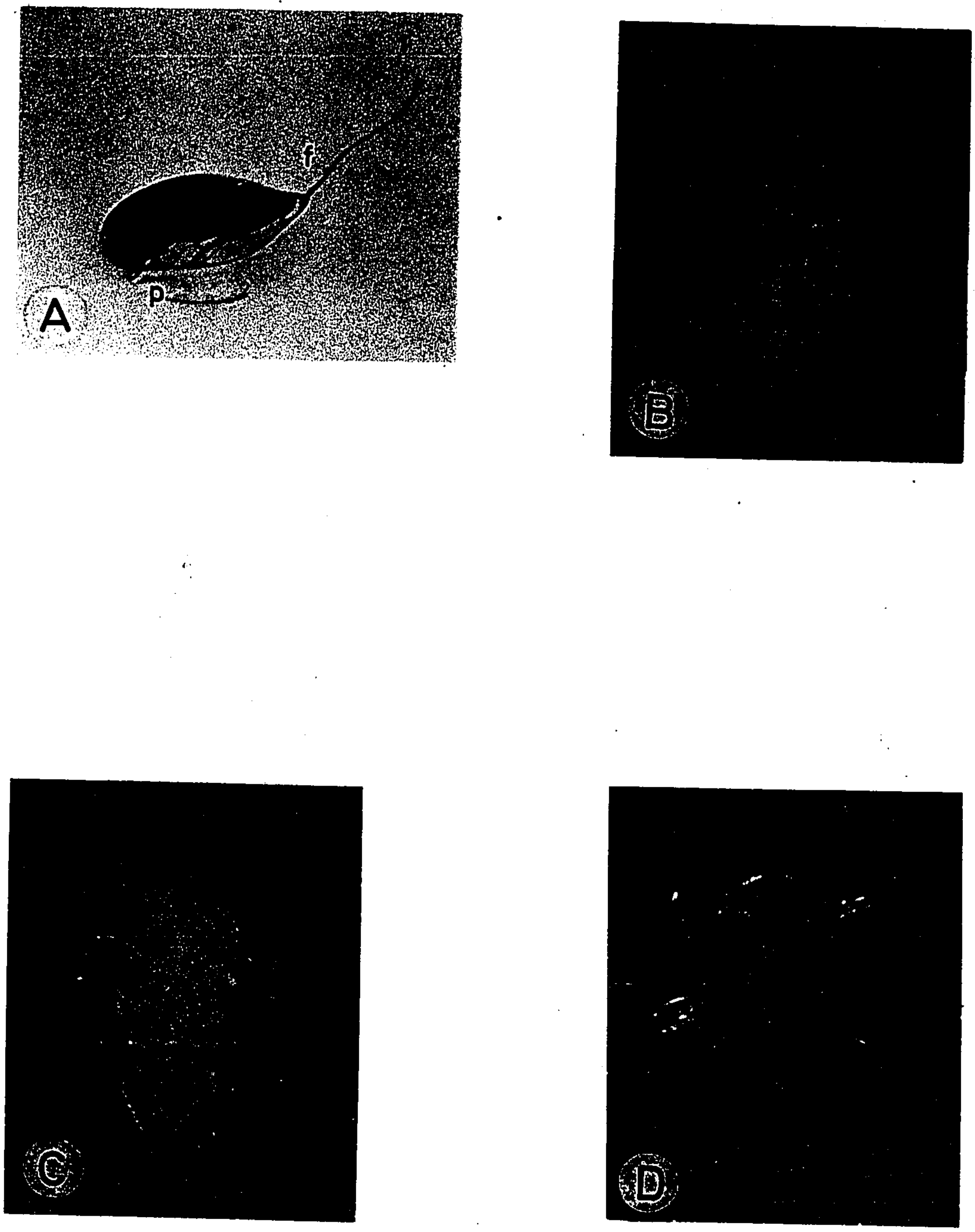

f
p
A
B
C
D

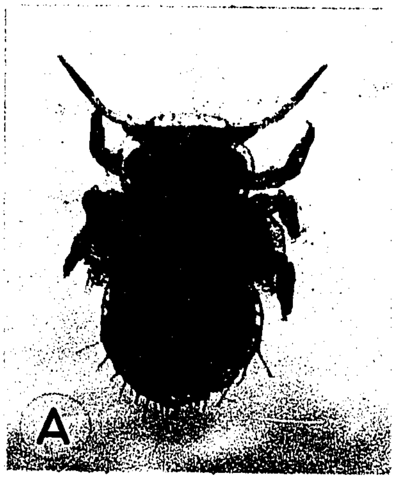
PLATE 4. Pear Psylla Development. Late Nymphal Instars.

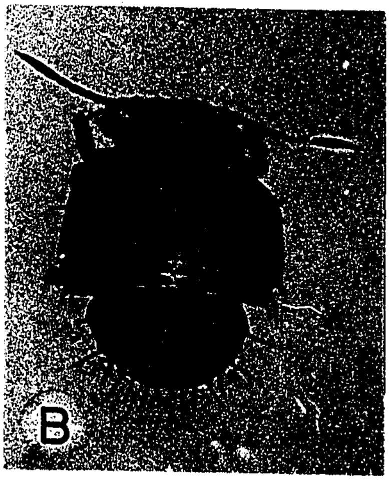
A.- Fourth instar nymph showing dorsal tanned areas and wing pads, x 40.

B.- Fifth instar nymph showing dorsal tanned areas and well developed wing pads, x 20.

C.- Dorsal view of fifth instar nymphs, male at right and female form at left, x 15.

D.- Abdominal view of fifth instar nymphs, showing abdomen dimorphism of male and female forms, x 15.


A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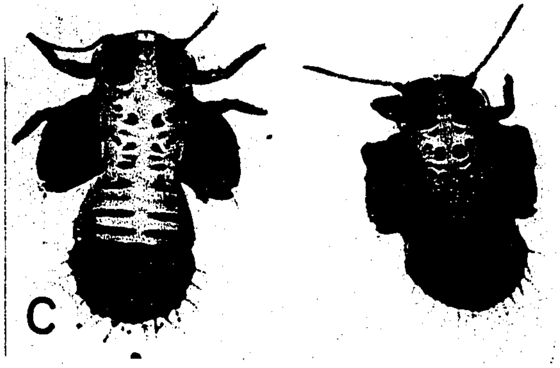
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D

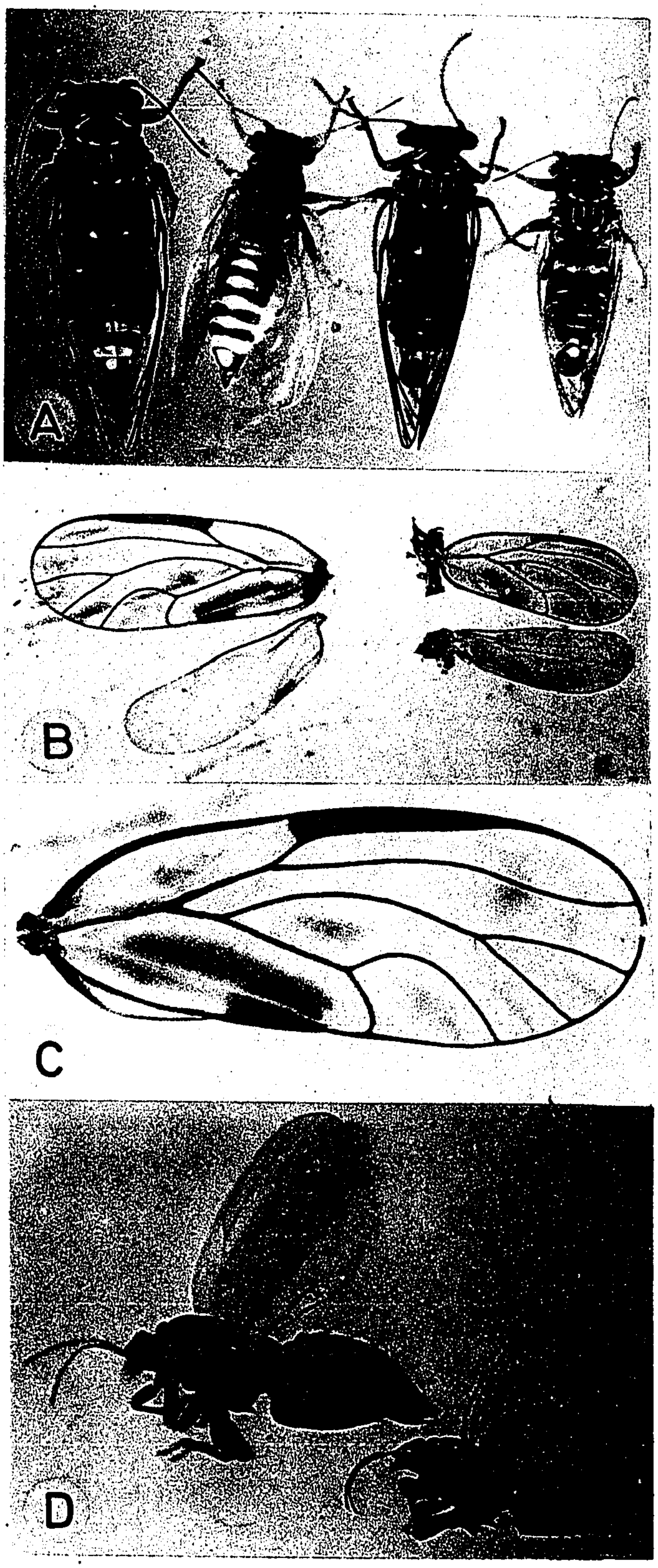
PLATE 5. Adult Pear Psylla, Wings and Genitalia.

A.- Winter and summer female adults left, winter and summer male adults right, x 12.

B.- Forewing and hindwing of overwintering female left, and summer female right, x 12.

C.- Forewing of overwintering female showing the venation and melanized areas, x 24.

D.- Lateral view of summer pear psylla female (top) and male (bottom) showing the abdominal dimorphism, x 15.


A
B
C
D

In the fifth instar nymph, before moulting, the body takes a light green colour, the wing pads, sides of the head, smaller areas of the thorax (compared to the 4th instar), and dorsal abdominal segments are further darkened to dark brown (Plate 4 B). This form is usually called a scale because it is covered with honeydew and superficially resembles a scale insect. The fourth instar has larger tanned areas on the thorax which becomes smaller in the fifth instar.

The three early instars produce abundant honeydew which covers the nymphs and they moult inside the honeydew drop. These early instars are usually found on the leaf surface close to the mid rib vein. The last two instars also produce honeydew, although not as much as the early instars. Fourth instar nymphs are more mobile and usually crawl from the honeydew before moulting. Most fifth instars (commonly referred to as a roaming non-feeding stage) were found quiescent in the leaf axil, occasionally changing position in the same leaf axil or moving to another. This sedentary habit could be an explanation for the difficulty experienced in controlling this stage of the insect with insecticidal sprays.

Two types of scales were found in the field (Plates 4 C & D). The one with an ovoid abdomen usually metamorphosed to adult females while the other type, which has a more roundish and dorso-ventrally flattened abdomen, developed into a male.

The adult morphological description for winter and summer generations (Plates 5 A), wings (Plate 5 B & C), and genitalia (Plate 5 D), and accesory filament of the egg were similar to that reported by Bonnemaison (1964) for P. pyricola. Since the adults are the most mobile form of all the stages, these were used in all bioassays.

1.1.- Results of the Bioassays Used to Determine Pear Psylla Behaviour Collected at Three Different Times of the Day in Response to Four Pear Taxa, Under Chamber Conditions.

The effects of time of sample collection on *Psylla* movement, under bioassay chamber conditions, in response to the different pear taxa (Bartlett, d'Anjou, Old Home and *P. ussuriensis*) were observed. The leaf material for Old Home and *P. ussuriensis* (rootstocks) was selected from trees in a nursery plot, while the leaves for Bartlett and d'Anjou (scions) were selected from trees planted in a mature pear orchard. The insects were collected at 6:00 (CST), 10:00, and 15:00 hours, and released one hour after collection into chambers already prepared with leaf samples. The leaf in each cell was taken from a different test plant, half an hour prior to collecting the insects from the field. A minimum of 80 insects (collected from the mature pear orchard) were released into each chamber, and the number of insects in each cell and on each leaf were counted every hour until 23:00 hours, at which time the chambers were cleaned. The bioassays were repeated 10 times.

The relationship between the average number of insects per cell and on each taxon leaf, with respect to time of collection is given in Fig. 1. At no time were all insects found on the leaf as shown by the lower curves in the graph. The number of insects in each chamber increased with time, and apparently in different ratios in response to the different pear types. However, an 'F' test (analysis of variance) for each time of collection indicated no significant discrepancies in the number of insects among the different cells by 20:00 hours. Fluctuations in the curves indicated that the insects moved from one chamber to another, and onto and off the leaf.

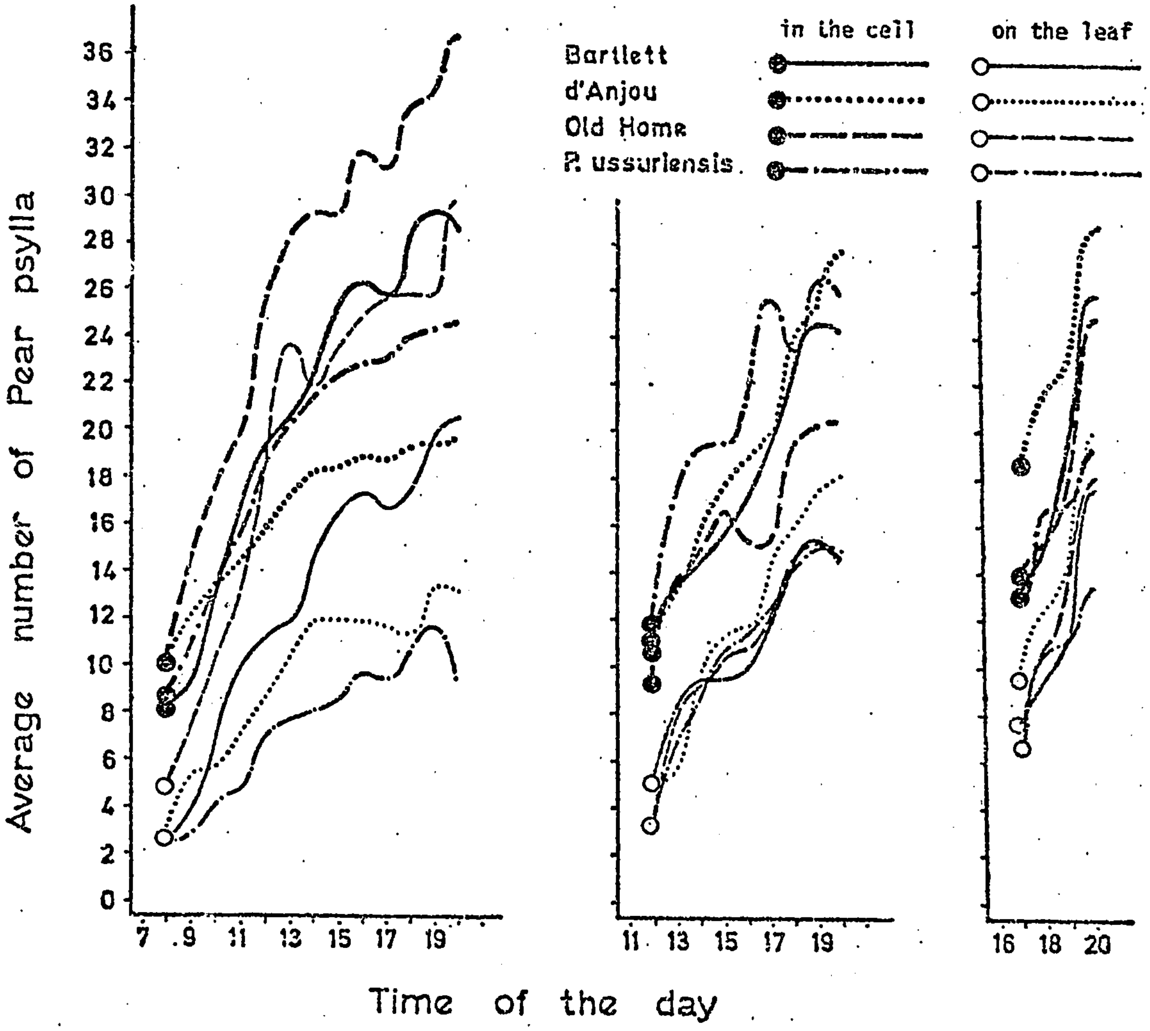


FIGURE 1. Adult psylla displacement under bioassay chambeer conditions per cell and per leaf, from three different collection/release times of the day on four pear taxa.

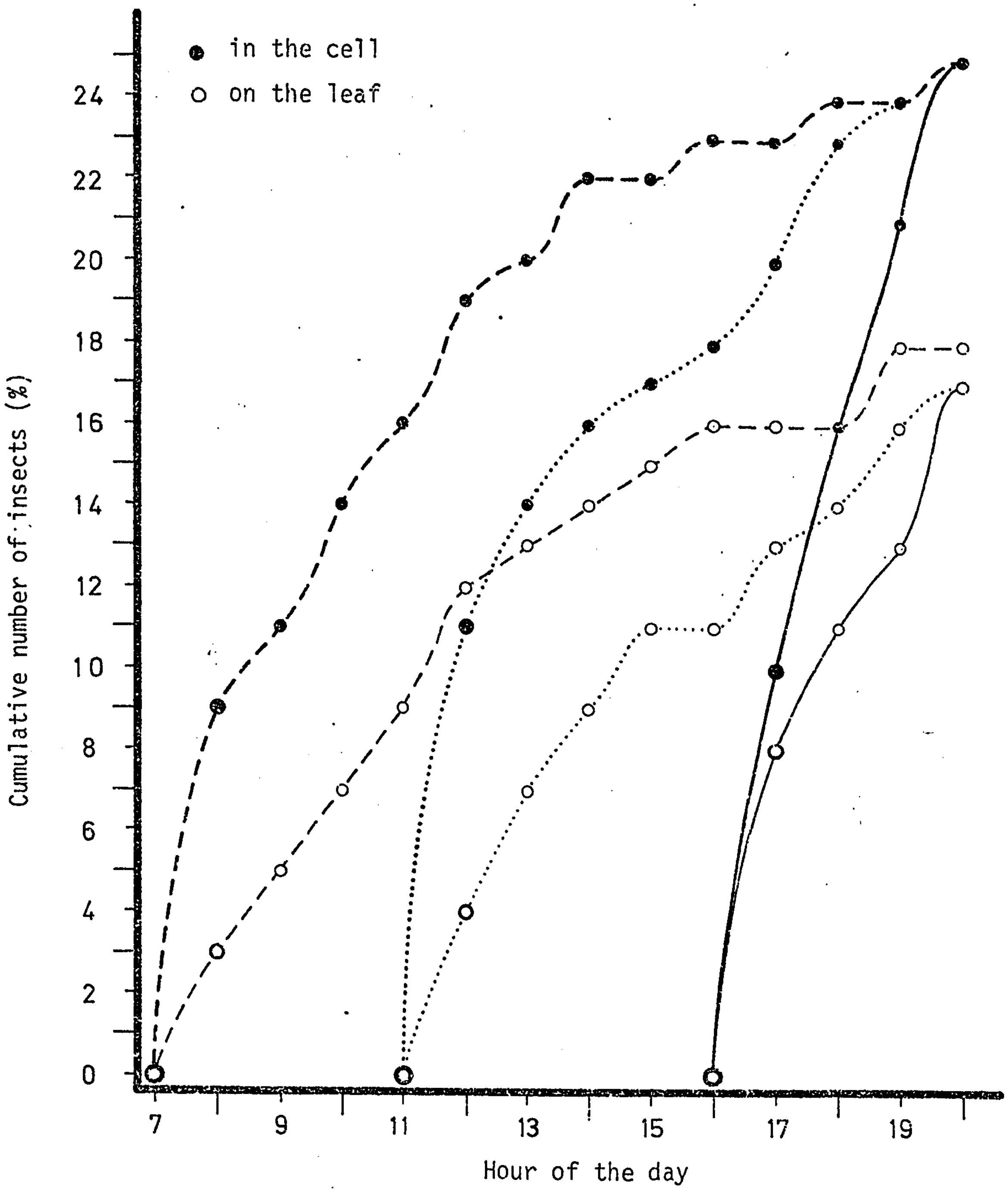


FIGURE 2. Average number of adult Psylla displacement at three different collection/release times of the day per cell and per leaf of a chamber.

Hourly average number of pear psylla per cell expressed as a percentage at three different periods of the day and on the leaf is depicted in Fig. 2. This shows that all the insects were distributed in the cells by 20:00 hours regardless of the time of the day they were released.

1.2.- Results of the Bioassays Used to Determine Pear Psylla Degree of Preference on Two Scions and Two Rootstocks of Pear.

The response of pear psylla to the foliage of two scions (Bartlett and d'Anjou) and two rootstocks (Old Home and *P. ussuriensis*) which are most commonly cultivated, was measured in bioassay chambers. This was measured from frass deposition over a period of 48 hours. In order to standardize the treatments, all plant material was collected from the nursery plot. Chamber preparation, leaf selection, insect collection, and data processing were as described in materials and methods (page 29). The insects in this group of bioassays were released at 18:00 hours. To observe the effect of the test plant attractants (if present), the released insects were allowed 12 hours to disperse randomly without restrictions, throughout all cells in the chamber. Following this chamber-conditioning-period, the opening of the central cell were blocked with a sponge cube. Then the insects were counted every 12 hour period. The experiment was replicated 10 times and each replication lasted 48 hours, after which the insects were carefully removed from the cells so as not to disturb the frass pellets left on the acetate sheets.

Psylla eggs on the leaf surface were also counted in six of the replications. On the average it was found that Old Home had 223 eggs, Bartlett had 23, d'Anjou 30, and *P. ussuriensis* 27.

TABLE 1. DUNCAN MULTIPLE RANGE TEST FOR:

Amount of frass per insect among two scions and two rootstocks, during 48 hours, in micrograms.

Treatment	Average	SSR
Old Home	220.2	a
Bartlett	121.7	b
d'Anjou	67.9	b c
P. ussuriensis	27.0	c

ANALYSIS OF VARIANCE

Source	df	S.S.	M.S.	F
Treatments	3	209364.932	69788.307	14.90 *
Replications	9	51487.610	5760.845	1.23
Error	27	125462.082	4683.410	---
Total	39	387664.615	--------	

(*) The statistical analysis was carried out at 5 % significance level.

TABLE 2. DUNCAN MULTIPLE RANGE TEST FOR:

Relative number of insects per cell among two scions and two rootstocks after 48 hours.

Treatment	Average	SSR
P. ussuriensis	28.1	a
d'Anjou	27.4	a
Bartlett	24.9	a b
Old Home	19.6	b

ANALYSIS OF VARIANCE

Source	df	S.S.	M.S.	F
Treatments	3	445.4	148.466	2.83 *
Error	36	1882.6	52.294	----
Total	39	2328.0	-----	

(*) The statistical analysis was carried out at 5 % significance level.

TABLE 3. Number of insects on the leaf surface of two scions and two rootstocks after 48 hours.

	Replications										
	1	2	3	4	5	6	7	8	9	10	$\bar{X}$
P. ussur.	15	19	22	24	35	8	14	14	19	20	19.0
d'Anjou	20	17	28	15	9	18	27	22	8	19	18.3
Bartlett	17	16	12	28	21	25	13	13	13	11	16.9
Old Home	10	18	21	8	15	11	12	23	15	17	15.0
Rep. $\bar{X}$	15.5	17.5	20.8	18.8	20.0	15.5	16.5	18.0	13.8	16.8	17.3

Analysis of variance

Source	df	S.S.	M.S.	F
Treatments	3	93.4	31.133	0.686
Replications	9	167.4	18.600	0.410
Error	27	1225.6	45.393	---
Total	39	1486.4	----	

The statistical analysis was carried out at 5 % significance level

The Duncan Multiple Range Test for the amount of frass per insect produced by pear psylla in micrograms during 48 hours, on two scions and two rootstocks, indicates that the insect produced significantly more frass on Old Home than the other plants tested. There were no significant differences in the amount of frass produced on leaves of Bartlett and d'Anjou, and between d'Anjou and P. ussuriensis. However the amount of frass produced on Bartlett was significantly greater from that produced on P. ussuriensis. There were no significant statistical discrepancies among the different replications for this group of bioassays as indicated by the 'F' test in the analysis of variance (Table 1).

The statistical test for the relative number of insects (Table 2) shows that there were no significant differences in the relative number of insects among P. ussuriensis, d'Anjou, and Bartlett, nor between Bartlett and Old Home. However, the relative number of insects on Old Home was significantly smaller than from P. ussuriensis and from d'Anjou.

The number of insects on the leaf surfaces for each specimen is shown in Table 3. The 'F' Test (analysis of variance) indicates that there were no significant differences among treatments, nor among replications.

1.3.- Results of the Bioassays Used to Determine Pear Psylla Degree of Preference on Four Cultivars of Pyrus communis.

Psylla response in terms of frass production on the foliage of four cultivars of P. communis (Bartlett, Bosc, d'Anjou, and Kieffer), which are primarily cultivated in the Niagara Peninsula, was measured in bioassay chambers. All the plant material came from a mature pear orchard. The conditions of the experiment were as previously described (Section III, p.

TABLE 4. DUNCAN MULTIPLE RANGE TEST FOR:

Amount of frass per insect among Pyrus communis cultivars, during 48 hours, in micrograms.

Treatment	Average	SSR	Replication	Average	SSR
Bosc	208.16	a	I	220.8	a
d'Anjou	152.86	a b	IV	215.8	a b
Kieffer	116.01	b	II	202.9	a b
Bartlett	88.38	b	III	126.2	a b c
			IX	118.3	a b c
			VIII	115.1	a b c
			VI	103.8	a b c
			VII	95.1	b c
			V	73.4	c

Analysis of variance

Source	df	S.S.	M.S.	F
Treatments	3	72380.687	24126.895	4.60 *
Replications	8	100491.197	12561.399	2.39 *
Error	24	125837.769	5243.245	--
Total	35	298709.769	-----	

(*) The statistical analysis was carried out at 5 % significance level.

TABLE 5. Relative number of insects per cell among 4 cultivars of pear after 48 hours.

	Replications									
	1	2	3	4	5	6	7	8	9	$\overline{X}$
Bartlett	38	17	29	28	25	39	23	23	28	27.9
Bosc	16	29	26	25	30	24	30	29	30	25.4
Kieffer	17	47	22	22	23	17	28	22	15	23.7
d'Anjou	29	17	23	25	22	20	19	26	27	23.1
Rep. $\overline{X}$	25	25	25	25	25	25	25	25	25	25.0

Analysis of variance

Source	df	S.S.	M.S.	F
Treatments	3	119.333	39.778	0.864
Error	32	1472.667	46.020	—
Total	35	1592.000	—	

The statistical analysis was carried out at 5 % significance level

TABLE 6. Number of insects on the leaf surface among four cvs. of pear after 48 hours.

	Replications									$\overline{X}$
	1	2	3	4	5	6	7	8	9	
Bartlett	21	9	24	18	19	35	15	8	16	18.3
Bosc	12	14	22	14	22	22	21	22	13	18.0
Kieffer	11	29	14	16	16	13	23	12	12	16.2
d'Anjou	17	10	19	15	16	13	14	14	13	14.6
Rep. $\overline{X}$	15.3	15.5	19.8	15.8	18.3	20.8	18.3	14.0	13.5	16.8

Analysis of variance

Source	df	S.S.	M.S.	F
Treatments	3	82.444	27.481	0.797
Replications	8	209.722	26.215	0.760
Error	24	826.055	34.460	—
Total	35	1118.222	—	

The statistical analysis was carried out at 5 % significance level.

29). The insects were also released at 18:00 hours. This group of bioassays was replicated 9 times due to the number of insects available in the field, and each replication lasted 48 hours.

The Duncan Multiple Range Test for the amount of frass per insect produced by pear psylla in micrograms during 48 hours, on the four cultivars of P. communis, indicated that there were no significant differences in the amount of frass produced between the leaves of Bosc and d'Anjou, or among d'Anjou, Kieffer, and Bartlett. However, the amount of frass on Bosc was significantly greater than that produced on Kieffer and on Bartlett. There were significant discrepancies among the different replications for this group of assays, and the Duncan Multiple Range Test for it indicated that replications 1 and 4 were significantly different from 5 and 7; and that replication 2 was significantly different from 5. There were no significant differences among replications 1, 4, 2, 3, 9, 8, and 6, nor among replications 3, 9, 8, 6, 7, and 5.

The 'F' Test (analysis of variance) for the relative number of insects per cell (Table 5) on the different cultivars of P. communis indicated that there were no significant differences among the cultivars tested.

The number of insects on the leaf surfaces of each cultivar is shown in Table 6. The 'F' Test (analysis of variance) indicated that there were no significant differences among the treatments, nor in the replications.

1.4.- Results of the Bioassays Used to Determine Pear Psylla Degree of Preference on Two Transitory Hosts in Relation to Three of Its Regular Hosts.

TABLE 7. DUNCAN MULTIPLE RANGE TEST FOR:

Amount of frass per insect on two transitory hosts in relation to three of its regular hosts, during 48 hours, in micrograms.

Treatment	Average	SSR
Old Home	193.5	a
Bartlett	88.1	b
P. ussuriensis	38.1	c
Quince	17.2	c d
Apple	1.6	d

ANALYSIS OF VARIANCE

Source	df	S.S.	M.S.	F
Treatments	4	2885.848	721.462	78.55 *
Replications	11	115.172	10.470	1.14
Error	44	404.090	9.183	---
Total	59	3405.111	----	

(*) The statistical analysis was carried out at 5 % significance level.

To determine the response of pear psylla in terms of frass deposition, during 1976, to the foliage of apple (on which Psylla adults were observed), quince (on which eggs, some nymphal stages up to the 4th instar, and adults were found), against the most preferred (Old Home), intermediately prefered (Bartlett), and least preferred (P. ussuriensis) common hosts, bioassays were conducted. The plant material was collected from several places: Old Home and P. ussuriensis from the nursery plot, Bartlett and quince from the mature pear orchard, and apple from the mature apple orchard. All the leaf material for each taxon was selected from one tree, and to normalize the location factor for the different trees, leaves were collected from the outer eastern side of the tree. A set of five bioassay chambers with four replications were prepared each time, and the leaves were positioned at random in the same manner as previously described in the materials and methods (Section III, p.29). A minimum of 30 insects were introduced into each cell of the bioassay chambers. Preliminary assays in 1976, and assays carried out in 1975 with apple, cherry, nightshade, peach, and pear (cv. Bartlett) did not show significant statistical differences for the number of insects per cell of bioassay chamber or the number of insects on the leaf. The insects were released at 18:00 hours, and each test was replicated twelve times for 48 hours, after which time, the insects were carefully removed.

Psylla eggs on the leaf surface were also counted in 8 of the replications. On the average there were no eggs on apple, 1 per female on P. ussuriensis, 2 on quince, 4 on Bartlett, and 9 on Old Home.

The Duncan Multiple Range Test for the amount of frass per insect produced by pear psylla in micrograms for 48 hours in response to the leaves of two transitory hosts and three pear psylla hosts, indicated that the amount of frass produced on Old Home leaves was significantly greater than on the other plant tested. It was also significantly greater on Bartlett than on _P. ussuriensis_, quince, and apple. There were no significant statistical discrepancies in the amount of frass produced on leaves of _P. ussuriensis_ and quince, and between quince and apple, but the amount of frass produced on _P. ussuriensis_ was significantly greater than on apple. There were no statistical differences among the various replications as indicated by the 'F' Test (analysis of variance) in the lower half of Table 7.

1.5.- Results of Bioassays Used to Determine the Response of Pear Psylla to the Polar and Lipid Fractions of Two Pyrus Species.

Psylla degree of preference, measured in terms of frass production, on the foliage of the least preferred host (_P. ussuriensis_) coated with lipid and polar extracts of the most preferred (Old Home), and vice-versa was determined in bioassay chambers. The most preferred (Old Home) and least preferred (_P. ussuriensis_) taxa of pear, as indicated by the amount of frass in response to the foliage of taxa tested during 1975, were chosen to characterize the type of effect on the response of pear psylla by frass deposition.

The primary feeding response characterization of Old Home and _P. ussuriensis_ extracts were performed with the two fractions: lipid and polar. Lack of information on the following conditioned the nature of the experiments: 1) type and nature of the chemical receptors of the insect, 2) nature of the compounds activating those receptors, 3) the activity of the compounds alone or combined with other compounds, 4) the complexity of the phenolic compounds, and 5) the qualitative and quantitative variations of leaf texture and content with age, and other factors such as the length of the growing season, and availability of plant material.

The leaf material was selected from trees cultivated on the nursery plot. Leaves collected from one species were coated by immersion in the extract of the other specimen. The extracts were diluted in water accordingly: 1) 1:1 lipid soluble extract, water (Lipid treatment), 2) 1:1 polar soluble extract, water (Polar treatment), 3) 1:1:2 lipid soluble extract, polar soluble extract, water (Lipid & polar treatment), 4) 1:1 ethanol, water (Alcohol treatment) as a control for the alcohol carrier in the lipid fraction, and 5) water as a carrier for the polar fraction (Water treatment). Pure extracts applied topically interfered with the survival of the leaf in the alcohol and lipid treatment, and the polar treatment interfered with insect survival. Pure or diluted extracts added to the five milliliter test tube in the proportion of 2 ml of extract to 3 ml of water also affected the viability of the leaf. The alcohol and the lipid treatment usually killed the leaf petiole and the lower central area of the leaf, then the leaf shrivelled slowly after 20 hours of mounting. The polar treatment usually fermented, pushing the solution through the spaces between the surrounding stopper and the petiole, flooding the acetate sheet with liquid. Therefore, the blade of the leaves were dipped in each treatment and rubbed gently with a camel hair brush to eliminate air bubbles. Then the leaves were fastened to the bioassay chambers and were left to dry for two hours.

Approximately the same number of insects (a minimum of 40 pear psylla) were released into each cell of the bioassay chamber, to standardize the amount of frass produced per treatment. The experiment was replicated eight times, and each replication lasted 48 hours after which the insects were carefully removed. However, in 3 replications mortality was higher than 40% in either the lipid or alcohol treatment, and those bioassays were discarded. A set of five bioassay chambers with two replications for the leaf of each species and their five treatments were prepared each time, and the treatments were set per chamber.

The Duncan Multiple Range Test for the amount of frass per insect produced by pear psylla in micrograms during 48 hours, on *P. ussuriensis* leaves coated with Old Home extracts, indicates that there were no significant statistical differences in the amount of frass per insect among water, lipid, and alcohol, nor between alcohol and the lipid & polar, or between lipid & polar and the polar treatment. However, the amount of frass on water and lipid were significantly greater than from the lipid & polar and the polar, and that produced on alcohol also was significantly greater than on the polar treatment. There were no significant differences among the five replications as indicated by the 'F' Test (analysis of variance) in the lower half of Table 8.

The Duncan Multiple Range Test for the amount of frass per insect produced by pear psylla in micrograms during 48 hours, on Old Home leaves coated with *P. ussuriensis* extracts indicates that the amount of frass produced per insect in the water treatment was significantly greater than the one produced on the other treatments. Frass produced on alcohol was also greater than that produced on the remaining treatments. It was also greater on the polar than on the lipid, and the lipid & polar treatments.

TABLE 8. DUNCAN MULTIPLE RANGE TEST FOR:

Amount of frass per insect on <u>Pyrus ussuriensis</u> leaves coated with Old Home fractions, during 48 hours, in micrograms.

Treatment	Average	SSR
Water	43.4	a
O. Home lipid	43.0	a
Alcohol	31.7	a b
O. Home lipid & polar	14.8	b c
O. Home polar	9.5	c

ANALYSIS OF VARIANCE

Source	df	S.S.	M.S.	F
Treatments	4	49.533	12.383	7.70 *
Replications	4	7.151	1.787	1.11
Error	16	25.827	1.607	----
Total	24	82.412	----	

(*) The statistical analysis was carried out at 5 % significance level.

TABLE 9. DUNCAN MULTIPLE RANGE TEST FOR:

Amount of frass per insect on Old Home leaves coated with _Pyrus ussuriensis_ extracts, during 48 hours, in micrograms.

Treatment	Average	SSR
Water	226.2	a
Alcohol	178.7	b
P. uss. polar	92.7	c
P. uss. lipid	51.1	d
P. uss. lipid & polar	42.5	d

ANALYSIS OF VARIANCE

Source	df	S.S.	M.S.	F
Treatments	4	1310.283	327.570	45.01 *
Replications	4	47.868	11.967	1.64
Error	16	116.423	7.276	---
Total	24	1474.575	----	

(*) The statistical analysis was carried out at 5 % significance level.

However, there were no significant differences in the amount of frass produced between the lipid and the lipid & polar treatments. There were no significant statistical differences among the five replications as indicated by the 'F' Test (analysis of variance) in the lower half of Table 9.

2.- Results of Observations on Psylla Development in the Field After a period of 21 Days.

In 1975 pear psylla development in the field was observed after a time lapse of 21 days to establish a comparison with observations carried out under bioassay conditions. The work was performed with screen sleeves, placed on the terminal branches of four cultivars of P. communis (Bartlett, Bosc, d'Anjou, and Kieffer), planted in the mature pear orchard at the Jordan Experimental Farm. The sleeve tests were replicated five times and were placed on the eastern outer side of each tree, because the insect was observed to prefer the shadowed side of the tree during the afternoon, and the eastern side during the morning. Twelve couples of recently moulted pear psylla were collected early in the morning, from 7:00 to 10:00 hours, and were introduced into each sleeve. Special care was taken with the females, since the full egg complement was required to observe the number of larvae developing after 21 days. Westigard and Watson (1963) reported that pear psylla required 29 days to develop, and the adult live about the same time period during the summer.

From five replications made on each pear cultivar, at least three of them were spoiled because of the presence of Anthocoris nemoralis Reuter (Hemiptera), which preys on eggs and nymphs of pear psylla. Anthocoris

	Psylla instars					
Cultivar	Eggs	1st	2nd	3rd	4th	5th
Bosc	503	45	51	55	46	40
d'Anjou	344	30	35	50	47	68
Bartlett	139	17	19	33	34	40
Kieffer	137	34	33	30	17	19

TABLE 10. Average number of pear psylla per instar under field conditions after 21 days, on 4 pear cvs.

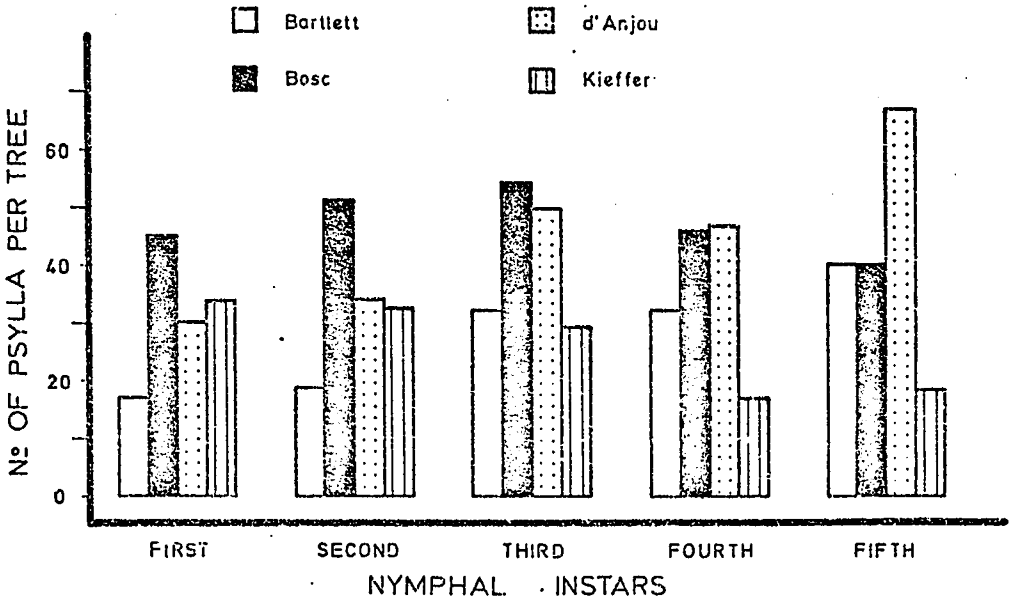


FIGURE 3. Psylla distribution relative to each instar under field conditions after 21 days, on 4 pear cvs.

lays its eggs underneath the leaf cuticle, which makes it difficult to eliminate the eggs from the leaf surface, by simple rubbing with a wet sponge. Nonetheless, there was sufficient material for observations on the trend of pear psylla development after 21 days on the four cultivars of *P. communis*. The terminal branches were harvested with the sleeves intact, and the psylla instars on the leaves were counted. These results are tabulated in Table 10, and graphically represented in Fig. 3.

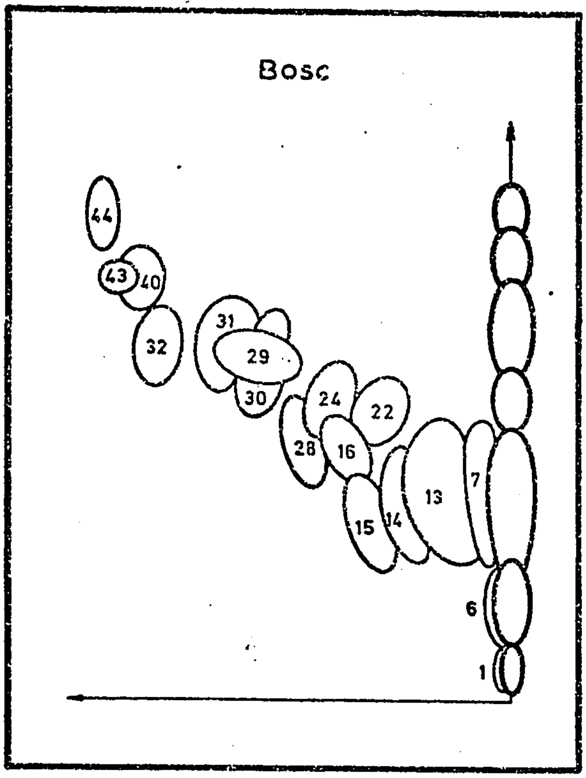
After 21 days on the different cultivars of *P. communis* the number of eggs on Bosc was greater than on the other cultivars, and Kieffer had the smallest number (Table 10). For the number of first, second, and third nymphal instars Bosc also had the largest number, while Bartlett had the smallest number for the first and second instars, and Kieffer had the smallest third instar number. In the fourth nymphal instar on the average d'Anjou had one more nymph than Bosc, and Kieffer had the lowest number. The greatest number of the fifth nymphal instar was present on d'Anjou, while Bosc and Bartlett had the same number, and Kieffer had the smallest number.

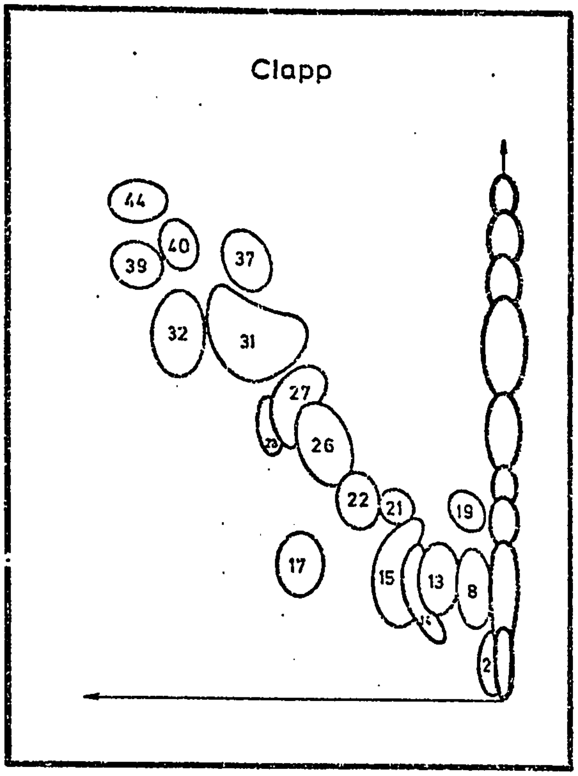
3.- Qualitative Analysis of Soluble Phenolic Compounds of Some Pear Taxa and Quince by Two Dimensional Chromatography.

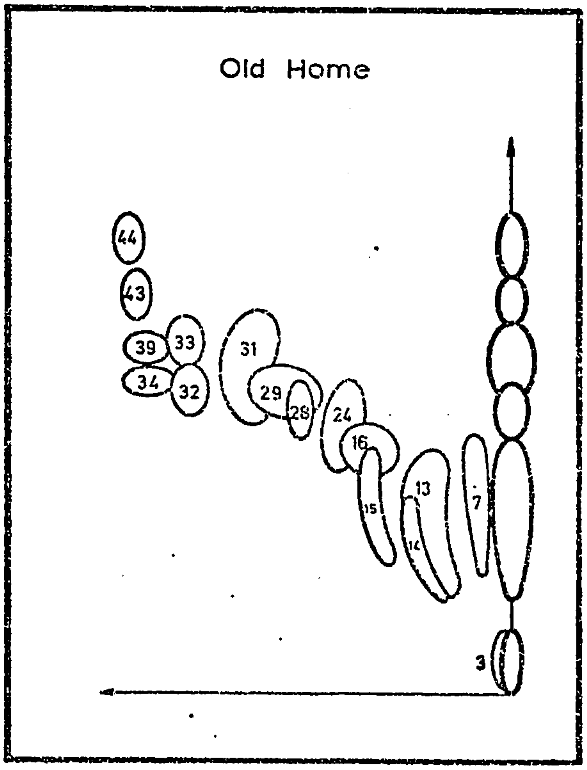
Williams *et al*. (1963) reported the susceptibility of some pear species to injury by pear psylla, pointing out that on *P. calleryana* pear psylla nymphs were not able to find a suitable place to feed on the plant. Catlin and Olsson (1966) reported some chemotaxonomical studies with phenolic compounds on different *Pyrus* species for identification purposes on susceptibility of scions and rootstocks to pear decline, and they reported that P. calleryana shows minute amounts of arbutin (a major glycoside of the genus Pyrus). These references and the work done in phenolic compounds as secondary plant substances by (Beck, 1974; Hedin et al., 1974; Kogan, 1976; Matsumoto, 1962; Swain, 1976; Thorsteinson, 1960; Todd et al., 1971) revealed that these compounds are important for specific feeding responses in some insect-plant relationships, and Alston and Turner (1963), and Mosel and Herrmann (1974) indicated that phenolic compounds are important constituents of pear. An attempt was therefore made to relate the phenolic constituents and the response of pear psylla in terms of frass production, under bioassay conditions, to the leaves of some pears and quince.

A phenolic determination by ascending two-dimensional chromatography was conducted on each taxon (Bartlett, Bosc, d'Anjou, Kieffer, Old Home, P. ussuriensis, and quince) utilized in the bioassays and on which Psylla produced frass. Clapp and Lawson were added in these analysis because they were also available. The leaf material was collected accordingly: Old Home and P. ussuriensis from the nursery plot; Bosc, Kieffer, and quince from the mature pear orchard; and Clapp planted adjacent to the mature cherry orchard at the Jordan Experimental Farm; Bartlett, d'Anjou, and Lawson from the greenhouse. Figs. 4 and 5 show the two dimensional chromatograms of polar and lipid phenolics respectively, of some taxa, in which the thick lines indicate the primary separation, and the thinner lines the secondary migration. The tabulated results show the compounds with the same colouration before and after the ammonia bathochromic shift under UV radiation and the approximate R_f values. The 'A' R_f value indicates the primary separation, and 'B' the secondary. All the chromatograms were replicated three times and the solvents for the first polar

FIG. 4. Two dimensional chromatograms of polar phenolic extract four pear taxa in n-butanol saturated water, water, acetic acid (49:49:2), and 5 % acetic acid. Description of the methods in page 36, and colorimetric identification of the spots in Table 11, page 69.


Bosc


Clapp


Old Home

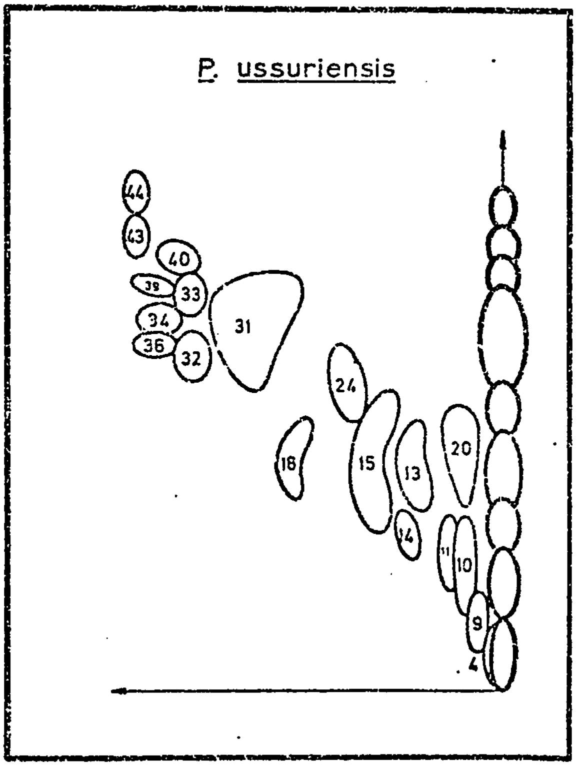
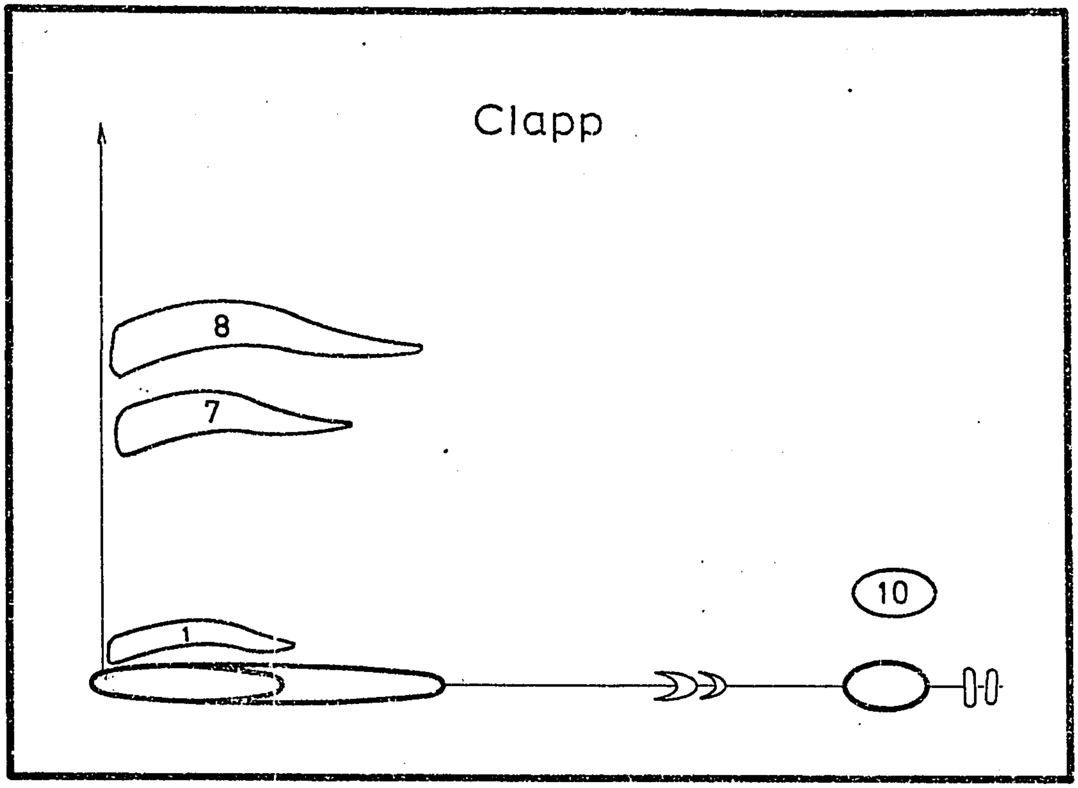
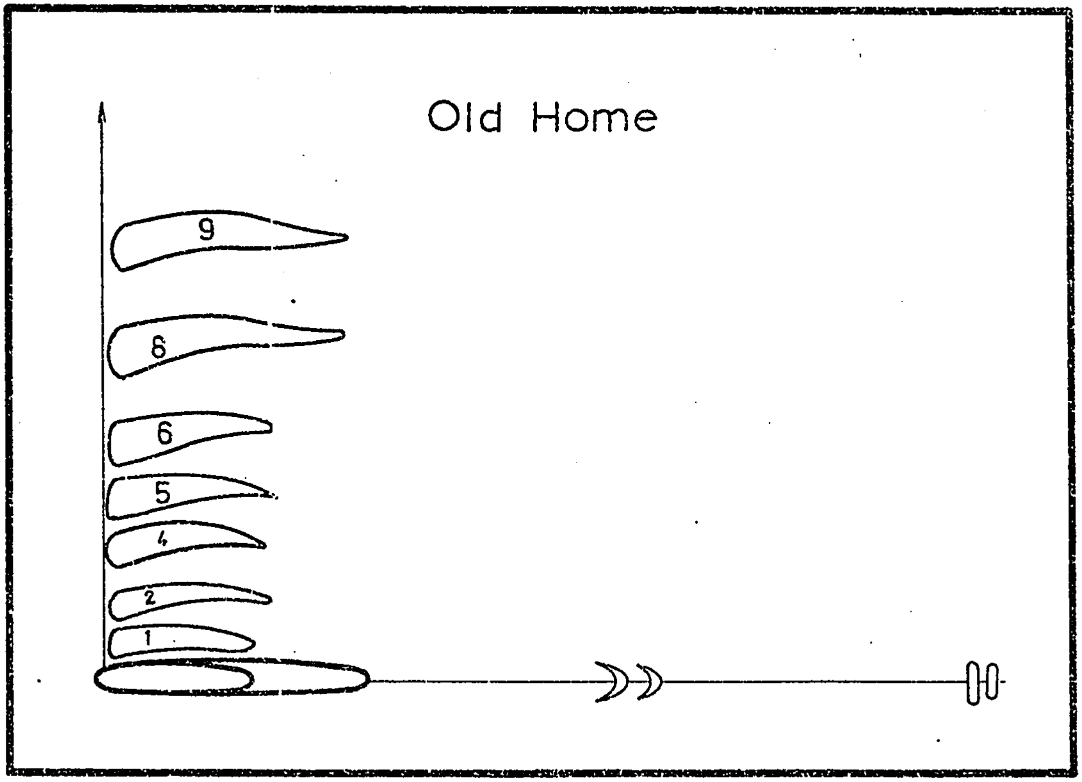

P. ussuriensis

FIG. 5. Two dimensional chromatogram of lipid phenolic extract of two pear taxa in acetone, hexane (1:3 v/v), and 5 % acetic acid. Description of the methods in page 36, and colorimetric identification of the spots in Table 12, page 69.


Clapp


Old Home

run and both second runs were modifications from Harborne (1973), while the solvents for the first lipid run was a modification from McGarrity and Armstrong (1975). The solvents were chosen, after extensive trial and error tests, when the spots were distinctively isolated. The tabulation of the data, for listing and grouping, was done manually.

The results of the two dimensional chromatography of polar soluble phenolic compounds of some pear taxa and quince are given in Table 11, and Fig. 4 shows the two most preferred (Bosc and Old Home) and two of the least preferred (Clapp and P. ussuriensis) hosts, as indicated by the amount of frass deposition under bioassay chamber conditions. These four taxa present 90 % of the isolated phenolic spots. The P. ussuriensis polar extract presents 12 phenolics also present in the P. communis group and 7 particular ones, Clapp present 14 phenolics also present in the other P. communis cvs. and 4 different ones, and quince 15 out of 21 phenolics also present in the pear group (although, spot 46 was only present in Bartlett). According to published information spots 13, 14, and 15 are chlorogenic acid related compounds because they present green colouration under UV - NH_3 (Harborne, 1973; Melin et al., 1974, Ribereau, 1972); and 16, and 29 are catechin-related compounds because they present red colouration with Vanillin-HCl reagent (Harborne, 1973; Mosel and Herrmann, 1974; Ribereau, 1972). Catechinic compounds were present in the Bosc, Old Home, and quince chromatograms, but as reported by Catlin and Olsson (1966) 1-epicatechin was present in 12 out of 50 P. communis cvs. tested, although both compounds were absent in 44 cvs. of P. ussuriensis. The presence of catechinic compounds in the other P. communis cvs. seems to be in minute amounts, which could not be differentiated in the chromatograms, because 2 ml samples of the other extracts treated with 0.2 ml of Vanillin-HCl resulted in a light positive reaction except for Clapp

N°	Colour UV+NH$_3$	Bartlett		Bosc		Clapp		D'Anjou		Kieffer		Lawson		Old Home		P. ussur.		Quince	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	Pinkish	.05	.01	.06	.01			.12	.02			.06	.01						
2	Dark Yellow					.13.	.04												
3	Yellowish											.12	.03	.13	.02			.11	.02
4	Whitish Blue															.14	.02		
5	Yellowish																	.20	.04
6	Greenish	.29	.04	.25	.03			.27	.03										
7	Greenish			.46	.05									.46	.07				
8	Purple					.27	.06			.26	.04	.28	.05						
9	Dark Green															.26	.07		
10	Yellowish															.33	.09		
11	Gray															.33	.12		
12	Light Blue																	.35	.09
13	Turoucise	.29	.16	.46	.20	.27	.18	.27	.14	.26	.16	.28	.15	.46	.24	.43	.23	.35	.17
14	Green	.29	.19	.46	.23	.27	.20	.27	.18	.26	.20	.28	.18	.46	.22	.33	.22	.45	.24
15	Turquoise	.29	.18	.46	.33	.27	.28	.27	.29	.26	.28	.28	.29	.46	.32	.54	.34	.35	.31
16	Reddish			.46	.39									.46	.38			.43	.42
17	Light Blue	.29	.50			.27	.50	.27	.46	.26	.46	.28	.51						
18	Light Blue															.33	.54		
19	Light Blue	.39	.10			.35	.09	.36	.10	.34	.10	.39	.09						
20	Greenish															.54	.10		
21	Light Blue					.35	.26												
22	Yellowish	.39	.24	.56	.35	.41	.36	.36	.26	.34	.26	.39	.26						
23	Orange																	.43	.47
24	Dark Green	.49	.38	.56	.44			.45	.37	.44	.35	.48	.38	.56	.43	.54	.43	.43	.41
25	Dark Green																	.52	.47
26	Turquoise					.53	.48												
27	Purple					.53	.51												
28	Light Blue			.56	.50	.53	.55			.44	.45			.56	.49				
29	Reddish			.56	.60									.56	.61			.52	.60
30	Light Blue			.71	.61														
31	Light Blue	.72	.63	.71	.71	.73	.63	.72	.60	.70	.58	.73	.63	.71	.65	.70	.72	.68	.70
32	Light Blue	.72	.77	.71	.79	.73	.78	.72	.77	.70	.72	.73	.79	.71	.81	.79	.79	.68	.82
33	Light Blue													.71	.83	.79	.83	.68	.84
34	Light Blue													.71	.92	.70	.87		
35	Purple																	.68	.82
36	Brown Green															.70	.90		
37	Light Blue	.83	.64			.77	.64	.82	.61	.81	.59	.85	.59					.68	.65
38	Blue																	.68	.93
39	Purple					.77	.89							.71	.93	.76	.87		
40	Purple	.83	.82	.81	.84	.86	.78			.81	.82					.82	.81	.81	.82
41	Light Blue							.82	.81			.85	.78						
42	Purple	.91	.88					.90	.94	.89	.85	.90	.88						
43	Light Blue			.81	.88									.78	.90	.82	.90	.75	.93
44	Light Blue			.88	.92	.92	.90							.89	.96	.99	.94	.81	.95
45	Light Blue							.98	.84	.96	.92	.96	.88						
46	Purple	.97	.97															.83	.97

TABLE 11. R_f Values for the phenolic spots present in the polar fraction of: (A) R_f for the first run in n-butanol saturated water, water, acetic acid (49:49:2), (B) R_f for the second run in 5 % acetic acid.

N^o	Colour UV+NH$_3$	Bartlett		Bosc		Clapp		D'Anjou		Kieffer		Lawson		Old Home		P. ussur.		Quince	
		a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
1	Light Blue	.16	.09	.12	.10	.15	.08	.21	.10	.25	.09	.20	.10	.16	.08	.22	.12	—	—
2	Yellowish	.16	.16	—	—	—	—	—	—	.25	.17	.20	.16	.16	.15	—	—	—	—
3	Yellowish	—	—	.12	.25	—	—	.21	.27	—	—	—	—	—	—	—	—	—	—
4	Greenish	—	—	—	—	—	—	—	—	.25	.24	—	—	.16	.23	—	—	—	—
5	Yellowish	.16	.32	—	—	—	—	—	—	.25	.33	.20	.35	.16	.34	—	—	—	—
6	Light Blue	—	—	—	—	—	—	—	—	—	—	—	—	.16	.43	—	—	—	—
7	Purple	—	—	—	—	.40	.46	—	—	—	—	—	—	—	—	—	—	—	—
8	Light Blue	.44	.61	.32	.60	.40	.66	.38	.63	.34	.62	.42	.58	.31	.60	.43	.64	—	—
9	Blue	.44	.75	.32	.75	—	—	.38	.79	—	—	.42	.76	.31	.78	—	—	—	—
10	Purple	—	—	—	—	.92	.20	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 12. R_f Values for the phenolic spots present in the lipid fraction of:

(A) R_f for the first run in acetone, hexane (1:3 v/v), (B) R_f for the second run in 5 % acetic acid.

and *P. ussuriensis*.

The results of the two dimensional chromatography of the lipid soluble phenolic compounds of some pear taxa and quince are given in Fig. 5. Chromatograms of the lipid fraction presented phenolic compounds for all the pear taxa, but not for quince (Table 12). Old Home presents 70% of the phenolic bands, instead of spots, because the two primary spots present in all chromatograms, did not separate completely from the starting point, but they separated in the secondary run into 10 different bands. Bosc and d'Anjou have spot 3 which is absent in Old Home, and Clapp presents two purple spots (7 and 10) that are completely different to the other taxa tested.

V.- DISCUSSION

1.1.- Bioassays Used to Determine Pear Psylla Behaviour Collected at Three Different Times of the Day in Response to Four Pear Taxa, Under Chamber Conditions.

Regardless of the time of the day the insects were released, on the average all were distributed in the large cells by 20:00 hours (CST) (Fig. 2). After this hour the number remained constant for the next nine hours in most of the assays with the different leaves.

The insects were free to move in and out of the large bioassay cells (Fig. 1). Lack of significant statistical discrepancies in the number of insects among the different pear taxa by 20:00 hours, indicate that the attractant factor cannot be clearly defined. The insects could have followed a moisture humidity gradient released by the leaves. However, it was noticed that the insect rate of displacement was faster as nightfall approached, and dark conditions (under which the experiments were performed) did not affect pear psylla apparent circadian rythm, since most of the insects were inside the large cells by 20:00 hours. Therefore, the bioassays set at 7:00 or 11:00 hours indicated that the insects spent more energy moving around the central cell, and by leaving and entering the larger cells. Nonetheless, if pear psylla was released at 16:00 hours it would go faster to the larger cells, as well as on the leaves.

On the average there were 69 % of the insects per chamber with extremes of 56 to 81 %. They moved from the leaves to roam all over the cells, this interfered with the observations of attractancy or repellency. Several authors (Borror and DeLong, 1966; Comstock, 1966; Imms, 1964;

Little, 1972) report that pear psylla is a very active creature, jumping and taking short flights when disturbed. In the presence of oriented sunlight, pear psylla accumulated on the upper part of the lighted side of the small cell, while the ones which did not jump went to the large cell oriented towards the light.

Under field conditons it was observed that during sunny cold early mornings pear psylla would remain on the pear tree until the day was warm (basking habit). Then they were very active, reacting readily when disturbed by jumping and flying from the source of disturbance. By late morning the number of insects on the trees was smaller, mostly ovipositing females. Nichols _et al_. (1965), and Rasmy and McPhee (1970) report that adult Psylla are carried by prevailing winds. Inside the orchard where the insects were collected, prevailing winds and changes in the air temperature produce convection currents. These currents are used by the insect to their advantage for migration. During the warmest period of the day _Psylla_ present on the pear tree moved to the inner part of the canopy, or to the shadowy side of the tree. At early evening pear psylla went to the pear trees, and it was difficult to collect from the surface or petioles of the leaves. This was interpreted as active feeding on the host plant, since _Psylla_ uses its leg-contraction power to attach itself to the substrate while feeding.

1.2.- Bioassays Used to Determine Pear Psylla Degree of Preference on Two Scions and Two Rootstocks of Pear.

In the course of the previous set of bioassays, the presence of white coloured particles were noticed at the bottom of each cell. These were the insects fecal droppings, which were encapsulated within a waxy coat that melted when exposed to direct sunlight for long periods of time.

The largest amount of frass was produced on Old Home (Table 1), a P. communis cv., which is recommended as rootstock in most areas infested with pear psylla (Hartmann et al., 1963; Higdon et al., 1964; Westwood, 1968), because it does not present the vascular necrosis in the grafting zone. The amount of frass produced on P. ussuriensis was on the other hand very small, 12.3 % of that produced on Old Home. This indicates that in the case of P. ussuriensis there should be either a compound or compounds which deter Psylla from feeding, or that the balance of compounds acting as feeding stimulants are in unfavourable proportions, for the pear psylla studied in the Niagara Peninsula. The amount of frass produced on Old Home was also significantly greater than that produced on Bartlett and d'Anjou, but there were no statistical differences between the last two, which indicates that there should be some phagodeterrents in them, or that the phagostimulants are lacking.

The number of insects per cell in each chamber were counted and the data expressed in percentage, to determine if there was an attractant factor affecting insect movement from one cell to another. Old Home the most preferred taxon had the smallest number of insects (Table 2). This shows that either Old Home does not have the attractant or pear psylla is not affected by any specific pear attractant if present. Pear psylla may follow a humidity gradient related to the moisture released by the leaves. The leaves of Bartlett, d'Anjou and P. ussuriensis are almost glabrous, while Old Home has a fine pubescence which does not entirely cover the leaf surface. This could influence the rate and amount of moisture released from the leaf surface.

The number of insects on the leaf surface per cell is not an accurate means of determining feeding, because their presence could be explained by other reasons than feeding. Actual feeding could not be observed due to the size of the insect, and of holes in the leaves that results from probing by the insect.

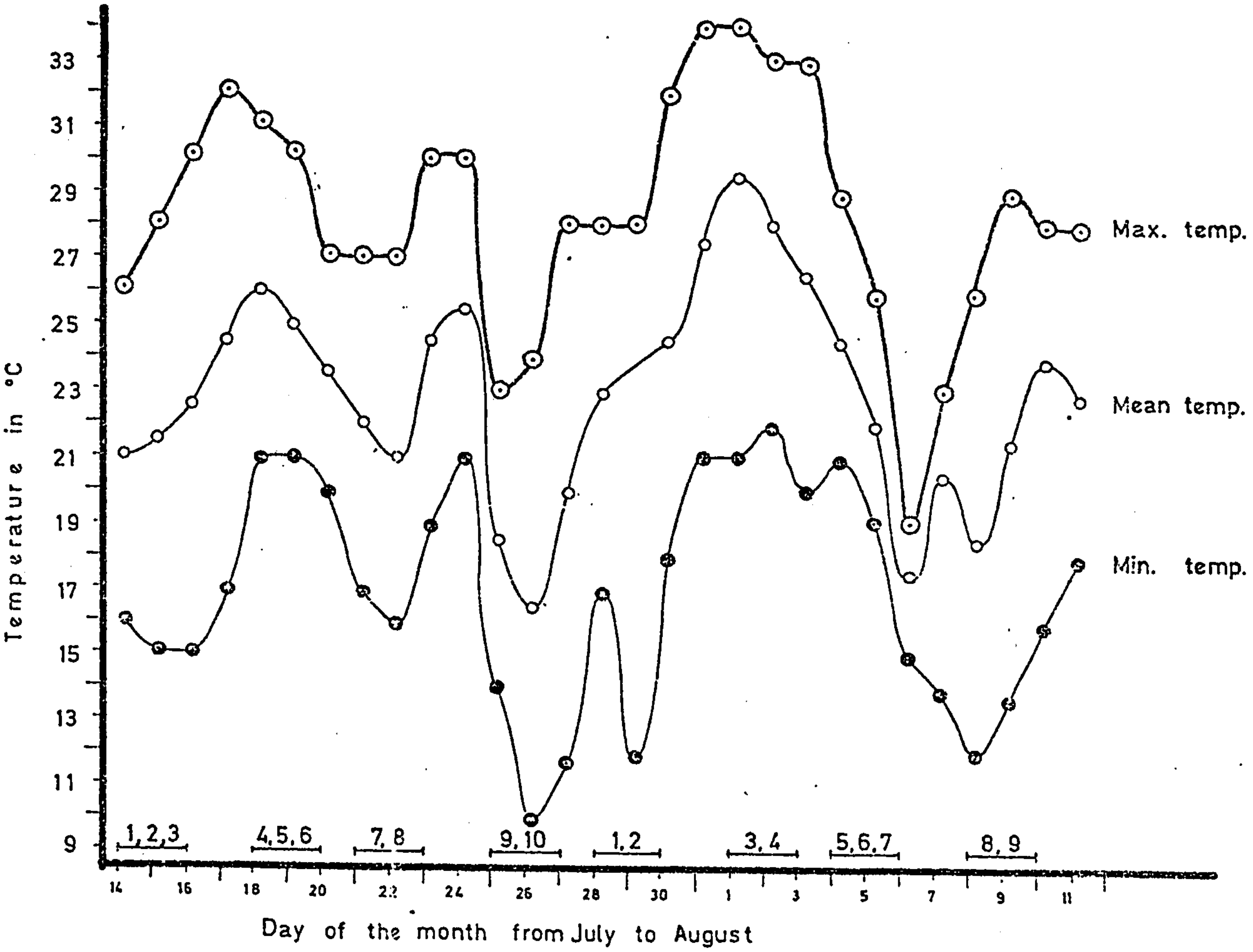
Frass production is the result of digestive transformation. In some cases plant sucking insects ingest a larger amount of food to screen the nutrients required for growth and development (Kennedy, 1953), therefore a large amount of frass occur. Consequently, other parameters had to be looked at apart from frass weight. The number of eggs on the leaves were counted, and it was noted that Old Home in spite of having the smallest number of insects, had the largest number of eggs per leaf in the replications on which eggs were counted. This indicates that there should be a factor favouring oviposition. Another result stressing the possibility of the presence of an ovipositional attractant is the male/female ratio, which for Old Home was 10/18, and for _P_. _ussuriensis_ 10/25. Therefore, even when Old Home had less females in the cells, it had more eggs than the other specimens.

1.3.- Bioassays Used to Determine Pear Psylla Degree of Preference on Four Cultivars of _Pyrus communis_.

Frass production by pear psylla in these bioassays was greatest on Bosc (Table 4), indicating that the insect fed well on this host, which implies that phagodeterrents are absent or in low levels. When the production of frass by the insect on Bosc is compared to d'anjou the feeding elicitors for these two taxa are not significantly different. However, in Bartlett and Kieffer the presence of deterrent factors lowers the amount of frass produced, if these two cultivars are compared to Bosc.

The differences among the tests for the four cultivars of pear, indicate that there were some factors affecting the insect's performance on different days when the tests were conducted. The insect's performance depends on the insect's physiological state. The ethology of the insect is affected by environmental cues working through the physiological responses of the insect. The maximum, the mean, and the minimum temperatures for the period in which the assays were done are given in Fig. 6. An unseasonal cold spell occurred in the field on the 26th and 27th of July 1975, and a hot spell on the 31st of July and 1st of August. Bioassays for two scions and two rootstocks did not show differences among replications, and the temperature in the field for that group of assays fluctuated normally for the season. However, Psylla utilized in replications 1 and 2, and 3 and 4 in the bioassays among four cultivars of _P. communis_, experienced seasonal cold temperatures, which could have influenced pear psylla to feed more. _Psylla_ utilized in replications 5, 6, and 7 experienced an unseasonal hot spell which could have lowered the amount of food intake, causing the insect to remain inactive by avoiding hot areas or the insect would remain in those cooler microclimatical areas of the plant. Besides, pear psylla is known to disappear from the field once the hot season starts, and to return once it has cooled down. Several authors (Burts, 1970; Rasmy and McPhee, 1970; Wilde and Watson, 1963) report that pear psylla disappearance from the field is caused by hardening off of the tree during mid-summer accompanied by warm and dry weather

FIGURE 6. Field maximum, mean, and minimum temperatures during the bioassay conductance period. Bioassays among two scions and two rootstocks were done July 14th to 27th, 1975; among four Pyrus communis cvs. July 28th to August 10, 1975.


Max. temp.
Mean temp.
Min. temp.
Temperature in °C
33
31
29
27
25
23
21
19
17
15
13
11
9
1,2,3
4,5,6
7,8
9,10
1,2
3,4
5,6,7
8,9
14
16
18
20
22
24
26
28
30
1
3
5
7
9
11
Day of the month from July to August

that suppresses population development. The onset of the seasonal hot conditions on July 18th, lowered the number of insects available in the field, which in turn reduced the number of bioassays to two from July 21st to July 28th. However, the drop in the temperature on July 25th, 26th, and 29th could have triggered their return, since the number of insects available for replications 5, 6, and 7 was sufficient to prepare three bioassay chambers.

The relative number of insects in the cell, and the number of insects on the leaves did not show any statistical discrepancies. Therefore, it could be inferred that the attractant factor, if present, did not help the insect in discriminating among the four pear cultivars. The cultivars do present some differences in _Psylla_ feeding activity, caused by the presence of a deterrent factor or factors, which inhibit feeding, or by more favourable proportions of plant compounds stimulating feeding activity. The large variances in the amount of frass produced seems to indicate differences in the leaf quality within the same tree, or differences in the reactions of the insects towards the same leaf. Measures were taken to eliminate or minimize these inherent factors from the experiments by taking the leaves from the same tree of each cultivar according to size, colour and length of the petiole, but nonetheless, all such variables could not be totally removed.

1.4.- Bioassays Used to Determine Pear Psylla Degree of Preference on Two Transitory Hosts in Relation to Three of Its Regular Hosts.

Psylla feeding among the three _Pyrus_ taxa was as described previously (page 72), Old Home seems to have the least amount of deterrent factors.

Bartlett has some, and P. ussuriensis seems to have the largest amount of phagodeterrent factors among the Pyrus taxa tested. During 1975 bioassays were set to determine if Psylla fed on other plant species or not: cherry, peach, quince, pear (Bartlett cv.), and nightshade (Solanum nigrum) were used, but frass and eggs were found only on Bartlett. Thus, it was concluded that Psylla did not feed on other plant species. However, at the end of July 1976, adult pear psylla were found on apple and quince. Therefore, in order to explain the presence of the insects on these species that had formerly shown to be non-host plants for pear psylla, bioassays were repeated to determine if pear psylla was indeed feeding on these species.

As indicated on Table 7, Psylla did produce frass while on quince. The amount of frass produced on apple was 9% of that produced on quince but the Duncan Multiple Range Test indicated no significant differences between these two species. Besides, frass produced on P. communis cvs. was significantly greater than on P. ussuriensis, quince, and apple suggesting that the amount of deterrent factors in these species is high or lack the required feeding stimulants, especially in apple which is significantly different from P. ussuriensis.

The egg count was related to the amount of frass produced, except in the case of quince and P. ussuriensis. Therefore, it could be inferred that the amount of frass is a function of the amount of food ingested. However, as indicated by quince and P. ussuriensis the pubescence factor has some influence in the amount of eggs deposited on the leaf surface. Quince leaves are more pubescent than all other species tested, but there was a low frass production on the quince leaves, while egg deposition was higher than on P. ussuriensis leaves, which is near glabrous. The presence of hairs on the leaf surface may be a factor stimulating egg deposition by pear psylla, since on Old Home leaves (a hairy leaf surface) more eggs were deposited. There are other factors concerning egg deposition than hairiness of the leaf surface alone, but consideration of this pubescence factor must be taken into account.

In the bioassays carried out during 1975 and 1976, plants belonging mainly to the genus Pyrus proved to be suitable hosts for the pear psylla. However, the insect was able to feed and lay eggs in 1976 on quince. Preliminary assays carried out on quince and nightshade leaves coated or not with d'Anjou leaves soluble extracts revealed that the insect did not feed or lay eggs early in the season. Weather conditions seem to have affected this specific Psylla-Pyrus host plant relationship, because during 1976 the summer was wet and cool. The high temperature climax did not appear during early July to trigger pear psylla disappearance from the field, and high precipitation prevented Psylla mortality by dry conditions. Therefore, pear psylla high population density conditioned the state of the foliage, especially where the fields were left fallow, the trees underwent an early defoliation, while the foliage from the mature pear orchard became brittle and dry. Williams et al. (1963) reported that pear psylla inoculated some phenolic compounds inside the leaf tissue, and Miles (1969) stated that salivary glands of phytophagous Homoptera secrete a polyphenol oxidase which reacts with the phenolic substrate inside the host leaf. Then the leaves' reaction to the insect could be caused by an early senescence or a production of phenolic subproducts which could condition the new emerging adults for subsequent infestations on the same tree, or in this case condition the insect to colonize other hosts such as quince.

Pear psylla frass production seems to change with each generation, probably as a result of the state of the host plant and the Psylla population on this host. Egg deposition as recorded on Old Home shows that the insect oviposited in early June (15 to 20 eggs per female) and in early August (7 to 12 eggs) among the different replications counted, and this could be conditioned by the physical state of the leaves.

1.5.- Bioassays Used to Determine the Response of Pear Psylla to the Polar and Lipid Fractions of Two *Pyrus* species.

The response of pear psylla to pear leaves of Old Home and *P. ussuriensis*, coated topically with the polar and non polar soluble fractions of the alternative plant test was observed.

P. ussuriensis was treated with: 1) water, 2) Old Home polar fraction: 3) Old Home lipid fraction, 4) alcohol, and 5) the mixture of both Old Home fractions. The deterrent factor or factors seems to be absent in the Old Home lipid fraction, or the amount of phenolics present in this fraction could mask the deterrent factors released by the alcohol, although there were no statistical differences in the amount of frass deposition among the water, lipid fraction, and alcohol treatments (Table 8). However, compounds present in the Old Home polar fraction, will enhance the deterrent factors already present in *P. ussuriensis*, which indicates that the concentration of secondary compounds (polar phenolics) beyond the threshold limit, will have a negative effect on the insect's feeding behaviour (Beck, 1974; Hsiao, 1969).

Old Home leaves were treated with *P. ussuriensis* extracts. A deterrent factor seems to be present in both fractions of *P. ussuriensis* as revealed by the water treatment on Old Home. Compared to the water treatment the polar fraction reduced frass deposition by 59% while the lipid fraction reduced it by 77%, and the reduction caused by the mixture of both fractions was 81%. This indicates that a stronger feeding deterrent factor is present in the lipid fraction, although the effect of the 50% alcohol treatment has to be also accounted for, since it reduced frass production by 21% which is significantly different from the water treatment. Alcohol may cause the removal of the wax cover of the leaf surface, initially by speeding up dehydration and changing the leaf structure, or speeding up oxidation of the external cell layers, which will interfere with the insect's feeding.

The alcohol treatment seems to reduce feeding in both species, speeding up oxidation of some compounds, or by solubilization of some compounds from the interior of the cells, bringing them up to the surface where oxidation could occur. Or it may completely remove the waxy cuticle, in which case a greater amount of compounds would be released through the leaf surface, thus increasing deterrency by an immediate saturation of the Psylla receptors.

Old Home lipid fraction seems to stimulate feeding on P. ussuriensis when compared to the alcohol treatment, which tends to reduce feeding in both taxa, 27% on P. ussuriensis, and 21% on Old Home. P. ussuriensis lipid fraction on Old Home leaves, however seems to produce a stronger deterrent effect than the polar fraction. Old Home lipid phenolics present in the leaf could have buffered the effect of the P. ussuriensis polar components, by hindering its reducing effect on frass production, while the P. ussuriensis lipid fraction enhanced this reduction.

Old Home polar fraction has a strong deterrent effect on P. ussuriensis, while P. ussuriensis polar fraction on Old Home seems to be less deterrent than the lipid fraction. In both cases they were significantly different from the water treatment, indicating that the water soluble compounds have a feeding deterrent effect on pear psylla, and the Old Home polar fraction will act synergistically with the compounds already present in P. ussuriensis especially the lipid soluble ones.

The response of the insect to both polar and lipid fractions seems to follow the response of the insects to the independent fractions. Old Home mixture seems to be less deterrent than the polar component, while P. ussuriensis mixture was most deterrent of all, which implies that in P. ussuri ensis the deterrent factors are present in both fractions, and their effect is additive. One must take into account that the concentration of the mixture of each fraction is half of the concentration of the individual fraction. In Old Home the deterrent factors are present in the polar fraction only. Tests carried out on Old Home in 1975 and 1976 show that it is the most preferred taxon for pear psylla by the amount of frass deposition and the number of eggs laid. Old Home polar compounds concentrated in a single layer, plus the polar and lipid components present in the leaves of P. ussuriensis will enhance the deterrent effect towards pear psylla. However, the concentration of each fraction must be determined further, if the fractions are to be applied topically, unless an appropriate artificial medium is developed to act as a carrier for pear psylla feeding bioassays.

2.- Observations on Psylla Development in the Field After a Period of 21 Days

In the field Bosc seems to have an ovipositional factor compared to the other cvs. (Table 10). D'Anjou also presents this stimulatory component for egg laying, but for Kieffer and Bartlett this stimulatory effect is not as marked. The observed number of eggs follows what was found in the bioassays among four cultivars of *P. communis*, in which the number of eggs was directly related to the amount of food ingested, as indicated by frass deposition.

Bosc seems to harbour a fairly constant number of different larval instars at a given time, while Bartlett and d'Anjou have relatively more of the older instars (Fig. 4), which indicates that most of the eggs could have been laid at the very beginning of the season, and oviposition decreased gradually, or that the viability of the eggs was higher at the beginning and decreased with time. In the case of Kieffer, insect maturity was delayed and the number of eggs deposited increased with time, or egg viability was higher as the adult *Psylla* became more mature. More observations are necessary in this area to determine the relationships of egg viability and age of insects.

3.- Qualitative Analysis of Soluble Phenolic Compounds of Some Pear Taxa and Quince by Two Dimensional Chromatography.

Plant phenolics have been shown by other workers (Meyer and Norris, 1974; Reese and Beck, 1976; Rodriguez and Levin, 1976; Todd *et al*., 1971) dealing with host plant relationships to be a constituent in determining the presence of a feeding response in insects other than pear psylla. Observations from the bioassays carried out during the summer of 1975 and 1976, show that among the taxa tested, pear psylla produced more frass on the leaves of Bosc and Old Home; less on Bartlett, d'Anjou, and Kieffer, and even less on P. ussuriensis, quince, and Clapp (in preliminary tests). The purpose of chromatographic identification of soluble phenolic compounds is to determine if phenolics (among all compounds present in the leaves) have a phagostimulative or a phagorepressive effect on Psylla, and in which fraction these phenolics occurred in relation to bioassays carried out on the leaves of the different taxa available, where frss was found.

The single polar spot number 32 in most cvs. of P. communis (Fig. 4), separated in two out of three Old Home chromatograms (into 32, 33, 34, & 39) as occurred in the three replications of P. ussuriensis, and quince. Spot 37 appears to have separated from spot 31, but spots 17 and 19 were consistently present in all P. communis cvs. except in Bosc and Old Home. This inconsistency in the isolation of the spots could have been caused by the adsorptivity of the paper, which could interfere with the differential movement of some compounds. Moreover, temperature has to be considered, since preliminary tests showed to affect the isolation and possibly the speed of solvent absorption by the paper, this being further complicated by the evaporation and quantity of the solvents. In some cases differentiation of some spots is not very clear, such as spot 31 present in Clapp and P. ussuriensis, which seems to show more than one compound. This could be due to the concentration of compounds present in the leaf since small amounts, although not spotted in the chromatogram, could condition the migration of other compounds while large amounts would mask the presence of others.

Though there are differences in the number of lipid phenolic spots among the taxa (Table 12), their nature is not clear. Nonetheless, tests performed during 1976, between Old Home and P. ussuriensis, and their extracts, indicated that the Old Home lipid fraction seems to have a phagostimulative effect on Psylla feeding. It can also be hypothesized that the phenolics were able to mask the deleterious effect produced by alcohol alone. The number of phenolic spots present in the lipid fraction showed that Old Home has 7 such constituents which are also present in the other P. communis cvs. and P. ussuriensis. However, Bosc and d'Anjou had an extra phenol not present in the other specimens, and Clapp also had two unique purple spots (Fig. 5). Pyrus ussuriensis had one distinct spot which did not migrate far from the starting point with either solvent. As stated previously, phenolic compounds do not occur as free substances, but in combination with a sugar, a protein, organic acids (such as chlorogenic acid which is an ester between caffeic and quinic acids) or are polymerized. Phenolic glycosides are very soluble in water (polar fraction), but as aglycones most of them becomes soluble in organic solvents (lipid fraction) (Harborne, 1973, Ribereau, 1972). The presence of phenolics in the lipid fraction cannot be explained if there are aglycones present in the leaves of the different taxa or if there are glycosides soluble in organic solvents or terpenoid bound phenolics.

Lipid phenolics could have been a contaminant from the polar fraction, but all the samples were processed under the same experimental procedure, and quince which had the largest number of polar phenolics, did not contain a single lipid in their chromatograms. Therefore, it can be stated that the difference in the number of lipid spots is inherent to and characteristic of each taxon tested.

The total number of polar or lipid phenolic compounds for each taxon does not by itself explain the phagostimulative or phagorepressive effect induced on Psylla by the leaves of the taxa tested. Bosc and Old Home have exclusively spot number 7, they share spots 16 and 29 with quince, but there is no feeding stimulation on the latter. The ratio between the common number over the total number of different (polar and lipid) phenolics between two taxon is tabulated in Table 13. From the bioassays it can be inferred that the 12 polar and 3 lipid soluble phenolic spots common to Bosc and Old Home are the compounds responsible for high feeding stimulation (7, 13, 14, 15, 16, 24, 28, 29, 31, 32, 43, and 44 for the polar; and 1, 8, and 9 for the lipids). The other phenolics present could increase, decrease or remain neutral towards the effect on pear psylla. From those 12 polar phenolic spots 6 of them are common to the other taxa (13, 14, 15, 24, 31, and 32), except Clapp in which spot number 24 is missing. From the lipid fraction spots 1 and 8 were common to all pear specimens. This seems to be the minimum number of phenolic compounds required to be a Psylla host plant. The threshold for the concentration and proportion among phenolics to elicit a positive response from an insect have to be considered. Such information has been reported in other insect-plant interactions (Hamamura, 1970; Hedin et al., 1976; Munakata, 1970; Nault and Styer, 1972). Moreover, the 6 polar and 2 lipid phenolics common to Bosc and Old Home, the cultivars Bartlett, d'Anjou, and Kieffer have 5 more polar phenolics in common (7, 19, 22, 37, and 42). These compounds could elicit some positive responses, but obviously not as positive as the ones common to Bosc and Old Home. In the chromatograms P. ussuriensis shares 9 out of 27 different polar phenolic spots with Bosc, and 11 out of 24 with Old Home. The lipid phenolics 1 and 8 are also found to be common to Bosc, Old Home, and P. ussuriensis. Quince shares 11 out of 27 different polar spots with Bosc, and 11/25 with Old Home, but no lipid phenolic. Clapp shares 9/26 with Bosc and 8/26 with Old Home, seven of which are common to the three cvs. (13, 14, 15, 28, 31, 32, and 44),

POLAR / LIPID	*Pyrus communis* cultivars							Other Species	
	Bart.	Bosc	Clapp	Anjou	Kieff.	Laws.	O.Home	*P.uss.*	Quin.
Bartlett		10/22	10/23	13/17	12/18	12/19	6/25	7/27	9/27
Bosc	3/6		9/26	9/23	9/23	8/25	12/21	9/27	11/27
Clapp	2/7	2/6		9/24	10/23	10/24	8/26	8/29	8/31
d'Anjou	3/6	4/4	2/6		12/18	14/17	6/25	6/28	7/29
Kieffer	4/6	2/7	2/7	2/7		13/18	7/24	7/27	8/28
Lawson	5/5	3/6	2/7	3/6	4/6		7/25	6/29	7/30
Old Home	5/7	3/8	2/9	3/8	5/7	5/7		11/24	11/25
P. ussuriensis	2/5	2/4	2/4	2/4	2/5	2/5	2/7		10/33
Quince	0/5	0/4	0/4	0/4	0/5	0/5	0/7	0/2	

TABLE 13. Ratio of phenolic spots found in the polar and the lipid fraction, common to the two specimens (upper number) over the total different phenolics between the two taxa (lower number) compared.

two lipid spots (1 and 8) being common to the other taxa as well. However, P. ussuriensis, Clapp, and quince were not preferred by the insect, and from the ratio of phenolics, the indication is that the particular phenolic components of the three taxa would be responsible for low feeding stimulation. Moreover, certain compounds did not migrate far from the starting point, and exhibited an unusual colouration. Such was the case for Clapp (polar spot number 2, which is bright yellow), and for P. ussuriensis an immobile whitish blue spot in the lipid fraction which resembled polar spot number 4. Quince is not a regular host, but it presents large amounts of catechinic compounds (spots 16 and 29).

Whether pear psylla attraction to pears is olfactory or/and ovipositional, or whether, it finds its host at random had not so far been determined (Kennedy, 1965; Painter, 1953; Yamamoto et al., 1969). Work done during 1975 and 1976 characterizes the differential relationships between pear psylla and its host plant. Electrophysiological experiments must however be carried out to determine the specific chemical components present in the leaves of the host plant to which the insect is responding and which controls insect-plant association. Before, this can be done the following steps must be taken: 1) identification of the ideal host, 2) isolation and identification of the plant active substances responsibles for the specific response, and 3) localization and classification of receptor types responsibles for host recognition.

Raw fractionation of the foliar soluble compounds into polar and lipid portions of the most preferred (Old Home) and the least preferred (P. ussuriensis) pear host produced peculiar responses when the leaves were coated with the fraction of the alternative species. The bioassays and chromatographic analysis of the phenolic spots indicated a relationship between the insect phagostimulation by its host plant and the type of phenolic compounds present in the different taxa tested. As reported by Harborne (1973), Ribereau (1972), and Salisbury and Ross (1969) phenolic compounds have the capacity to bind to other soluble or structural compounds present inside the plants. Therefore, it is difficult to determine the effect of different sugars to each phenolic aglycone. Work on the susceptibility of some pear species to injury from pear psylla infestations showed that P. calleryana had the lowest infestations (Westigard et al., 1970; Williams et al., 1963). Working with this species, Catlin and Olsson (1966) found that the phenolic arbutin which is universal in most pear species, it was present in trace amounts only. Qualitative differences among the different cultivars of Pyrus communis are indicated in Tables 11 and 12. Identification of the different spots from the published material proved difficult because extraction, isolation, and identification were different in all the reported cases, and at the same time conditioned by the purpose of the study and taxa utilized.

The number of polar phenolic spots among the P. communis cvs. ranged from 15 to 18, while P. ussuriensis had 19, and quince (a reservoir host) had 21. Catechin-related compounds were found in the chromatograms of Bosc, Old Home and quince. These compounds were also detected in the other cvs. of P. communis, after a Vanillin-HCl test was carried out on their extracts, suggesting that the presence of these compounds is in smaller concentrations. But as reported by Catlin and Olsson (1966) there were no catechinic compounds on P. ussuriensis. The number of phenolic spots from the lipid fraction among the different cvs. of P. communis ranged from 4 to 7, while for P. ussuriensis there were only two, plus the immobile spot in the starting point. This further increases the number of phenolic spots for P. communis to 23.

During the summer of 1976, it was also found that the feeding behaviour of the insect changed as the insect generation changed. This could be caused by internal or external qualitative changes of the foliage, such as nutritional factors which govern the time and place of insect infestation on the plant and in turn are influenced by the degree of synchronization of the plant and the insect's life cycle (Painter, 1953). Internal changes in the foliage could be affected by the Psylla infestation itself, since sap sucking insects inoculate in the leaf substrate salivary phenolases while feeding. It is more than probable that these phenolases would react with plant phenolics and condition the palatability of the host. Consequently, this palatability conditioning for the new adults would add other experimental variables to be considered such as: 1) time for harvesting the leaves during the growing season, 2) position of the leaves on the tree, 3) amount of infestation on the leaves harvested, and 4) time of day for leaf collection.

Lack of information on the sugar fraction, the effect of the different types of sugars with one aglycone, and the insect's receptors add more complexity to the study of these compounds, and their role in host-plant relationships. These could increase the number of phenolic compounds present capable of eliciting a feeding response, but it cannot be determined conclusively if the response is due to the aglycone types or the types of sugars bound to the aglycone. The type and concentration of certain soluble compounds in the leaves which are accumulated and do not intervene in the primary metabolism (that are the secondary plant substances) are responsible for these phagostimulative or phagorepressive responses between the insect and its host plant (Beck, 1974; Dethier, 1970; Fraenkel, 1969; Jermy, 1969; Schoonhoven, 1972; Swain, 1976; Whittaker and Feeny, 1971). Bioassays carried out on different cultivars of P. communis indicated some of the trends as how the insect behaves towards these cultivars. The ratio of the common number over the total number of different phenolic spots between two taxon helps to understand the biological response between pear psylla and the different taxa tested. Results from the bioassays and the ratio of polar phenolic spots present between two taxa (Table 13) indicate that Bartlett, d'Anjou, and Kieffer had a large number of common phenolics when they are compared to the other taxa. The phenolic ratio between Bosc and Old Home was also large, suggesting that among P. communis there are some cultivars such as Bosc and Old Home in which the phagodeterrents are in minute amount or are missing, or that the common polar phenolics present in both of them are responsible for Psylla's high food intake. However, in the other cultivars tested (Bartlett, d'Anjou, and Kieffer) their particular polar phenolics would be responsible for phagodeterrence and the polar phenolics common to the other two cultivars mentioned above would account for their intermediate susceptibility to pear psylla.

The various phenolic components in each taxon of pear appear to be responsible for the differential feeding stimulation or suppression in Psylla pyricola, this being further indicated by the bioassays on frass deposition. More studies are now required on the biochemistry of the plant soluble components, the biological effect of the interaction between the aglycone and the sugar fraction, the time for harvesting of the leaves, and the insect receptors. Once the ideal host for pear psylla has been determined, by the close association between this insect and the soluble plant compounds, present in its host, then this association could be studied by means of electrophysiological methods. Even without such information it is possible to see, from the results obtained in this thesis that horticulturists must reassess their recommendations on the desirable commercial varieties of pear, if damages by the insect are to be limited to economically acceptable levels.

VI.- SUMMARY AND CONCLUSIONS

Experimental work performed in the field and under bioassay chamber conditions between pear psylla and the different plant taxa tested showed that:

1.- Pear psylla feeding behaviour in response to leaves of different hosts can be studied under bioassay chamber conditions.

2.- Adult pear psylla is the optimal stage for feeding studies under bioassay situations, since the insect at this stage is sufficiently mobile.

3.- Fifth instar pear psylla, for the second and third generation, as observed during 1975 and 1976, shows a nymphal dimorphism, and a quiescent habit not formerly reported.

4.- _Psylla_ movement towards the pear leaves, under bioassay situations, is faster during early evening. Early evening _Psylla_ counts in the field also show an increase in the number of insects on the tree.

5.- Pear psylla, under bioassay conditions, exhibited a positive phototactic response.

6.- Bioassays to determine _Psylla_ activity compared to field observations, indicated that the apparent circadian rythm of the insect under dark conditions was not affected.

7.- _Psylla_ olfactory organs did not seem to differentiate between its usual host (European pears) and the non hosts (_P. ussuriensis_, apple, cherry, nightshade, peach, and quince) as indicated by the number of insects found on their leaves.

8.- Pear psylla movement under bioassay chambers and dark conditions, towards the different cells of each chamber, could be conditioned by the humidity gradient created by the leaves, as indicated by the relative number of insects per cell in most bioassays.

9.- The attractant factor or factors were not specific enough to be measured under artificial conditions, as shown by the presence of insects even in the non host plants. However, the deterrent factor or factors are more specific and their effect measurable, by the amount of frass deposition.

10.- _Psylla_ host preference, under bioassay chambers, in response to plant test leaves, could be quantified only as a function of the collected frass produced.

11.- The amount of frass produced by pear psylla in response to the leaves in the bottom of each cell, varied in a consistent and reproducible manner with the plant taxa tested.

12.- _Psylla_ feeding could be related to the amount of frass deposition, which in turn bears a relationship to the number of eggs laid by the insect.

13.- Pear psylla is a specific pest of _Pyrus communis_, attacks _P. ussuriensis_, but under unfavourable conditions is able to feed and produce eggs on quince in the conducted bioassays.

14.- The number of _Psylla_ among the different _Pyrus communis_ cvs. tested did not show any significant statistical differences, therefore the attractant factor, if present, is not effective in helping the insect discriminate among cultivars; but the deterrent factor (as indicated by frass deposition) shows that discrimination occurs among cvs..

15.- Old Home is the most preferred cultivar as indicated by frass deposition under bioassay conditions, although in 1975 it was not necessarily the most attractive to pear psylla, if the relative number of insects per cell is meaningful.

16.- There seems to be an ovipositional factor in Old Home which stimulates pear psylla egg laying.

17.- The amount of hairs on the leaf of the hosts also influence the number of eggs laid. In the case of Old Home hairiness seems to be synergistic with the amount of frass produced and the unidentified ovipositional factor.

18.- Pear psylla seems to be affected by unseasonal extreme temperatures in the field, which in turn alter their performance in the bioassays.

19.- Intrinsic variations in the leaves are unavoidable factors in deciphering information on the feeding activity of the insects. Such parameters are difficult to measure and require more time and equipment than available.

20.- The physical and physiological state of the leaves seems to condition feeding behaviour, as indicated by the frass produced on quince during early August 1976.

21.- Alcohol treatment seems to condition the leaf surface, reducing the amoung of feeding as indicated by the amount of frass produced. In Old Home the reduction was 21%, while in P. ussuriensis it was 27%.

22.- Old Home lipid soluble fraction appears to have some phagostimulant effect, while P. ussuriensis lipid soluble fraction has a strong deterrent effect.

23.- Old Home polar soluble fraction had a strong deterrent effect once it was applied topically on P. ussuriensis, although synergism with the leaf components present in P. ussuriensis could have magnified this effect. P. ussuriensis polar components were not as deterrent as the lipid fraction.

24.- Leaves coated topically with the mixture of both soluble fractions suggest that for P. ussuriensis fractions, the effect of both fractions is synergistic, while for Old Home the lipid fraction buffered the deterrent effect.

25.- The qualitative internal differences in soluble phenolic compounds among the different taxa studied could be related to the differential preference of pear psylla to them.

26.- From this study it can be concluded that the minimum number of phenolic compounds required to be a Psylla host plant is six polar soluble phenolics (13, 14, 15, 24, 31, and 32) and two lipid soluble phenolics (1 and 8).

27.-. According to the results obtained in the field, in bioassays, and two-dimensional chromatography of phenolic compounds in the plants tested, these plants can be arranged in three categories: 1) most preferred hosts for Psylla pyricola (Bosc and Old Home), 2) intermediate hosts (Bartlett, Kieffer, and d'Anjou), and 3) least preferred hosts (Clapp, P. ussuriensis, and quince).

APPENDIX

TABLE 14. Amount of frass per insect among 2 scions and 2 rootstocks, during 48 hours, in micrograms.

	Replications										
Treatments	I	II	III	IV	V	VI	VII	VIII	IX	X	$\overline{X}$
Old Home	181.2	235.6	174.0	268.0	163.1	140.0	128.6	160.8	555.3	196.1	220.27
Bartlett	71.1	121.1	47.0	136.0	160.4	109.0	180.0	67.8	135.8	189.5	121.77
d'Anjou	29.5	57.0	39.4	33.9	77.5	81.4	33.2	145.3	119.0	63.5	67.97
_P_. _ussur_.	16.6	31.7	38.4	28.7	24.5	71.0	13.8	12.1	23.1	11.0	27.09
Rep. $\overline{X}$	74.6	111.4	74.7	116.7	106.4	100.4	88.9	96.5	208.3	115.0	109.28
Psylla # per assay	155	140	201	97	95	105	90	79	52	113	

Analysis of variance

Source	df	S.S.	M.S.	F
Treatments	3	209364.932	69788.307	14.90 *
Replications	9	51847.610	5760.845	1.23
Error	27	126452.082	4683.410	---
Total	39	387664.615	-------	

Duncan Multiple Range Test

Treatment	Average	SSR
Old Home	220.27	a
Bartlett	121.77	b
d'Anjou	67.97	b c
_P_. _ussuriensis_	27.09	c

(*) The statistical analysis was carried out at 5 % significance level.

TABLE 15. Relative number of insects per cell among two scions and two rootstocks of pear, after 48 hours.

	Replications										
	1	2	3	4	5	6	7	8	9	10	$\overline{X}$
P. ussuri.	35	29	26	32	42	18	23	18	31	27	28.1
d'Anjou	26	29	34	24	13	26	38	35	19	30	27.4
Bartlett	23	19	15	34	25	40	22	18	33	20	19.6
Old Home	16	23	25	10	20	16	17	29	17	23	19.6
Rep. $\overline{X}$	25	25	25	25	25	25	25	25	25	25	25.0

Analysis of variance

Source	df	S.S.	M.S.	F
Treatments	3	445.4	148.4667	2.839 *
Error	36	1882.6	52.2944	---
Total	39	2328.0	------	

Duncan Multiple Range Test

Treatment	Average	SSR
P. ussuriensis	28.1	a
d'Anjou	27.4	a
Bartlett	24.9	a b
Old Home	19.6	b

(*) The statistical analysis was carried out at 5 % significance level.

TABLE 16. Amount of frass per insect among 4 *Pyrus communis* cvs., during 48 hours, in micrograms.

Treatments	Replications I	II	III	IV	V	VI	VII	VIII	IX	$\overline{X}$
Bosc	424.7	260.9	196.4	322.7	88.5	158.1	140.9	182.1	99.1	208.16
d'Anjou	137.6	305.0	117.7	386.3	73.8	72.2	56.8	58.7	167.6	152.86
Kieffer	190.0	95.5	127.1	80.5	67.2	113.7	89.3	141.4	139.4	116.01
Bartlett	130.7	150.0	63.4	73.7	67.8	71.1	93.4	78.3	67.1	88.38
Rep. $\overline{X}$	220.8	202.9	126.2	215.8	74.3	103.8	95.1	115.1	118.3	141.35
Psylla # per assay	104	58	97	87	94	46	102	129	125	

Analysis of variance

Source	df	S.S.	M.S.	F
Treatments	3	72380.687	24126.895	4.60 *
Replications	8	100491.197	12561.399	2.39 *
Error	24	125837.769	5243.245	--
Total	35	298709.769	-------	

Duncan Multiple Range Test

Treatments	Average	SSR
Bosc	208.16	a
d'Anjou	152.86	a b
Kieffer	116.01	b
Bartlett	88.38	b

(*) The statistical analysis was carried out at 5 % significance level.

TABLE 17. Amount of frass per insect on two transitory hosts in relation to three of its regular hosts, during 48 hours, in micrograms.

	Replications												
Treatments	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	$\bar{X}$
Apple	1.7	1.2	1.5	0.7	1.4	0.5	0.7	0.8	1.9	5.8	1.1	1.4	1.6
Quince	16.5	14.8	4.3	14.7	27.3	36.8	14.7	20.0	14.0	14.3	15.5	12.9	17.2
Bartlett	154.6	54.0	56.8	135.9	76.2	72.2	58.1	62.8	90.0	116.2	72.2	108.8	88.1
P. ussur.	15.0	60.4	21.3	46.2	10.0	23.6	53.3	27.8	77.5	37.9	73.3	10.4	38.1
Old Home	143.3	181.5	174.2	220.7	101.3	183.6	201.3	169.2	230.4	152.8	304.3	259.3	193.5
Rep. $\bar{X}$	66.2	62.3	51.6	83.6	43.2	63.3	65.6	56.1	82.8	65.4	93.3	78.6	67.7
Psylla # per assay	142	132	130	140	142	140	173	138	141	152	145	139	

Analysis of variance

Source	df	S.S.	M.S.	F
Treatments	4	2885.8483	721.4620	78.5574 *
Replications	11	115.1724	10.4702	1.1400
Error	44	404.0908	9.1838	---
Total	59	3405.1116	----	

Duncan Multiple Range Test

Treatment	Average	SSR
Old Home	193.5	a
Bartlett	88.1	b
P. ussur.	38.1	c
Quince	17.2	c d
Apple	1.6	d

(*) The statistical analysis was carried out at 5 % significance level.

TABLE 18. Amount of frass per insect on <u>Pyrus</u> <u>ussuriensis</u> leaves coated Old Home fractions, during 48 hours, in micrograms.

	Replications					
Treatments	I	II	III	IV	V	$\bar{X}$
Water	66.0	35.7	30.3	31.9	53.3	43.4
O. Home polar fraction	6.7	2.7	6.3	17.7	14.3	9.5
O. Home lipid fraction	45.4	22.5	30.4	78.8	37.7	43.0
Alcohol	21.4	31.0	39.4	37.0	29.6	31.7
O. Home lipid & polar	15.6	19.0	8.1	17.0	14.1	14.8
Replication $\bar{X}$	31.0	22.2	22.9	36.5	29.8	28.5
Psylla # per assay	186	182	174	163	166	

Analysis of variance

Source	DF	S.S.	M.S.	F
Treatment	4	49.5337	12.3834	7.7012 *
Replications	4	7.1510	1.7877	1.1118
Error	16	25.8275	1.6079	--
Total	24	82.4122	---	

Duncan Multiple Range Test

Treatment	$\bar{X}$	SSR
Water	43.4	a
O. Home lipid fraction	43.0	a
Alcohol	31.7	a b
O. Home lipid & polar	14.8	b c
O. Home polar fraction	9.5	c

* The statistical analysis was carried out at 5 % significance level.

TABLE 19. Amount of frass per insect on Old leaves coated with <u>Pyrus</u> <u>ussuriensis</u> extracts, during 48 hours, in micrograms.

	Replications					
Treatments	I	II	III	IV	V	$\bar{X}$
Water	203.3	168.2	209.6	312.0	238.0	226.2
P. uss. polar fraction	95.0	91.9	64.4	100.0	112.2	92.7
P. uss. lipid fraction	59.3	64.4	54.0	40.5	37.5	51.1
Alcohol	176.5	156.9	158.7	183.0	218.3	178.7
P. uss. lipid & polar	40.0	45.0	25.3	46.0	56.0	42.5
Replication $\bar{X}$	114.8	105.3	102.4	136.3	132.4	118.2
Psylla # per assay	168	164	170	163	175	

Analysis of variance

Source	df	S.S.	M.S.	F	
Treatments	4	1310.2832	327.5708	45.0177	*
Replications	4	47.8685	11.9671	1.6446	
Error	16	116.4236	7.2764	---	
Total	24	1474.5753	----		

Duncan Multiple Range Test

Treatment	$\bar{X}$	SSR
Water	226.2	a
Alcohol	178.7	b
P. uss. polar fraction	92.7	c
P. uss. lipid fraction	51.1	d
P. uss. lipid & polar	42.5	d

* The statistical analysis was carried out at 5 % significance level.

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