BIOLOGY OF THE CLUSTER FLY, POLLENIA RUDIS (FABRICIUS) (DIPTERA : CALLIPHORIDAE)

By

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Abstract

Pollenia rudis adults were collected out of doors April 17 to November 5 on calm bright days and in unheated buildings starting September 2, 1970 and August 26, 1971. Entry increased below 10° C. Sometimes clusters included other flies. Carpoglyphus nymphs occurred on one group of adult Pollenia. Phycomycosis of adults by Entomophthora muscae commonly occurred. Copulation occurred at 27° C. following storage for 21 weeks at 4° C. Eggs hatched in 3 to 4 days at 25° C. In the laboratory some 2000 larvae were placed with Allolobophora chlorotica in soil, some penetrated the earthworms, none entered fully and only one reached the adult stage. Scanning electron microscopy revealed structures in the chorion of the egg suitable for plastron respiration and sensory structures on the ovipositor. A complete literature review is included.

M.Sc. Entomologie

Biologie de la mouche essaimeuse, Pollenia rudis (Fabricius) (Diptera:Calliphoridae)

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Résumé

Des adultes de Pollenia rudis furent capturés à l'extérieur du 17 avril au 5 novembre par jours calmes et ensoleillés ainsi qu'à l'intérieur de bâtiments non-chauffés à partir du 2 septembre 1970 et à partir du 26 août, en 1971. La baisse de température, sous 10°C., encouragea l'envahissement. Les essaims comportaient parfois d'autres espèces de mouches. Des larves de Carpoglyphus furent observées dans un groupe de Pollenia. La phycomycose des adultes, par Entomophthora muscae, s'observa fréquemment. La copulation se produisait à 27°C. après 21 semaines à 4°C. L'éclosion prenait 3 ou 4 jours à 25°C. En laboratoire, quelque 2000 larves furent placées avec Allolobophora chlorotica dans le sol. De celles qui perforèrent la peau des vers, aucune ne pénétra complètement, et seulement une parvint au stage adulte. Le microscope électronique à balayage montra le chorion de l'oeuf doté d'une structure propre à une respiration plastronique; ainsi que des structures sensorielles sur l'ovipositeur. Une bibliographie complète est incluse.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

They were at once a terror to all neat housekeepers, and from their peculiar habits a constant surprise. People soon learned to look for them everywhere; in beds, in pillow slips, under table covers, behind pictures, in wardrobes nestled in bonnets and hats, under the edge of carpets, and in all possible and impossible places. Words fail to describe their general depravity; it is beyond expression. If you wish to be happy, be sure you don't introduce cluster flies into your family.

Dall (1884)

I. INTRODUCTION

The cluster fly, Pollenia rudis (Fabricius), is a calliphorid fly which resembles the ordinary house fly, except that it has a slightly larger size. Although it is a common enough fly in Europe and North America, the literature reveals that very little is really known about its biology. Apart from brief reviews by DeCoursey (1927) and Hall (1948), no comprehensive literature review has been made on the biology of this insect. As a preliminary to this work, it was felt that a comprehensive review should be attempted even though large gaps would inevitably remain in an understanding of the insect's overall biology.

One definite fact that is known about the adult is its disconcerting manner of entering homes and buildings in the autumn, often in very large numbers, in order to overwinter. The overwintering adults may sometimes congregate as clusters in darkened recesses in a building and it is from this habit that the common name for the fly is derived.

There is no evidence that the fly transmits disease. They do not bite. Their claim to notoriety resides in their presence in large numbers in homes and buildings and the noise they make while buzzing about in windows. However, when hundreds, or even thousands, of living and dead flies occur in a home, they can hardly be considered an aesthetic

asset. Their distracting presence in such locations as schools, factories, military installations and hospitals may have an even stronger psychological impact as many people associate "flies" with disease and unsanitary conditions.

In order to form some conclusions about the general nature of infestations of buildings by P. rudis, studies were made on the occurrence and behaviour of the flies in a chalet and a radar weather observatory near to the Macdonald Campus. Complementary to this, overwintering flies were studied under artificial overwintering conditions in the laboratory. A questionnaire on the infestation of buildings by P. rudis was also completed by several pest control operators throughout North America. Other aspects on the biology of the adult which have been investigated in this work include copulation, oviposition, fungal disease, clustering, general behaviour and longevity.

Keilin (1915) extensively examined the immature stages of P. rudis and determined that the larvae are parasitic in the lumbricid earthworm Allolobophora chlorotica (Savigny). However, no one else has since observed the larvae parasitising A. chlorotica in the manner described by Keilin. This present work attempts to clarify the relationship of the larvae of P. rudis to mature (clitellate) A. chlorotica under laboratory conditions.

The structure of the egg of P. rudis has been examined with a scanning electron microscope to show the detailed structure of the chorion and its respiratory plastron areas.

II. LITERATURE REVIEW

A. Classification and description of adult.

Fabricius (1775) described the adult as Musca rudis. Robineau-Desvoidy (1863) made M. rudis the type of his genus Pollenia. The generally accepted name for the insect at the present time is Pollenia rudis (Fabricius). Shannon (1926) recorded, in addition to P. rudis, three other species of Pollenia for North America. These are P. glabricula (Bigot), P. obscura (Bigot) and P. vespillo (Fabricius). However, DeCoursey (1927) doubted that P. glabricula or P. obscura occurred in North America. Furthermore, Shewell (1961) maintained that P. vespillo was synonymous with P. rudis and reported the recent introduction of P. vagabunda (Meigen) into Canada. Hall (1965) placed the genus Pollenia in the following taxonomic scheme:

Order: Diptera
Superfamily: Oestroidea
Family: Calliphoridae
Subfamily: Polleniinae
Tribe: Polleniini
Genus: Pollenia Robineau-Desvoidy.

Detailed accounts of the taxonomic literature on the genus Pollenia have been given by Rohdendorf (1926), Séguy (1934), Zumpt (1956) and Lehrer (1963, 1967).

DeCoursey (1927) described the adult as follows: "The adult fly is somewhat larger than a housefly. The female is slightly larger than the male. The eyes of the female are dichoptic, while those of the male are holoptic. As a whole, the fly has a non-metallic, dark grey color. When at rest it overlaps its wings, which gives it a linear appearance. The antennae are rather small, the proximal segments are of a reddish color. The parafacials, or genae, are setose down to the ventral margin of the eye. The adult is easily recognized when it is in the newly emerged condition, by the coat of curly yellow hair on the dorsum of the thorax. This pile, however, is easily rubbed off. The thorax is without distinct stripes and there are two pairs of anterior acrostical bristles, two anterior and three posterior dorsocentrals, one posthumeral and one presutural. The fourth longitudinal vein of the wing (Media 1 and 2) is sharply bent. The abdomen is dark grey with irregular lighter patches."

Pollenia rudis is commonly known as the cluster fly (Muesebeck 1950, Colyer and Hammond 1968) although it has occasionally been referred to in the literature as the buckwheat fly (Felt 1917), the "bunch" or "honey" fly (Herrick and Griswold 1944) and the "attic fly" (Davis 1946).

B. Alimentary canal and food of the adult.

The anatomy and histology of the adult alimentary tract has been described by Jones (1942) and Singh and Judd

(1966). Jones maintained that the adult can only use liquid food since he regarded the salivary gland as too small to produce enough fluid for digesting solids.

Downes (1963) was unable to find a valve in the tracheal system in the neck region of P. rudis and this, together with studies on other calliphorids, led Downes to conclude that the rostrum of calyptrate Diptera is protracted by the direct action of a pair of rostral protractor muscles and not by the action of air or blood pressure.

DeCoursey (1927) recorded the fly as feeding on decaying fruits, the sap from shrubs and trees and the moist pith of cornstalks. Heming (1971) stated that the flies feed on the nectar of early flowers and the sap from maple and other trees. Séguy (1934) stated that the adults ordinarily feed on flowers but are occasionally coprophagous or saprophagous. Coffey (1966) reported an isolated instance of the fly being found on human excrement. Stewart and Leonard (1916) found the flies on apple, peach, pear and quince nursery stock during the summer. Steiner (1962) also recorded the flies on apple trees in the summer. In the laboratory, the flies have been fed on decaying fruits (DeCoursey 1927), bananas (Kisliuk 1917) and a mixture of powdered milk and granulated sugar (Pimentel and Epstein 1960).

The fly has been found on the flowers of Aralia racemosa Linnaeus, Cornus alternifolia Linnaeus, Cornus

stolonifera Michaux (Lovell 1898), Fagopyrum esculentum Moench (Felt 1917), Asclepias sp. (Weis and Dickerson 1921; DeCoursey 1927; Frost 1965; Judd 1968), Cornus amomum Miller, Erigeron canadensis Linnaeus, Philadelphus grandiflorus Willdenow, Salix cordata Michaux, Stellaria media Cyrillo (Robertson 1928), Melilotus alba Desrousseaux (Stewart 1930; Jones 1942), Angelica sylvestris Linnaeus, Lycopus europaeus Linnaeus, Oenanthe crocata Linnaeus, Sambucus nigra Linnaeus (Day 1948), Brassica rapa Linnaeus (Hall 1948), Senecio jacobaea Linnaeus (Harper and Wood 1957), Aster sp., Solidago sp. (Tyler 1961), Chrysantheum leucanthemum Linnaeus (Judd 1965), Eupatorium perfoliatum Linnaeus (Judd 1968a) and Daucus carota Linnaeus (Judd 1969).

In attempts to find chemical attractants for the fly, it has been shown that there is some slight attraction to amyl acetate (DeCoursey 1927) and ethyl malate (Marshall 1930). The adults have also been caught in traps baited with apple or banana (DeCoursey 1927) or malt extract (Judd 1956).

C. Response of adult to light, temperature, wind and atmospheric pressure.

During the summer, Pimentel and Epstein (1960) net-captured P. rudis most easily in the mornings on the east side of white-coloured farm buildings. They found that collections were best on warm mornings, sunny or cloudy, and poorest on those that were rainy, windy or cool (below

15°C.). Wellington (1946) showed that the antennal aristae of P. rudis are sensitive to small changes in atmospheric pressure and suggested that this may partly explain the scarcity of flies on wet days.

DeCoursey (1927) determined that the adult is negatively phototropic below 10° C., positively phototropic above 10° C. and positively thigmotropic below 10° C. DeCoursey maintained that these reactions account for the flies crawling into dark confined spaces in late autumn and also to their forming the clusters, from which their common name is derived. The postures adopted by Pollenia sp. in response to moving objects, the so-called "optomotor response" has been discussed by Gaffron (1934). Zeigler (1960) extracted light sensitive tetrahydrobiopterins from P. rudis and suggested that these substances may be important in the ability of the insect to perceive ultra violet light.

D. Overwintering.

Pollenia rudis adults have been recorded as overwintering in the old tunnels of wood-boring insects (Dennys 1927), behind bark and the sheaths of cornstalks (DeCoursey 1927), in birds' nests (Nordberg 1936; Woodroffe 1953), in cracks in timber (Twinn 1942), in hollows in trees (Kearns 1942; Chadwick 1972), under fallen leaves (Séguy 1941) and man's homes and buildings (Tyler 1961; Blakitnaya 1962; Dondero and Shaw 1971).

The overwintering flies survive on their fat reserves and remain in their refuges until the spring (DeCoursey 1927) although they can sometimes be found in the open on warm winter days (Roberts 1930; Mail and Schoof 1954; Blakitnaya 1962) or inside on window panes when the warmth of the sunshine, or household heating, induces them to crawl out from between the window frames (Lakon 1919; Wilhelmi 1920). A similar "overwintering activity" has been reported for Phormia regina Meigen (Wallis 1962). Argo (1939) showed that overwintering P. rudis exhibit an increase in oxygen consumption with an increase in temperature.

E. Number of generations each year.

Keilin (1915) reported one generation per year in Paris, but thought that there might be an additional summer generation. In the northern United States, Webb and Hutchison (1916) tentatively concluded that there are four generations per year. DeCoursey (1927) and Judd (1956, 1958) stated that the flies are most abundant around the first week of November; this representing the fourth or overwintering generation. Kisliuk (1917) kept adults alive, with banana as food, for 94 days.

F. Reproductive system and reproduction.

The arrangement of the abdominal sclerites, together with that of the male and female genitalia and its associated musculature, has been described by Snodgrass (1935). Lobanov

(1969) has compared the arrangement of the sclerites on the ovipositor of P. rudis with that of other species of Pollenia. The fully-extended ovipositor is about 1.7 mm in length (DeCoursey 1927). The male external genitalia has been described by several authors and figures prominently in taxonomical studies (Mercier 1927, 1930; Lehrer 1963).

Flamary (1917) stated that no reproductive development occurs in the overwintering fly. Roubaud (1927) described P. rudis as a heterodynamic insect, where general activity and development is arrested at a particular generation, independently of the temperature, but coinciding with the onset of winter.

The structure of the male reproductive system has been described by DeCoursey (1927) who stated that sperm is produced continuously in the overwintering fly.

The structure of the female reproductive system has been described by Keilin (1915) and DeCoursey (1927). There is little development of the ovaries during the winter (Kisliuk 1917; DeCoursey 1927). Barnes (1924) and Roubaud (1927) thought that fertilisation occurs in the autumn, whereas DeCoursey (1927) was unable to find sperm in the spermathecae of overwintering females and concluded that fertilisation occurs in the spring.

DeCoursey (1927) and Hammond (1940) observed P. rudis copulating in the open in the warm spring sunshine. DeCoursey briefly described the behaviour associated with copulation.

Pollenia rudis oviposits in the soil and the process has been described in detail by DeCoursey (1927, 1951). Similar observations on oviposition have been made by Webb and Hutchison (1916), Kisliuk (1917), Barnes (1924), Garrison (1924), Britten (1934) and Blakitnaya (1962).

G. Egg.

The egg has been described by Keilin (1915) and DeCoursey (1927). Eggs are reported as hatching after four to five days (Keilin 1915), three days (Webb and Hutchison 1916) and two to three days at 27° C. and 100 per cent. R.H. (Pimentel and Epstein 1960).

H. Larvae.

The literature shows that very little is definitely known about the feeding habits and development of the larvae of P. rudis. Although Keilin (1915) has given a comprehensive account of the parasitic development of the larvae in the lumbricid earthworm Allolobophora chlorotica (Savigny), other workers have reached very different conclusions on how the larvae feed and develop.

Pollenia rudis has three larval instars (Keilin 1915;

DeCoursey 1927). The external morphology of the first instar has been described by Keilin (1915), Tao (1927) and DeCoursey (1927); the second by Keilin (1915); and the third by Keilin (1915), James (1947) and Greene (1956). The internal structure of the larvae has been described by Keilin (1911, 1912, 1915, 1944).

Keilin (1909, 1911, 1915) was the first to record parasitism of earthworms by the larvae of P. rudis, although parasitism of earthworms by dipterous larvae, other than P. rudis, had been known for some time (Dugès 1837; Hoffmeister 1845) and is well documented in recent work by Fuller (1933), Kirchberg (1954), Eberhardt (1955), Krivosheina (1961) and Takano and Nakamura (1968). Colless and McAlpine (1970) speculated that all species of Pollenia are probably parasitic on earthworms.

The following is a brief account of Keillin's findings on the larval stages of P. rudis. The larval stages are parasitic in the lumbricid earthworms Allolobophora chlorotica (Savigny) or Allolobophora rosea (Savigny). Eggs are laid in the soil in late summer and hatch after about four or five days. The larva enters the seminal vesicles of the earthworm by the male genital pore. Keilin suggested that the diffusion of seminal fluid and epidermal secretions from the earthworm into the surrounding soil may play a part in guiding the larvae to their hosts. The larva remains in the seminal

vesicles during the winter. In the spring the larva becomes active and cuts its way forward, by means of its mouth hooks and cuticular spines, through the body cavity of the earthworm to the prostomium. Reaching the prostomium, the larva cuts through the cuticle so that its posterior abdominal spiracles are exposed. Migration and perforation takes about two days. Once perforation has occurred, the host ceases to feed or to move about in the soil. The larva moults to the second instar about eight days after perforation. The second and third instars each last for about nine days and both feed voraciously. The third instar eventually separates from the earthworm and pupates in the soil. A single earthworm can only support one larva to the pupal stage. Larvae which have entered an earthworm are frequently surrounded by cysts; the cysts being a form of defence reaction against the larvae.

Webb and Hutchison (1916) examined A. chlorotica taken from the field during the autumn and spring but were unable to find any dormant larvae as described by Keilin. In mid June they found infested A. chlorotica and noted that the larvae could penetrate the earthworm at almost any point. Kisliuk (1917) was also unable to find any parasitised A. chlorotica during the winter.

It has proven difficult to rear larvae on earthworm in the laboratory. Webb and Hutchison (1916), Garrison (1924) and DeCoursey (1927) placed eggs in an assortment of boxes

and flower pots containing soil and earthworms and managed to secure the emergence of a few flies, even though the duration and behaviour of the larvae could not be easily determined. Moreover, only first instar larvae were ever actually observed feeding on earthworms. Pimentel and Epstein (1960) developed a more satisfactory method of laboratory rearing, whereby earthworms and larvae are placed together in small glass vials. By this method they could observe the larvae directly, without undue disturbance to the earthworms, and secure flies under more controlled conditions.

Garrison (1924) reared the larvae on A. chlorotica and secured a few flies. The larvae did not appear to be confined to any particular region of the earthworm.

DeCoursey (1927) observed first instar larvae penetrating the cuticle of A. rosea. Parasitism usually occurred about two days after the larva had left the egg. The larvae never entered entirely within the earthworm and the posterior abdominal spiracles were always exposed. Penetration occurred posterior to the clitellum and frequently the larvae would withdraw from the wound.

DeCoursey (1927a) observed larvae penetrating Allolobophora calignosa (Savigny). Penetration was directly through the cuticle and various stages of penetration were noted from the time the mouth hooks were embedded until only

the posterior abdominal spiracles were exposed. Penetration usually occurred in the anterior region of the earthworm and the larvae were only seen to enter through its dorsal surface. Although larvae usually entered through the intersegmental furrows, they were seen to enter through the thicker parts of a segment as well as through the clitellum. Up to five larvae were seen to feed on a single earthworm.

Pimentel and Epstein (1960) found that larvae could penetrate and feed on A. rosea. However, successful penetration only occurred in segments behind the clitellum. A larva could reach maturity on a single A. rosea, although larvae could feed on as many as three A. rosea when larger pupae resulted. Larvae could also feed on Lumbricus terrestris Linnaeus, Lumbricus rubellus Hoffmeister, Octolasium lacteum (Oerley), Diplocardia communis Garman, Eisenia foetida (Savigny) and A. calignosa provided that the cuticles of these earthworms had been damaged.

In contrast to the statement by Keilin (1915) that the first instar larvae remain in the seminal vesicles for the duration of the winter, the duration of the larval stage has been given as three to 22 days (Webb and Hutchison 1916) and 21 days at 19° C. (Pimentel and Epstein 1960).

The larvae have been recorded as parasitising birds (Girschner 1893), the pupae of Dendrolimus pini Linnaeus

(Lebedev and Savenkov 1930) and the pupae of Chondrostegia maghrebrica Joan (Séguy 1934). The larvae have also been reported in "association" with the larvae of the cabbage maggot Hylemia brassicae Bouché (Pond 1956), the army worm Pseudaletia unipuncta Hawthorne (Pond 1960) and the crabonine wasp Ectemnius continuus F. (Krombein 1963). Séguy (1928) reported that a specimen of Pollenia sp. had been found in "relation" to the noctuid moth Sesamia nonagrioides Lefebvre.

Howard (1901) reported that he had "bred" a single fly from cow dung. Blackman and Stage (1918) suggested that the larvae can feed on the decaying frass of bark and wood-boring insects. DeCoursey (1927) stated that the larvae could not develop on cow dung, horse manure, decaying roots of grass in soil, decaying meat or dead earthworms. Tao (1927) was unable to rear the larvae on any common blowfly media. Felt (1910) stated that the larvae lived around the roots of grasses and Guyer et al (1956) reported the emergence of an adult fly from grass silage.

DeCoursey (1927) concluded that the larvae feed only occasionally on earthworms and when not feeding are free living in the soil. Séguy (1934) considered the fly to be too abundant to be an obligate parasite of earthworms and concluded that the larvae are saprophagous and, depending on circumstances, are occasionally parasitic on earthworms and various soil invertebrates.

I. Pupa.

The pupa has been described by Keilin (1915) and briefly by DeCoursey (1927). The duration of the pupal period has been reported as 30-40days (Keilin 1915), 11-14 days (Webb and Hutchison 1916) and seven days at 26° C. and 100 per cent. R.H. (Pimentel and Epstein 1960). Pupae have been found in the soil at a depth of 8 cm (Riley and Howard 1893) and five to 15 cm (Kisliuk 1917). Webb and Hutchison (1916) speculated that the pupae might be able to overwinter.

J. Mortality factors.

Almost nothing is known of the mortality factors affecting P. rudis. There are a few recorded predators and parasites of P. rudis in the literature together with some comments on the effect of weather. Heming (1971) remarked that the rate of mortality of overwintering adults was not known.

DeCoursey (1927) regarded weather as the main natural control of P. rudis with adults being killed by the cold in winter and larvae drowning in the soil after prolonged rain in the summer.

The flies are often parasitised and killed by the fungus Entomopthora muscae (Cohn) (Marlatt 1891; Spencer 1928; Judd 1955; Kramer 1971). Lakon (1919) stated that this fungus can spread more rapidly under humid conditions and

that it can survive the winter in the bodies of the overwintering adults of P. rudis.

The fly is parasitised by the protomonid Herpetomonas muscaedomesticae (Burnett) (Léger 1903; Pierce 1921) and the microsporidian Octosporea muscaedomesticae Flubert (Kramer 1964). The pupa is parasitised by the diaprinid wasp Trichopria brevipennis Kieffer (Keilin 1915).

The fly is recorded as being preyed upon by ants (DeCoursey 1927), the European mantid Mantis religiosa Linnaeus (James 1959), the ambush bug Phymata pennsylvanica coloradensis Melin (Knowlton 1947), the sphecid wasp Crabro advenus Smith (Evans 1960; Kurczewski and Acciavatti 1968), the common yellow coprophilous fly Scatophaga stercoraria Linnaeus (Hewitt 1914), the crab spiders Misomenops asperatus (Hentz) and Misumena vatia (Clerck) (Judd 1965) and birds (Kearns 1942).

Judd (1959) found P. rudis trapped in the pitcher plant Sarracenia purpurea Linnaeus. The flies are often trapped by the pollinial apparatus of milkweeds Asclepias sp. (DeCoursey 1927; Frost 1965; Judd 1968).

K. Distribution.

Pollenia rudis is widely distributed in Europe and North America (DeCoursey 1927; James 1947; Cole 1969). MacNay (1954) has given a distribution map for the fly in

Canada (Fig. 1). Strickland (1937) noted that P. rudis was first recorded in Alberta in 1936. The fly has also been recorded from North Africa (Séguy 1930), Hawaii (Joyce 1956) and the U.S.S.R (Petrovka 1968; Sychevskaya and Vtorov 1969) including Siberia (Veselkin 1966).

Lintner (1892) speculated that the fly was introduced into North America from Europe. Dall (1884) reported that it first made its appearance in the state of New York in about 1853 and Cockerell (1924) maintained that the fly became a problem in Colorado when European species of earthworms were brought in with plants.

L. Pest status

The Canadian Insect Pest Review shows that P. rudis has proved to be a continuing source of annoyance in dwellings in the autumn and, to a lesser extent, in the spring. Infestations in Canada have largely been recorded from Ontario and Quebec, especially from rural areas.

It appears that some years are marked by a particular abundance or scarcity of the flies (Allan 1968, 1969). Strickland (1937) noted that P. rudis was far less abundant in northern Alberta in 1937 than in 1936 and suggested that this was due to a severe drought that may have killed earthworms or have caused them to burrow too deeply for larvae to reach them. Similarly, MacNay (1966) maintained

that the scarcity of P. rudis in eastern Ontario in the autumn of 1966 was probably due to the poor establishment of the larvae on earthworms during the unusually dry summer. According to James (1947) the flies tend to be more troublesome in the more northern parts of their range.

Tyler (1961) remarked that there appears to be no particular feature of building structure which is common to infested buildings, although he noted that the flies are frequently found in isolated buildings in rural areas and suggested that this may be due to these buildings providing the nearest sunlit surfaces available for the flies to sun themselves. Kearns (1942) and Pimentel and Epstein (1960) noted that the flies are frequently encountered in buildings in rural areas.

Populations of P. rudis have been recorded as invading the same building for several years in succession (Riley 1883; Kearns 1942; Oldroyd 1964). Oldroyd noted that although a building may be invaded annually by the fly, one nearby may remain exempt from such visits. Oldroyd considered it possible that buildings which are repeatedly invaded may be selected by virtue of their location and dimensions and also that the flies may leave an attractant odour which attracts them to the same site in the following year. Tyler (1961) reported an unsuccessful attempt to encourage a cluster by painting crushed P. rudis on roof timbers where these flies had

clustered in previous years. Old and new houses may be invaded by the flies (Spencer 1928; Dondero and Shaw 1971).

Spencer (1928) recommended the removal of dead cluster flies from homes as they can act as food sources for dermestid beetles such as the museum beetle Anthrenus museorum L. and the larder beetle Dermestes lardarius L.

MacNay (1959) stated that P. rudis is attracted to few foods consumed by humans and so is unlikely to be a disease carrier. Studies have been made of the correlation between the occurrence of poliomyelitis epidemics and the prevalence of flies, including P. rudis (Power et al 1943; Power and Meinick 1945), although no direct proof that such insects act as natural reservoirs for the viruses was found.

Matthew (1961) cautioned that some reports of infestations of P. rudis may actually have been due to Musca autumnalis DeGeer. MacNay (1963) reported the case of a building in which overwintering P. rudis and M. autumnalis were found in approximately equal numbers. Shewell (1961, 1963) pointed out that Pollenia vagabunda Meigen, which has only very recently been recorded in Canada, is often mistaken for P. rudis. Other flies in buildings are also commonly confused with P. rudis (Chadwick 1972).

M. Insecticidal control.

Insecticides such as pyrethrum (Mann 1882; Lintner 1892; Riley and Howard 1893; Felt 1917), nicotine (Parrot 1914), HCN (Graham-Smith 1918), thiocyanates (Kearns 1942) and DDT (Harman 1946; Haseman 1947; Spencer 1947; Parkin 1958) have been used to kill the adults once they have gained access to buildings. Recent papers have stressed the importance of sealing entry points for the flies into buildings together with recommendations on the use and application of various organophosphorous insecticides (Tyler 1961; Hickin 1964; Rachesky 1969; Heming 1971; Chadwick 1972). It appears impracticable to direct chemical control measures against larvae in the soil (Kearns 1942; Chadwick 1972).

III. MATERIALS AND METHODS

A. Maintaining adults at 27°C.

The method employed by Pimentel and Epstein (1960) was closely followed. Each cage (Fig. 2) consisted of a glass jar with the opening closed with nylon netting secured with a strong elastic band. Food was a 1:1 mixture of powdered skim milk and granulated sugar in a petri dish. Pieces of pig liver were placed in some of the cages. Water was provided in a petri dish containing wet absorbent cotton wool. A petri dish containing damp peat loam was provided as a site for oviposition. About 12 females and 12 males were placed in each cage. The cages were illuminated by two 40 watt white fluorescent light strips which were placed 12 cm above them. The lights were switched on at 10.00 a.m. and off at 10.00 p.m. each day. The average temperature in the cages throughout the 24 hours was 27° C.

B. The Chalet and Observatory

The chalet (Fig. 3) is about three kilometers from the Macdonald Campus and is situated in a clearing bounded by trees. The building is made of log and stone and has a wood-shingled roof. The wood-framed windows are covered by wood-framed wire fly screens. The screens were slightly loosened in the last week of August 1971. Apart

from the occasional log-fire, the building was unheated throughout the period of study. The overall colour of the building is dark-brown.

The McGill Radar Weather Observatory (Fig. 4) is located about two kilometers from the Campus. It is situated in pasture land and, with a height of 36 meters, is the tallest building in the area. Three walls of the tower are almost completely taken up by windows. There is open communication between the tower and dome. The tower and dome are unheated. The overall colour of the building is white. The observatory was built in 1968.

C. Collection of adults

Adults were net-captured in the open during the summer of 1970 and 1971. The area over which flies were captured was arbitrarily confined to the outer walls of the chalet and the clearing around the chalet. Flies were transferred to glass vials and brought back to the laboratory where they were sexed and counted. Sexing was performed by noting the arrangement of the compound eyes. In females the eyes are dichoptic whereas in males they are holoptic. Note was taken of when flies first appeared in the open in the spring and when they made their last appearance in the open in the autumn.

Adults were collected from the inside of windows and in window frames in the chalet in the autumns of 1970 and 1971 and in the spring of 1971. Flies were caught individually in glass vials and brought back to the laboratory where they were sexed and counted. Daily fly catches in the chalet in the autumn of 1971 were compared to the daily minimum air temperature. Temperature data was obtained from the Department of Agricultural Physics of the Macdonald Campus. Temperatures were recorded at a location about one kilometre from the chalet.

Adults caught in the chalet in the autumn of 1971 were divided into three groups according to the quantity of golden-coloured epicuticular hairs on the thorax. The first group consisted of flies with a dense covering of hairs (Fig. 5A), the second with almost a complete absence of hairs (Fig. 5B) and the third with a hair covering about half-way between that of the other two groups.

Spiders and other species of insects present in the chalet in the autumn of 1971 were collected and identified.

General observations on the occurrence and behaviour of P. rudis in the observatory in the autumn of 1971 were made. A random sample of 325 dead flies was collected from the floor of the dome of the observatory on October 4, 1971 and the percentage of phycomycosis in the sample determined.

The criteria used for determining fungal infection were splayed-out legs, an extended proboscis and a definite distension of the abdomen. Only flies exhibiting these features were considered to have been infected. To ensure that recently-killed flies were chosen for the sample, the floor was completely cleared of dead flies with a vacuum cleared on October 2.

D. Questionnaire

A questionnaire (Table 1) was devised in an attempt to determine the types of buildings which are invaded by P. rudis. Questionnaires were distributed to pest control companies throughout North America by the Canadian and American Pest Control Associations.

E. Artificial overwintering at 4°C.

Pollenia rudis adults caught in the autumn of 1970 were stored in the dark, without food and water, in plastic petri dishes (13 X 55 mm) at 4°C. and 80 per cent. R.H. The lids were perforated and sealed down with transparent adhesive tape. About ten flies, the sexes being kept separately, were stored in each petri dish. The flies were examined at fortnightly intervals at room temperature (about 22°C.) and the number of dead flies counted. Flies which remained completely inactive after 30 minutes at room temperature were considered to be dead. No flies were kept at room temperature, for any one observation, for more than

30 minutes.

Ten females which were caught in the chalet in the last week of September and stored at 4 °C. for three weeks were examined for the presence of sperm in their spermathecae. This was performed by dissecting out the spermathecae, crushing them in a drop of distilled water between a slide and cover slip and observing them under a compound microscope at 700X magnification.

In the spring, flies were transferred to cages at 27 °C. and provided with milk powder and sugar, water, peat loam in which to oviposit and a 12 hour daily photoperiod (10.00 a.m. to 10.00 p.m.).

F. Ovipositor

Hairs on the ovipositor were examined with a dissecting microscope and a 2A-Cambridge scanning electron microscope. In both cases the ovipositors were first extended by gently pressing the abdomen of the flies and then cutting them off at their bases. The ovipositors remained extended after this treatment. Ovipositors were mounted on glass capillary tubing for examination under the dissecting microscope. Six ovipositors were examined with the scanning electron microscope. Ovipositors were prepared for electron microscopy by freeze-drying for 36 hours at -50 °C. and 0.002 (torr.) followed by gold-plating under vacuum.

G. Egg

Eggs were incubated as follows. Peat loam, with contained eggs, was transferred by means of forceps to a shallow bowl containing distilled water. The water was gently stirred to loosen eggs from the peat loam and the eggs then sucked into a Pasteur pipette and deposited on the surface of moist filter paper at the bottom of a petri dish. The dishes were then transferred to a sealed glass container at 100 per cent. R.H. and kept at 25 °C. The dishes were examined each day under a dissecting microscope and first instar larvae were removed with a fine camel-hair brush.

Egg size was determined by placing 50 unhatched eggs in a drop of distilled water and measuring their greatest length and maximum depth (maximum distance between convex and concave surfaces of the egg) under a dissecting microscope fitted with an eye-piece micrometer. Eggs which had collapsed due to dehydration were discarded.

Eggs were compared to drawings given by Keilin (1915) and DeCoursey (1927). The surface structure of the egg was examined with a 2A-Cambridge scanning electron microscope. A compound microscope was used to elucidate the structure of the chorion in transverse sections of the egg. Eggs were prepared for scanning electron microscope as follows. Eggs were rinsed in distilled water to remove peat

loam which had stuck to the egg. This was necessary since eggs stick firmly to surfaces on drying. Eggs were then glued to pieces of card, freeze-dried for 36 hours at -50°C. and 0.002 (torr) and then gold-plated under vaccuum. Transverse sections of the egg were prepared after the method of Huebner and Anderson (1970) and examined under a compound microscope.

H. First instar larva

Twenty-five live first instar larvae were mounted in distilled water and examined under a compound microscope at 700X magnification. The general morphology of these larvae was compared to drawings given by Keilin (1915).

The length and maximum width of 25 living first instar larvae were measured within 12 hours of their emergence. The larvae were measured when they appeared to be fully extended. The larvae were placed in a film of distilled water between a slide and cover slip and measured under a dissecting microscope fitted with an eye-piece micrometer.

I. Rearing trials with Allolobophora chlorotica

1. Handling the earthworm

The lumbricid earthworm A. chlorotica can be readily identified (Gerard 1964) and is commonly found in the

Morgan Arboretum. The earthworms were hand-collected from the top 15 cm of soil in the clearing around the chalet. They were then transferred, together with some soil from which they were collected, to wooden boxes (30 X 20 X 20 cm), and placed in the dark in an incubator at 22°C. and 95 per cent. R.H. To ensure that the soil remained damp, the boxes were placed in troughs of water to a depth of about five centimeters. Earthworms were taken from the boxes when required for rearing experiments with first instar larvae of P. rudis.

2. Rearing chambers for the larvae

Four types of rearing chambers were used in attempts to rear first instar larvae on live mature A. chlorotica. Chambers were kept in the dark and only one earthworm was used in each chamber. Earthworms were examined in their chambers with a dissecting microscope at least once a week for two months.

a. Pimentel and Epstein chamber

Although Pimentel and Epstein (1960) successfully reared P. rudis on earthworms using this method they did not work with A. chlorotica. The chamber (Fig. 6A) consisted of a glass vial (35 X 11 mm) which was one-third filled with a stiff agar (5 gms in 100 ml of water). An earthworm was placed on the agar. Ten first instar larvae were applied to

each earthworm by means of a fine camel-hair brush. The rest of the vial was then loosely-filled with pieces of well-rotted maple leaves and the vial loosely-stoppered with a cork. Vials were placed in a large sealed glass container at 100 per cent. R.H. in an incubator at 19°C. Twenty-five chambers were used.

b. Plaster of Paris chamber

The chamber (Fig. 6B) consisted of a Plaster of Paris cavity sealed with a solid Plaster of Paris lid. Chambers were moulded in plastic petri dishes. The cavity was formed by clamping a glass vial in the centre of a petri dish before pouring the plaster. The plastic was cut away with a hot needle after the plaster had solidified. Chambers were sandpapered and washed to improve porosity. Ten first instar larvae were placed on each earthworm and the cavity loosely filled with moist peat loam. The lid was secured to the cavity with a strong elastic band to prevent the earthworm from crawling out. Chambers were placed in a large sealed glass container at 100 per cent. R.H. Twelve chambers at 19°C. and 12 chambers at 23°C. were used.

c. Petri dish chamber

The chamber (Fig. 6C) consisted of a plastic petri dish (34 X 12 mm) with a 20 mm diameter ventillation hole in the lid screened with fine nylon netting. The netting

was secured to the lid with nail varnish and the petri dish and lid held together with a strong elastic band. An average of 30 first instar larvae were applied to the surface of an earthworm and the chamber loosely filled with soil (the same soil in which the earthworms were collected). Chambers were transferred to a large sealed glass container at 100 per cent. R.H. Twenty five chambers at 21°C. and 25 chambers at 23°C. were used.

d. Glass vial chamber

The chamber consisted of a glass vial (40 X 22 mm) with a perforated plastic lid. A 1:1 mixture of peat loam and soil (the same soil in which the earthworms were collected) was placed in the vial. An earthworm was placed in the vial and an average of 50 first instar larvae were added to the soil and peat-loam mixture. Chambers were kept in an incubator at 95 per cent. R.H. and 21°C. Fifteen chambers were used.

IV. RESULTS

A. Flies in the open

During the period May, June, July and August 1970, 269 P. rudis were net-captured on the walls of the chalet and in the clearing around the chalet (Table 2). The sex-ratio for the four months was 1:1. Only nine flies were caught from the same area during the same period in 1971 although the number of sorties with the net were only slightly fewer than in 1970.

Throughout the summer P. rudis were most easily caught in the mornings (7.30 to 10.30 a.m.) when they were found sunning themselves on leaves, tree-trunks, foot-paths and especially on the walls of the chalet. Almost no flies were found on rainy or windy mornings, although they were occasionally found on overcast mornings provided it was above 18° C.

During the last three weeks of October 1970 flies were not only found sunning themselves on the outside walls of the chalet in the mornings but increasingly during the afternoon and early evenings as well. This also occurred in 1971, but then the presence of flies was extended into the first week of November. Flies were last seen in the open in the first week of November, both in 1970 and 1971.

In the spring of 1971 three P. rudis were first found on the outside walls of the chalet on April 17. Three more were found crawling in the grass about four meters from the chalet on April 26.

B. Flies in the chalet

Pollenia rudis were first found on the inside of windows on September 2 (two flies) in the autumn of 1970 and on August 26 (five flies) in 1971. The last appearance of the flies inside on the windows was October 4 (ten flies) in 1970 and November 1 (14 flies) in 1971. Flies also appeared inside on the windows in December when the building was heated with a log fire.

The first appearance of P. rudis inside the chalet on August 26 coincided with a period when the minimum daily air temperature fell below 10° C. (Fig. 7). P. rudis continued to enter the chalet through September and October when minimum daily air temperatures were usually below 10° C. Fig. 7 also shows that the greatest number and activity of P. rudis inside on windows in the chalet was on October 28, when the maximum air temperature was 22° C.

The number of male and female P. rudis collected in the windows in the autumn of 1970 and 1971 is summarised in Table 3. There was a considerable increase in the number of P. rudis caught on the inside of windows in the chalet in

the autumn of 1971 (3225 flies) in comparison to the previous autumn (687 flies). The sex ratio for both years was 1:1. The sexes were found in almost equal numbers, for any daily catch, in the chalet in the autumn of 1971 (Fig. 8). There was a wide variation in the quantity of golden-coloured epicuticlar hairs on the thoraces of P. rudis collected in the chalet in the autumn of 1971 (Fig. 9). This figure also shows that males had less epicuticular hair covering than females. Epicuticular hairs are easily removed with a dissecting needle.

Clusters of P. rudis (Fig. 10) were found in window gaps in the autumn of 1970 and 1971. Accumulations of excreta were present in window gaps where P. rudis had clustered (Fig. 11). Vomit and excreta were also copiously deposited on the window panes. Both sexes were represented in a cluster. The clusters were composed of P. rudis with varying quantities of epicuticular hairs on their thoraces. Three clusters made up exclusively of small-sized P. rudis were found between windows and their frames in the chalet. These clusters occurred in particularly narrow parts of a window gap. In wider gaps, clusters composed of P. rudis of all different sizes were observed. No P. rudis were found in window gaps where the windows fitted tightly to the frames.

A cluster made up of P. rudis and Phormia regina (Meigen) was found in a window gap on August 27, 1971.

The cluster was composed of about 50 flies and the two species were present in about equal numbers. On September 13, 1971, a cluster of about 50 P. rudis was found mixed with three Muscina assimilis Fallen and two Adalia bipunctata Linnaeus.

A wide variety of insects were found inside chalet windows in the autumn of 1971 (Table 4) although they were not so numerous, either individually or collectively, as P. rudis. No specimens of P. vagabunda were found inside or outside the chalet throughout the period of study. Four species of spiders (Table 5) were also found inside windows in the autumn. Only about 25 P. rudis were found dead in webs.

Live nymphs of Carpoglyphus, probably lactis (Linnaeus) (Acaroidea:Carpoglyphidae) were found among the golden-coloured epicuticular hairs on the thoraces of five live P. rudis (Table 6) inside the chalet on October 19, 1971. The distribution of nymphs on the thorax of the most heavily covered P. rudis is shown in Fig. 12. Nymphs could easily be dislodged with a pin. The nymphs were lethargic and made little response when prodded. The nymphs were not killed by storage with the flies for a week at 4° C. Ten mounted nymphs (Lot 71-664) are retained in the Canadian National Insect Collection in Ottawa.

On October 19, 1971 a live male P. rudis was found in the chalet with its ptilinal sac everted (Fig. 13). In other respects the insect appeared normal. The fly was apparently an old one since epicuticular hairs were almost completely absent from its thorax. This was the only example of P. rudis found in this condition in some 4,500 specimens which were collected throughout the period of this study.

The observed first and last appearance of P. rudis in the chalet windows in the spring of 1971 was March 17 and May 6 respectively (Table 7).

C. Flies in the observatory

On warm, sunny days in the autumn of 1971 P. rudis were commonly found in the tower and dome of the observatory. Most flies were found towards the top of the tower and in the dome, especially on the sunlit surfaces. An indication of the number of P. rudis present in the observatory on these warm autumn days can be gained from Fig. 14. The greatest number and activity of P. rudis observed was on October 28, when the highest air temperature reached during the day was 22° C. The infestation on this date was spectacular since the noise produced by flies colliding with the roof of the dome sounded like the impact of heavy rain. Flies died in large numbers during these warm periods. When three to four hundred dead flies were collected in a container they

gave off a sharp offensive odour. Clusters of P. rudis were commonly found in window frames in the tower (Fig. 15).

Close examination of the tower and dome revealed several points of entry by which flies could gain access to the building. Principally these were gaps around ill-fitting metal windows, a wire fly-screen covering which inadequately covered a service hatch in the floor of the dome and spaces between the concrete blocks making up the structure of the tower.

Staff at the observatory reported heavy infestations of "flies" (probably P. rudis) in the autumn of 1969 when the construction of the observatory was fully-completed and also in the autumn of 1970.

D. Phycomycosis

During the summer of 1970 flies collected from the Arboretum died of a fungal disease after a few days in the laboratory. This curtailed work on the flies that summer. Dead flies typically displayed an extended proboscis, splayed out legs and a bloated abdomen (Fig. 16). The bell-shaped spores had a sharply pointed apex and a truncated base.

Dead fungal infected flies were found attached on the inside of windows in the observatory in the autumn of 1971. A white-coloured spore halo on the window surrounded each

dead fly. The extent of phycomycosis in the sample of 325 dead P. rudis collected from the observatory on October 4, 1971 is summarised in Table 8. Phycomycosis was demonstrated for 36 per cent. of the flies.

On November 1, 1971 a live male P. rudis collected in the chalet and brought back to the laboratory was observed in the early stages of phycomycosis. At 1.00 p.m. the fly was still alive but maintained its head in contact with the bottom of the glass collecting vial. The abdomen was also raised and the legs extended. At 1.15 p.m. the fly was dead and the wings were set in the upraised position. At 4.30 p.m. the abdomen was slightly swollen and fungal infection was evidenced by rings of white-coloured conidiophores in the intersegmental regions of the abdomen. By 6.00 p.m. the abdomen was considerably distended (Fig. 17) and spores were observed being discharged under a dissecting microscope in a darkened room. After a further 14 hours the fungus had collapsed and the abdomen had almost reverted to its normal size. At this stage the conidiophores at the surface were light brown in colour and the form of the internal tissues of the insect were lost. Phycomycosis also occurred in flies stored at 4° C.

E. Questionnaire

Completed questionnaires were received from nine pest control operators in the United States. The results are summarised in Table 9.

F. Artificial overwintering at 4°C.

At 4°C. some P. rudis adults were observed to crawl about and to fly for about one meter when disturbed during handling. Fig. 18 shows the percentage mortality of 300 P. rudis adults (150 females and 150 males) which were kept for 21 weeks at 4°C. One female survived for 33 weeks at 4°C. The figure shows that females survived longer than males at 4°C. No sperm was found in the spermathecae of live females which had been kept at 4°C. for three weeks following their capture in the chalet in the last week of September.

G. Flies at 27°C. following artificial overwintering at 4°C.

Flies soon became active when they were transferred from 4°C. to cages at 27°C. in the spring. Most flies were observed walking, flying, feeding or drinking within five to ten minutes following the transfer. After about four days at 27°C. the flies appeared to adopt set periods of activity throughout the 24 hours. At night the flies were inactive and invariably rested in a cluster at the top of the netting. When the light was switched on at 10.00 a.m. the flies became active and started to feed and drink or to crawl or fly about. Activity declined from about 1.00 p.m. and by about 5.30 p.m. most of the flies had formed a cluster at the top of the netting. Almost no activity occurred up until the light was switched off at 10.00 p.m. and then throughout the night.

When males and females were placed together in cages, after separately overwintering at 4°C. for 21 weeks, females laid viable eggs after about 12 days. Most eggs were laid during the second and third week, although a few females were still laying eggs after two months.

Copulation was observed in three pairs of flies within eight days of their being brought to 27°C. (Table 10). The postures adopted by these flies during copulation is shown in Fig. 19. During copulation the flies remained still. At the end of copulation the males moved away from the females, whereas the latter remained in the same place for two or three minutes while they slowly protracted and retracted their ovipositors.

When pieces of fresh pig liver were placed in cages, the flies became agitated and a few females appeared to feed on the liver.

Two females survived for 13 weeks and another female survived for 16 weeks at 27°C. following storage for 21 weeks at 4°C. However, these three flies appeared old and exhibited tattered wings and reduced activity.

H. The ovipositor and oviposition

The appearance of the ovipositor, as seen in specimens mounted on glass capillaries, is shown in Fig. 20. This method of preparation shows the shape of the sclerites and the overall distribution of the large sensilla. Each segment bears a tergal and sternal sclerite with the area between consisting of pliable cuticle covered with microtrichae. The ninth abdominal segment bears two hollow anal leaflets.

Sensilla on the ovipositor are confined to the tergal and sternal sclerites and the anal leaflets. Fig. 21 shows that most of the sensilla appear to be articulated setae (sensilla trichodea in Schenk's classification of 1903) similar to those found elsewhere on the body. Scanning electron microscopy revealed two peg-like structures (Fig. 22) on the ventral surface of one of the anal leaflets in the six ovipositors that were examined.

Oviposition was not observed in the field. In the laboratory most eggs were laid in the peat loam in the ovipositing dishes, especially when it was kept moist. Eggs were frequently laid in the gap between the floor of the cage and the bottom edge of a petri dish. When the petri dish was removed a ring of eggs was then left firmly stuck to the floor of the cage. Sometimes eggs were deposited on the

netting, walls and ceiling of a cage, on liver and on the moist cotton wool which was provided as a source of drinking water.

An ovipositing fly usually walked quickly over the peat loam "testing" it with her ovipositor. Localised orientation movements also occurred during oviposition. Having selected a site the fly quickly laid a few eggs to a depth of about two milimeters in cracks and crevices in the peat loam. A fly would frequently curve her ovipositor and obtain support by resting on her wing tips (Fig. 23) in order to force her ovipositor into cracks. Egg laying at one spot usually took no longer than ten seconds after which the fly would move to another area of the peat loam to lay more eggs. Before laying eggs the fly would invariably brush her ovipositor with her hind legs.

I. The egg

The method of egg incubation proved satisfactory and several thousand first instar larvae were obtained. Eggs appeared to develop and hatch equally well whether they were incubated in the dark or not. Eggs hatched within three to four days at 25°C. and 100 per cent. R.H. Eggs also hatched when immersed in pools of excess water at the bottom of the petri dish. The length and depth (maximum distance between convex and concave surfaces of the egg) of 50 eggs is summarised in Table 11.

The form of the white-coloured egg, as seen with a dissecting microscope, is shown in Fig. 24. In lateral view, the dorsal surface is slightly concave and the ventral surface is convex. Two longitudinal ridges extend along the dorsal surface from the anterior end of the egg almost to the posterior end. The overall shape of the egg, as seen with a dissecting microscope, appears slightly different to the drawing given by Keilin (1915). Taking into account Keilin's drawing of the egg from the latero-dorsal position, the median area between the longitudinal ridges is too narrow to be typical of P. rudis, although this condition is approached in a collapsed egg. DeCoursey (1927) stated that "The surface of the egg with the exception of the ridges and the groove between them is finely etched into irregular figures." However, even with a dissecting microscope a definite patterning can be observed on the longitudinal ridges and, to a lesser extent, in the median area between the ridges as well. Furthermore, the surface of the chorion outside the longitudinal ridges is more regularly patterned than DeCoursey indicated in his drawings.

The scanning electron microscope clearly reveals the patterning on the outer surface of the chorion. The convex surface of the chorion, that is the area outside the longitudinal ridges is shown in Fig. 25. Its surface is indented with somewhat regularly arranged depressions which

run approximately parallel to the longitudinal axis of the egg. Within these depressions are further small indentations which represent the impressions left on the egg by the surface cells of the ovarian follicles. The surfaces of the longitudinal ridges present a perforated ramifying network (Figs. 26, 27, 28). The median area between the longitudinal ridges is similar, but less regularly arranged, to the chorion outside the longitudinal ridges (Fig. 27). It further differs in having a few evident perforations.

Transverse sections through the mid-region of the egg (Fig. 29) show that the internal structure of the chorion is basically a regularly-arranged meshwork. The meshwork appears to be more elaborate in the region underlying each longitudinal ridge and the median area (Fig. 30) than in the rest of the chorion (Fig. 31). The perforations which can be seen in surface view of the longitudinal ridges and median area are, in transverse section, seen to communicate with the open spaces of the underlying meshwork. Covering the outer surface of the chorion, except for the longitudinal ridges and the median area, is a densely-staining layer.

J. The first instar larva

The morphology of the first instar larva of P. rudis appears to be identical to drawings given by Keilin (1915). The length and maximum width of 25 fully-extended first instar larvae is summarised in Table 12.

While measuring first instar larvae in a film of water between a slide and cover slip, several larvae were observed to vigorously extend and retract their posterior abdominal spiracles (Fig. 32) into the surrounding water. Extension of the spiracles appeared to be associated with an increase in the hydrostatic pressure of the body fluid caused by a vigorous contraction of the body wall starting at the anterior end of the larva and progressively working backwards. Several larvae moved towards air bubbles in the water film provided they were close to them. Arriving at an air bubble, the larvae rapidly thrust their posterior abdominal spiracles into the air bubble or came to lie with their bodies closely applied to its surface. These larvae survived longer than those not in contact with an air bubble.

First instar larvae actively moved about in their incubating dishes. Larvae were commonly found between the filter paper and the bottom of the petri dishes when they had been incubated in the light. Also, larvae were frequently trapped in pools of water when excess water had been added

to the filter paper. Even so, larvae were not readily asphyxiated when caught in this way. Larvae exposed to air of low humidity quickly dehydrated and died. Larvae survived without food for at least 24 hours at 100 per cent. R.H. and 25°C. A yellow colour in the Malpighian tubules was noted in some of the larvae.

K. Rearing

A total of about 400 mature A. chlorotica were collected in the clearing around the chalet in the summer and autumn of 1970 and 1971, but no specimens were found with larvae of P. rudis protruding from the earthworms. At the height of summer A. chlorotica occurred deeper in the dry soil when they were found in an inactive and rolled-up state.

Maintaining A. chlorotica in wooden boxes at 22°C. and 95-100 per cent. R.H. proved satisfactory and earthworms appeared healthy and produced viable cocoons.

Allowing earthworms to crawl over filter paper, before transfer to the rearing chambers, did not remove earthworm slime as was maintained by Pimentel and Epstein (1960). When earthworms were transferred to larval rearing chambers, the health and longevity of the earthworms were variously affected. The Pimentel and Epstein and Plaster of

Paris types of rearing chambers were unsatisfactory. In the case of the former type of chamber the earthworms simply pushed off the loosely-fitting cork and escaped, whereas in the Plaster of Paris chambers the earthworms all died within a week. Earthworms in the glass vial and Petri dish types of rearing chambers remained healthy in appearance, produced viable cocoons and survived for two months or more.

In all types of rearing chamber, some earthworms were found with a slightly enlarged prostomium. Also four A. chlorotica were found in the Petri dish type of chamber with the gut protuding about five millimeters from the anus (Fig. 33). Dissection under a dissecting microscope revealed that neither of these features were due to the presence of larvae.

When first instar larvae were placed on A. chlorotica they moved slowly over its surface making vertical picking movements with their mouth hooks. A few larvae were observed to cut through the cuticle, but always the last two or three abdominal segments remained exposed. The last three abdominal segments of the first instar larva possess large forwardly-directed hooks (Fig. 32). Penetration took no longer than half an hour. No penetration was observed to occur through the pre-clitellar segments or the clitellum. No larvae were observed to enter through the male genital aperture of A.

chlorotica, although this was suggested by Keilin (1915) as the principal site of entry for first instar larvae. First intar larvae placed on pig liver were also observed to burrow in with their mouth hooks but keeping their posterior abdominal spiracle exposed. Larvae placed on pig liver died within a day. No first instar larvae were observed to survive for more than two days. Almost all first instar larvae became entangled in the slime over the surface of the earthworm and died. First instar larvae were also brushed off the earthworm as it moved through the soil.

One specimen of P. rudis was reared in the laboratory in the glass vial type of chamber containing peat loam and A. chlorotica. As soon as the pupa was found it was transferred from 19 °C. and 100 per cent. R.H. to a petri dish containing moist filter paper and then placed in a sealed glass container at 25 °C. and 100 per cent. R.H. The larval stages for this specimen lasted for 18 days at 19° C. and 100 per cent. R.H. while the pupal period lasted for 11 days at 25 °C. and 100 per cent. R.H. This pupal period is shorter than the 30-40 days given by Keilin (1915) but similar to the findings of Webb and Hutchison (1916) and Pimentel and Epstein (1960). The fully-formed puparium was 6.5 mm in length and the maximum diameter was 1.8 mm.

The newly-formed puparium was light-brown in colour but became progressively darker, especially the anterior

segment, as development proceeded. The appearance of the fully-formed puparium is shown in Fig. 34A, B. The dark-coloured cephalopharyngeal skeleton of the third instar larva is clearly visible on the inner ventral surface of the puparium (Fig. 34A, C, D). As a preliminary to emergence the anterior three segments of the puparium were pushed aside (Fig. 34C) due to pressure exerted by the ptilinal sac. Fig. 35 shows the appearance of the newly-emerged adult with its everted ptilinal sac, unexpanded wings and its dense covering of golden-coloured epicuticular hairs on the dorsum of the thorax. The length of the adult, from the anterior end of the everted ptilinal sac to the posterior end of the abdomen, was 8.0 mm. The adult crawled about actively but died four hours after emergence. During this period the wings failed to expand and the ptilinal sac remained everted. The reared specimen, together with its puparium, is retained in the Lyman Entomological Museum at the Macdonald Campus.

V. DISCUSSION AND CONCLUSIONS

Collection of P. rudis by net-capture in the summer was time-consuming and only small numbers of flies were collected. An alternative method of stock-piling P. rudis for laboratory work is to collect them from buildings which are heavily infested in the autumn and to store them at 4°C. until needed. Possibly lower temperatures and humidities may allow the flies to be stored for even longer periods. Of course, the development of a technique for rearing large numbers of P. rudis in the laboratory would make this insect a more convenient experimental animal to work with.

As large numbers of P. rudis were found in the chalet and observatory it may be speculated that the flies come to these buildings from over a wide area. This in itself would make it difficult to control P. rudis by attacking the immature stages. Tyler (1961) noted that P. rudis are frequently encountered in isolated buildings in rural areas and suggested that this may be due to such buildings providing the nearest sunlit surfaces available for the flies to sun themselves. This may be particularly important in late autumn when the day is shorter and the sun is lower in the sky. Perhaps this could account for the large numbers of flies found on the chalet and observatory in the late afternoon and evening in the last two weeks of October.

Although the distances over which P. rudis can fly is not known, the capacity for sustained flight over several kilometers has been well-established in the Calliphoridae (Norris 1965).

DeCoursey (1927), who worked at Urbana in Illinois, stated that "The hibernating generation makes its appearance near the first week of October and is regarded as the fourth generation" and also that "The adults of the hibernating generation have a newly-emerged appearance and usually have a glistening coat of yellow pile on the dorsum of the thorax." However, P. rudis were found in the chalet as early as August 26. Also, P. rudis were found with a dense covering of golden-coloured epicuticular hairs on their thoraces in June, July, August and September as well as on a fly which emerged in the laboratory in June. Furthermore, P. rudis were found in the chalet in the autumn with wide differences in the quantity of thoracic epicuticular hair covering. It seems reasonable to suggest that it is not a single large generation arising in October which enters overwintering quarters but rather that all flies which have survived the season do so. Thus, the accumulation of P. rudis throughout the season would give the appearance of there being a large single generation which invades buildings in the autumn.

Pollenia rudis entered the chalet throughout September and October, with peaks occurring in the last two weeks of October. Such a relatively long period of entry should be taken into account when insecticides are applied to buildings to effect control of this pest.

Only nine completed questionnaires were received and this precluded statistical treatment of the results. Comments appended to the questionnaires by pest control operators raised serious doubts as to whether the infestations they reported were actually due to P. rudis. Furthermore, several insect species were found in the chalet in the autumn and Chadwick (1972) has also commented on the variety of "cluster flies" which invade buildings.

The high mortality of P. rudis in the observatory in the autumn may have been partly caused by dehydration of the insects due to their intense activity when trapped behind windows during warm sunny days.

Phycomycosis appeared to be important factor in the mortality of P. rudis in the observatory in the autumn. Infection was probably due to E. muscae. That phycomycosis occurred in P. rudis stored at 4°C. provides support for the suggestion put forward by Lakon (1919) that E. muscae can pass the winter in the bodies of overwintering P. rudis adults. Perhaps an entomophagous fungus could be

used as a control agent against P. rudis.

That clusters made up exclusively of small-sized P. rudis were found in narrow window gaps in the chalet may be accounted for by larger-sized P. rudis being unable to squeeze into those particular gaps. In larger gaps all sizes of P. rudis were found. No flattening of P. rudis, such as would facilitate their creeping into cracks, was observed in the chalet or observatory. The only structural peculiarity noted was that of a fly which had failed to retract its ptilinal sac.

The overwintering of P. rudis in narrow concealed places may have the effect of reducing water loss by evaporation as well as reducing heat loss by cold, moving air. In this respect it may be noted that in winter Dennys (1927) found P. rudis behind bark on the sunlit sides of trees and also that these trees were shielded by other trees from the wind. Concealment may reduce the possibility of predation by birds. A further possibility is that clustering of P. rudis may increase the chances of those flies which have survived the winter being nearer to one another so that they can mate in the spring. How the flies come together to form clusters is not known but possibly the extensive accumulations of excreta which were found in window gaps in the chalet may be attractive to the flies.

The obvious answer to control is to prevent the flies from physically being able to enter a building in the first place; a step which would obviate the need for repeated application of insecticides. One way this could be partly solved is to manufacture close-fitting doors and windows which do not warp unduly with changes in humidity and temperature. Ill-fitting windows appeared to be the major entry points for P. rudis into the observatory.

The greatly increased number of P. rudis caught on the inside of windows in the chalet in the autumn of 1971, in comparison to the autumn of 1970, can probably be accounted for by the wire fly-screens having been loosened in the summer of 1971. Evidently, the number of entry points available to flies influences the extent to which a building is infested.

Sperm was not found in the spermathecae of females collected from the chalet in the autumn. Evidence that copulation is delayed until the spring is provided for by the fact that pairs copulated within a week of being held at room temperature following a 21 week overwintering period at 4 °C. Furthermore, DeCoursey (1927) and Hammond (1940) observed P. rudis copulating in the open in the warm spring sunshine.

Postures adopted by copulating P. rudis appear similar to those described by Richards (1927) for a number

of muscid flies. The extension and retraction of the ovipositor could possibly assist in the transfer of seminal fluid to the spermathecae.

It is not known when P. rudis first entered Canada. However, examination of labelled specimens of P. rudis in the National Insect Collection in Ottawa showed that a fly was caught in a building in Ottawa on March 12, 1891. Since this was probably an overwintering fly then P. rudis, at the latest, had made its debut in Canada by 1890.

The long setae on the ovipositor of P. rudis may be involved in locating cracks in the soil in which to lay eggs. The peg-like structures on the ovipositor structurally resemble the receptors which Wallis (1962) found on the anal leaflets of Phormia regina (Meigen). Perhaps they are employed by the female to determine the most suitable site for oviposition in relation to the food requirements of the larvae.

The chorionic structure of the egg of P. rudis appears to meet the requirements for a plastron method of respiration. Hinton (1959) has described a plastron as follows "The term plastron has been restricted to describe a gas film of constant volume and an extensive water-air interface. Such films are held in position by a system of hydrofuge structures and are capable of resisting water

under a pressure. In well-aerated water a plastron enables the insect to remain immersed indefinitely, when it obtains the oxygen it requires from the ambient water." Plastron respiration has been shown to occur in the eggs of several Diptera (Hinton 1959, 1960, 1960a, 1962, 1962a, 1963; Anderson 1960).

The plastron surface in the egg of P. rudis is apparently provided for by the perforated outer surfaces of the longitudinal ridges. These apertures are in continuity with the open spaces throughout the rest of the chorion and probably allow respiratory gases to diffuse throughout the chorion to meet the respiratory requirements of the embryo. Further support for plastron respiration occurring in the egg of P. rudis is provided by the observation that eggs are able to develop and hatch when immersed in water.

The sticky surface of the egg of P. rudis appears to be the same as the dark-staining layer seen in transverse sections of the egg. In transverse section, this layer is confined to the surface of the chorion outside the longitudinal ridges and the median area. Hinton (1960) described a similar layer covering the egg of Calliphora erythrocephala.

The meshwork underlying the longitudinal ridges is more compacted than elsewhere in the chorion and these areas

may represent lines of weakness (hatching lines) that break when the larva exerts pressure to leave the egg. Anderson (1960) has noted a similar arrangement for hatching lines in the egg of C. erythrocephala.

The arrangement of the chorion and its plastron areas has been used as a means of differentiating between eggs of some species of the subfamily Muscinae (Hinton 1960a). Perhaps this method can be used for differentiating between eggs of the Polleniini, although so far only the egg of P. rudis appears to have been described in the literature.

Although first instar larvae of P. rudis were placed together with A. chlorotica under a variety of experimental conditions only one P. rudis was reared. This could have been due to conditions in the rearing chambers being unsuitable for the larvae, although the earthworms generally appeared healthy and produced viable cocoons. An alterative possibility is that P. rudis is not primarily a parasite of A. chlorotica. Webb and Hutchison (1916) and DeCoursey (1927) were also unable to achieve a satisfactory method of rearing P. rudis on this earthworm. Séguy (1934) may possibly have been nearer the truth when he argued that there are far too many flies to be accounted for by obligate parasitism of earthworms alone and proposed that larvae of P. rudis live saprophytically in the soil but occasionally

are parasitic on earthworms and other soil invertebrates. Séguy also pointed out that the wide variation in adult size was indicative of the polyphagous nature of the larvae.

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Fig. 1

Known distribution of P. rudis in Canada up to 1954 (after MacNay 1954).

▲ Specimens reported from Winnipeg, Manitoba in 1970 by Dr. Phillip Barker.

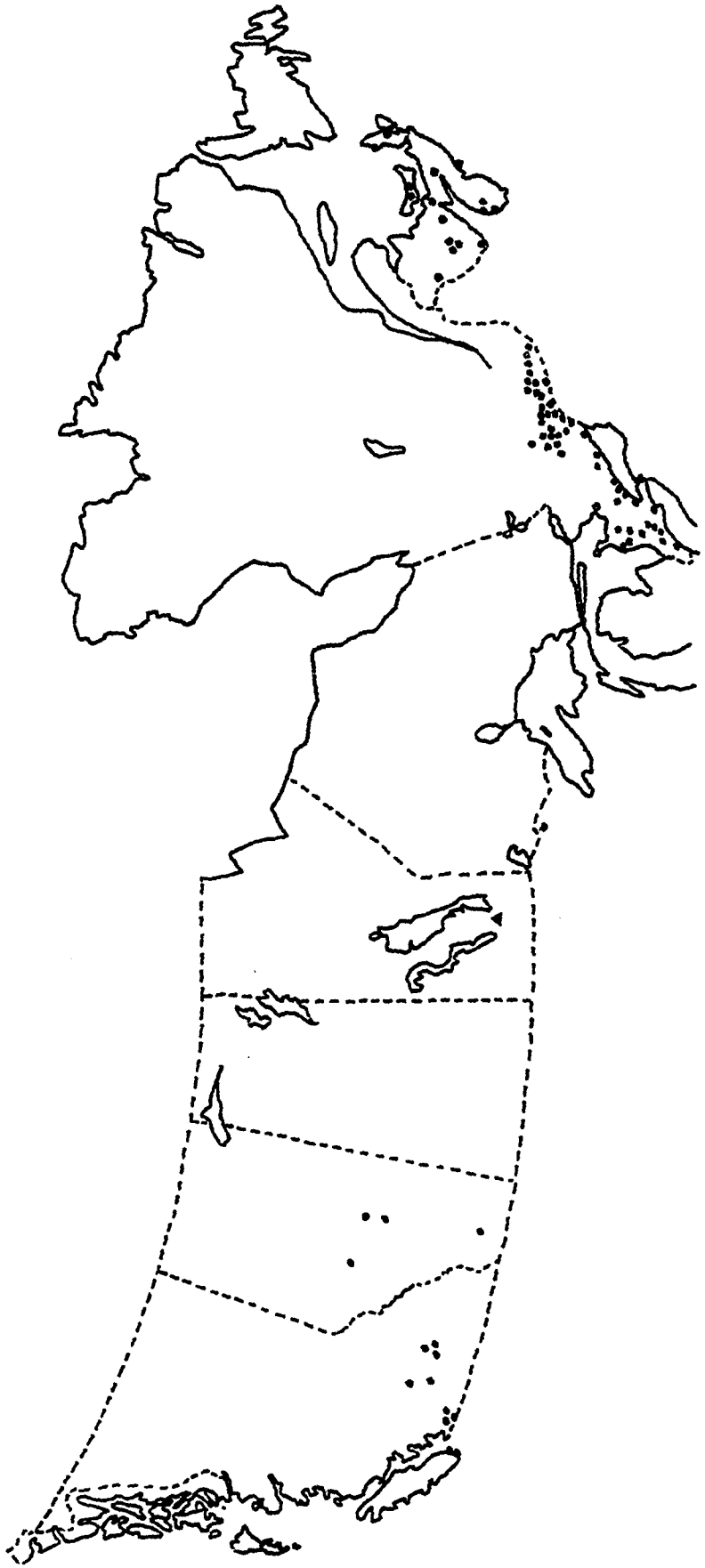


Fig. 2

Glass cage used for maintaining adult *P. rudis* in the laboratory.

(a) Dish containing granulated sugar and powdered milk powder (1 : 1).

(b) Dish containing moist absorbent cotton wool.

(c) Dish containing moist peat loam.

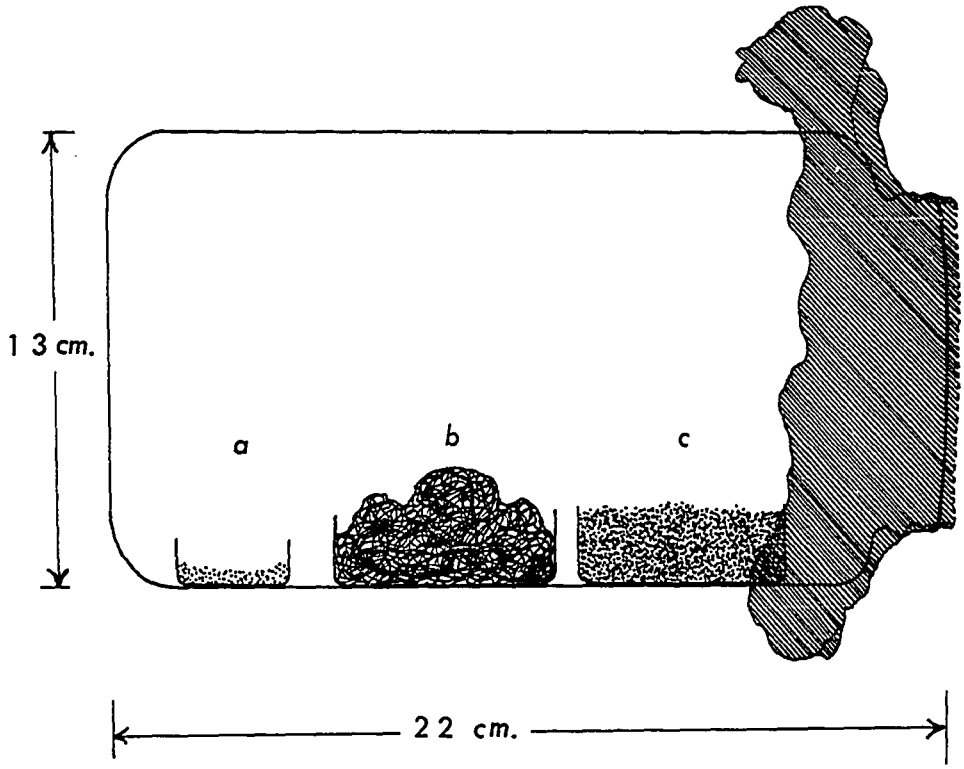
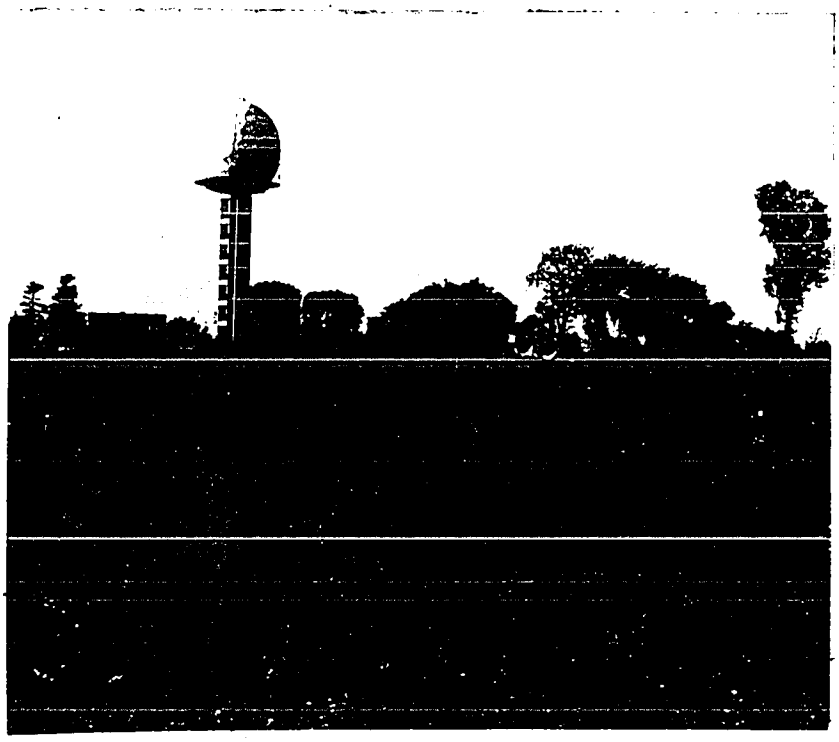

13 cm.
a
b
c
22 cm.

Fig. 3

The chalet in the Morgan Arboretum.

Fig. 4

The McGill Radar Weather Observatory.



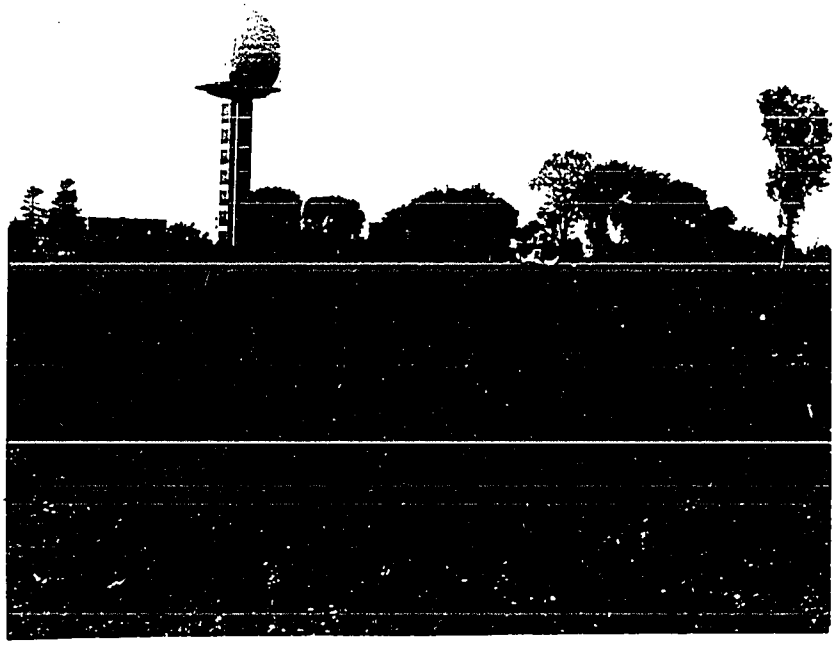


Fig. 5

Dorsal surface of the thorax of adult female P. rudis.

A. Presence of epicuticular hairs characteristic of newly-emerged flies.

B. Absence of epicuticular hairs characteristic of older flies.

A

B

A

B

Fig. 6

Rearing chambers.

A. Pimentel and Epstein type.

B. Plaster of Paris type.

C. Petri dish type.

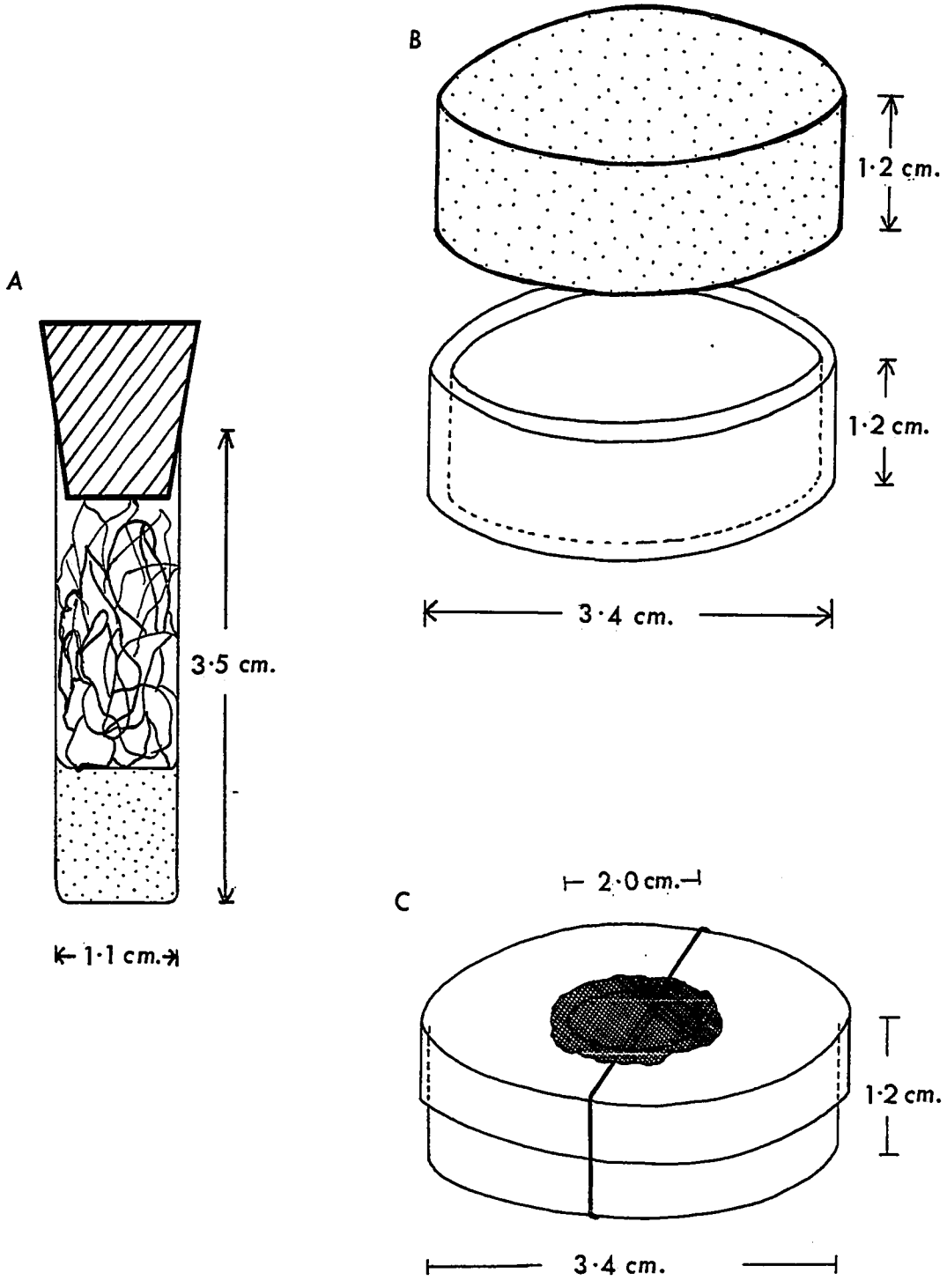

A
3·5 cm.
1·1 cm.
B
1·2 cm.
1·2 cm.
3·4 cm.
C
2·0 cm.
1·2 cm.
3·4 cm.

Fig. 7

Number of *P. rudis* caught on the inside of windows in the chalet in relation to minimum daily air temperatures in the autumn of 1971.

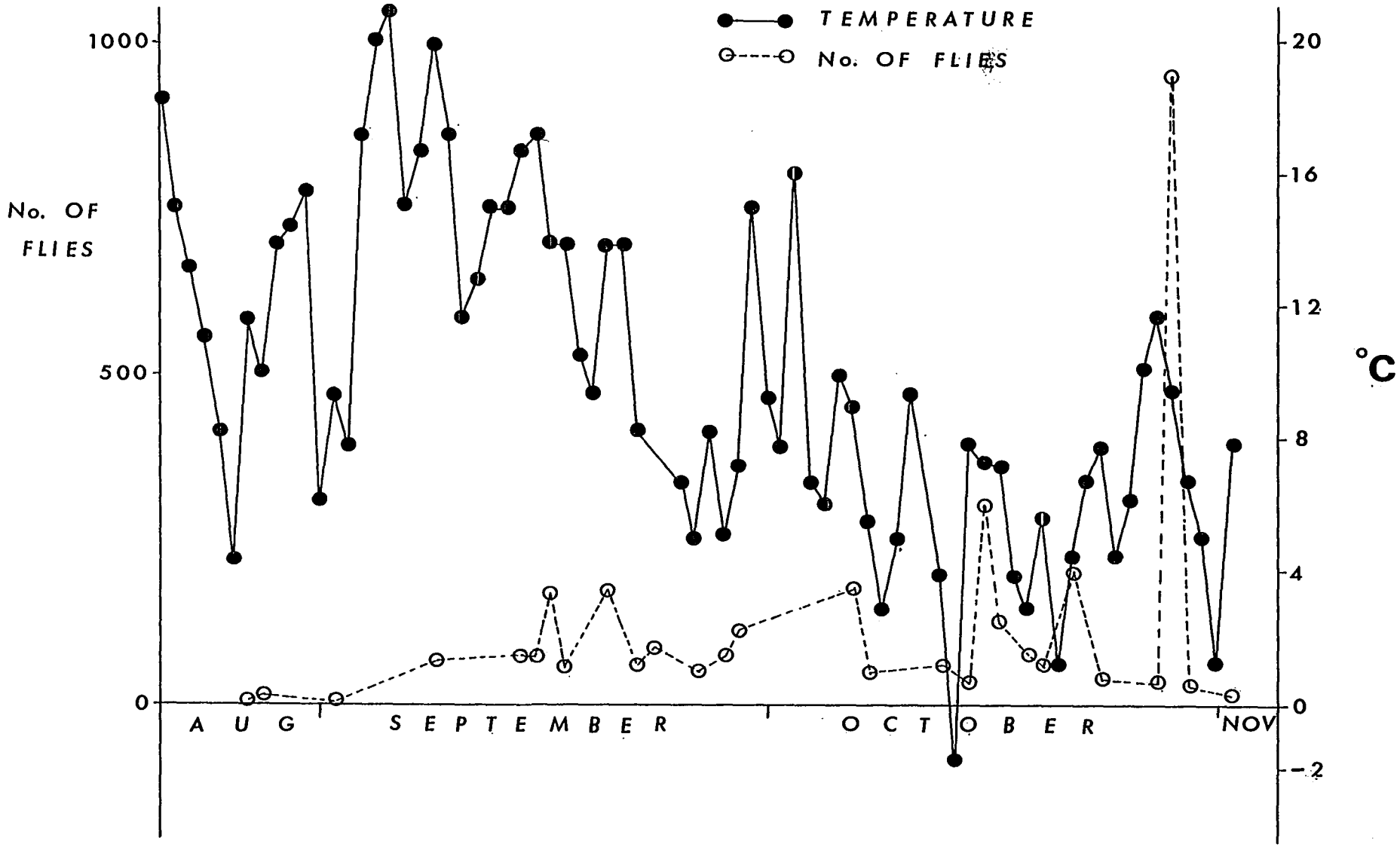

TEMPERATURE
No. OF FLIES
1000
500
0
No. OF FLIES
20
16
12
8
4
0
-2
°C
AUG
SEPTEMBER
OCTOBER
NOV

Fig. 8

Number of P. rudis caught on the inside of windows in the chalet in the autumn of 1971.

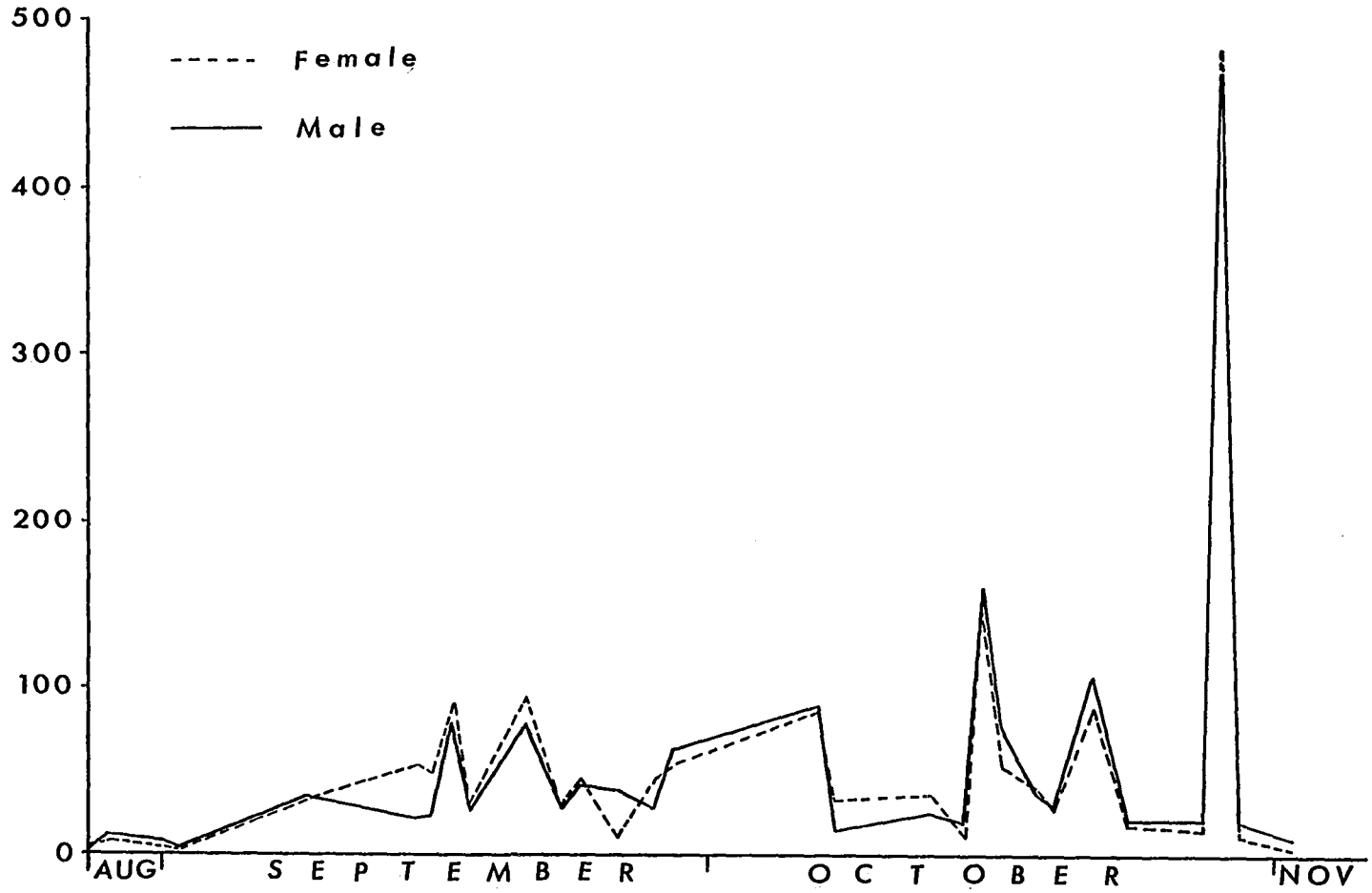

500
400
300
200
100
0
No. of Flies
Female
Male
AUG
SEPTEMBER
OCTOBER
NOV

Fig. 9

Pollenia rudis caught in the chalet in the autumn of 1971 divided into three groups according to the quantity of golden-coloured epicuticular hairs on the dorsal surfaces of their thoraces. Numbers of flies expressed as a percentage (ordinate axis).

DC = dense covering of hairs

A = absence of hairs

I = hair covering intermediate between perious two groups

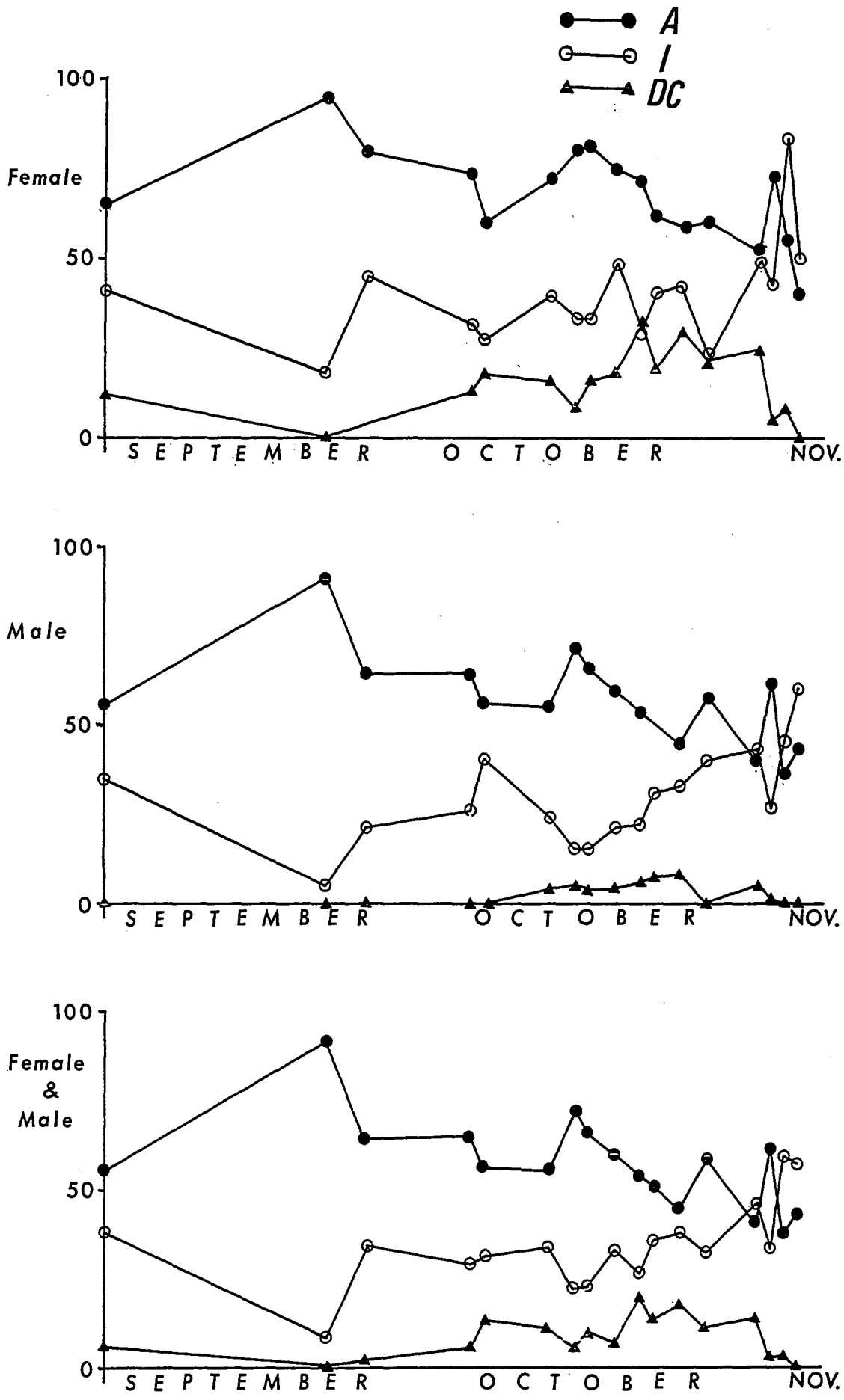

A
I
DC
100
Female
50
0
SEPTEMBER
OCTOBER
NOV.
100
Male
50
0
SEPTEMBER
OCTOBER
NOV.
100
Female
&
Male
50
0
SEPTEMBER
OCTOBER
NOV.

Fig. 10

Pollenia rudis clustering in a window angle in the chalet in the autumn. The dark speckling represents excreta. The window has been opened to expose flies.

Fig. 11

Excreta of P. rudis in an upper angle of a window frame in the chalet. The dark patch represents several years of accumulation. The window has been opened to expose flies.

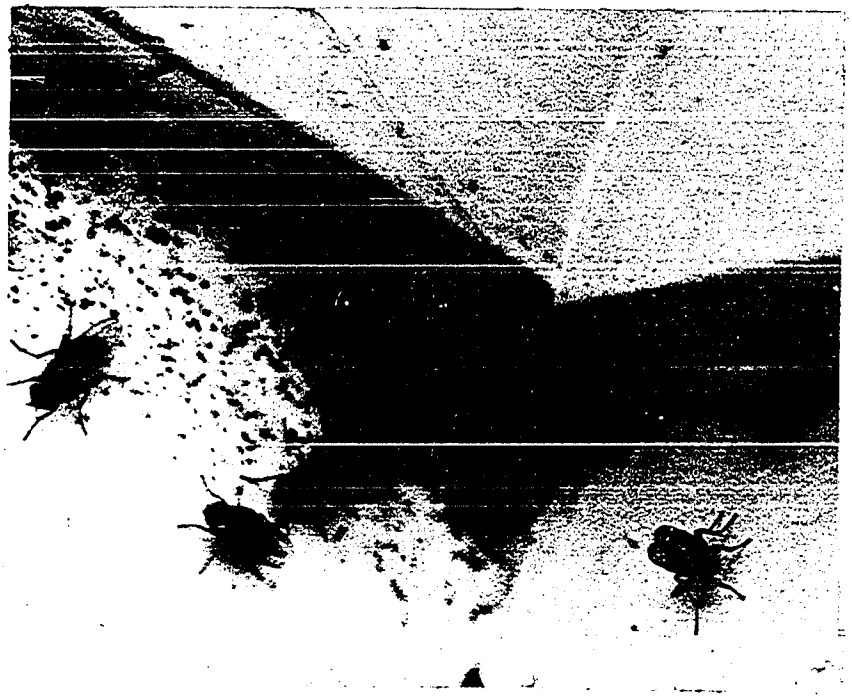


Fig. 12

Dorsal surface of the thorax of a specimen of P. rudis showing the distribution of nymphs of Carpoglyphus sp. among the epicuticular hairs. Nymphs are absent from the areas devoid of these hairs.

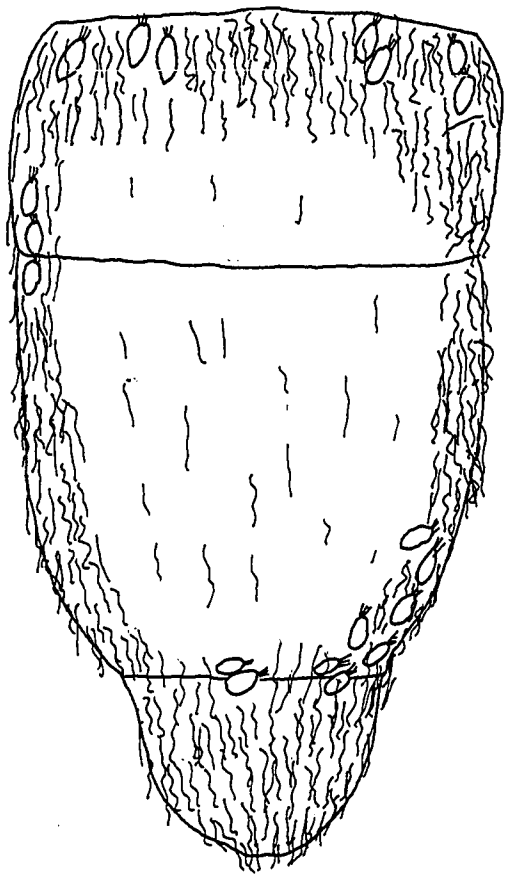


Fig. 13

Head of an adult male P. rudis showing its appearance when the ptilinal sac has failed to retract. Ptilinal sac indicated by stippling. (A) Dorsal and (B) frontal view of head.

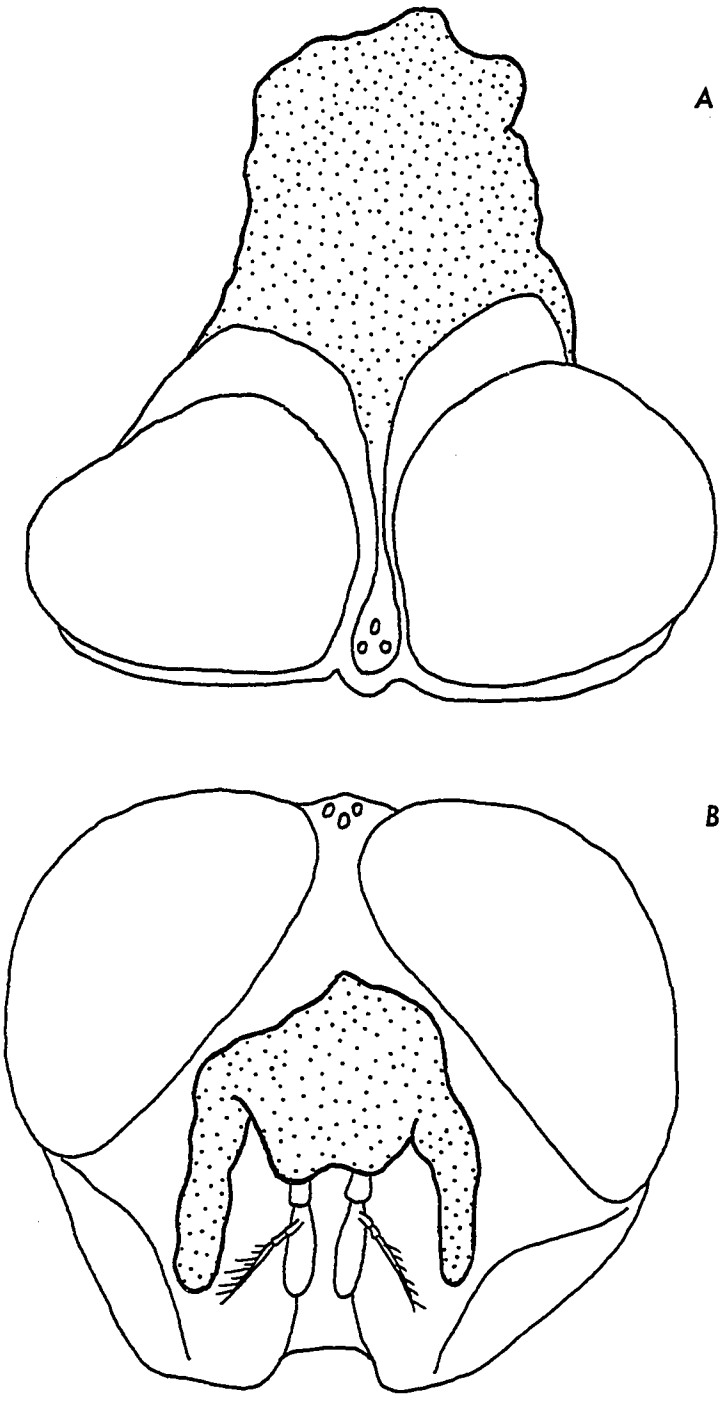
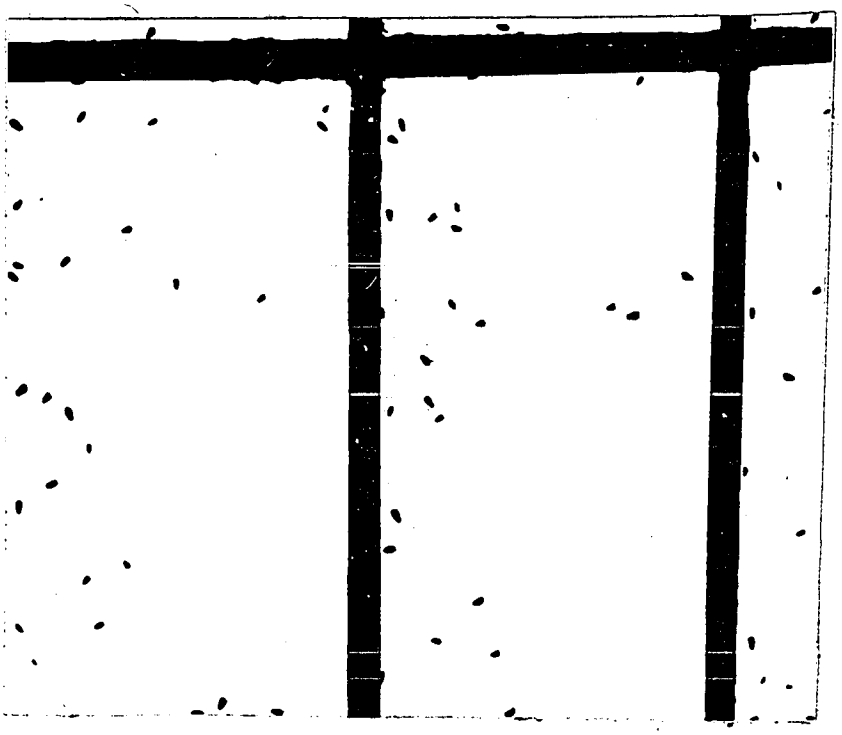

A
B

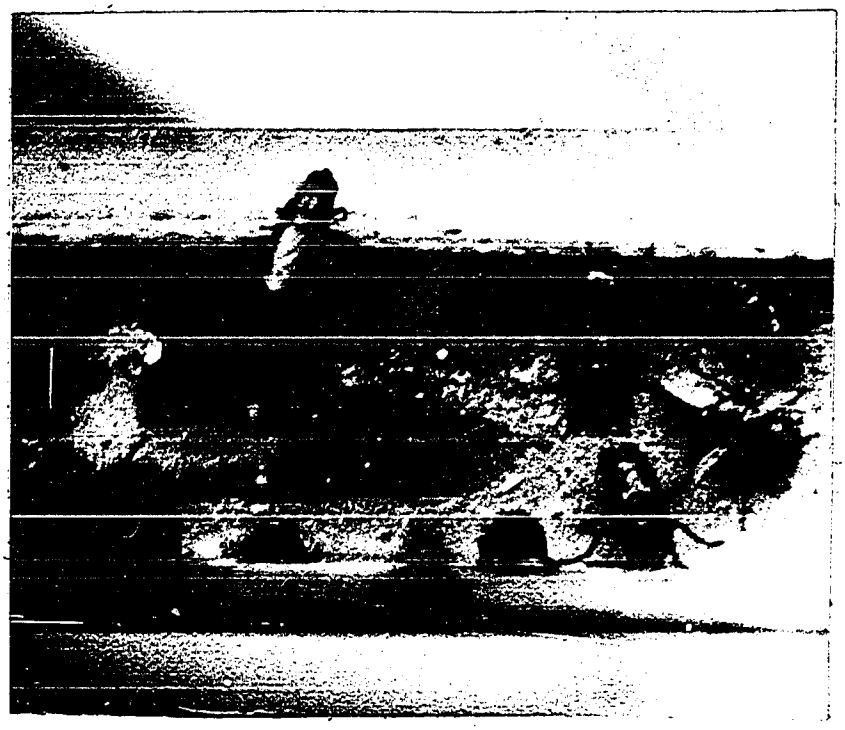
Fig. 14

Pollenia rudis on the inside of windows on the west side of the tower of the McGill Radar Weather Observatory in the autumn.

Fig. 15

Pollenia rudis in a window frame in the McGill Radar Weather Observatory in the autumn. Window has been opened to expose flies.





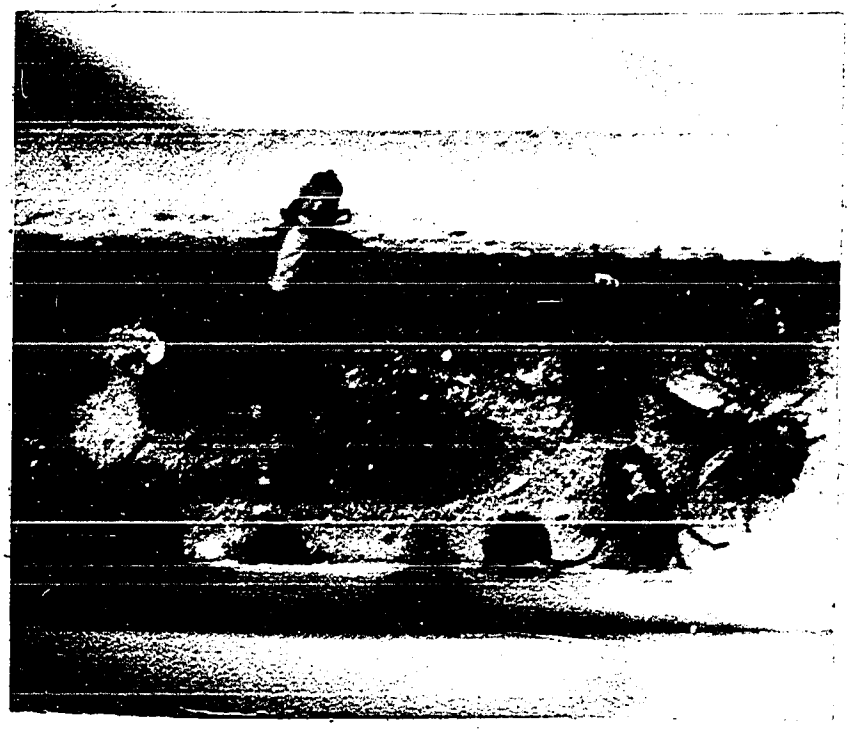
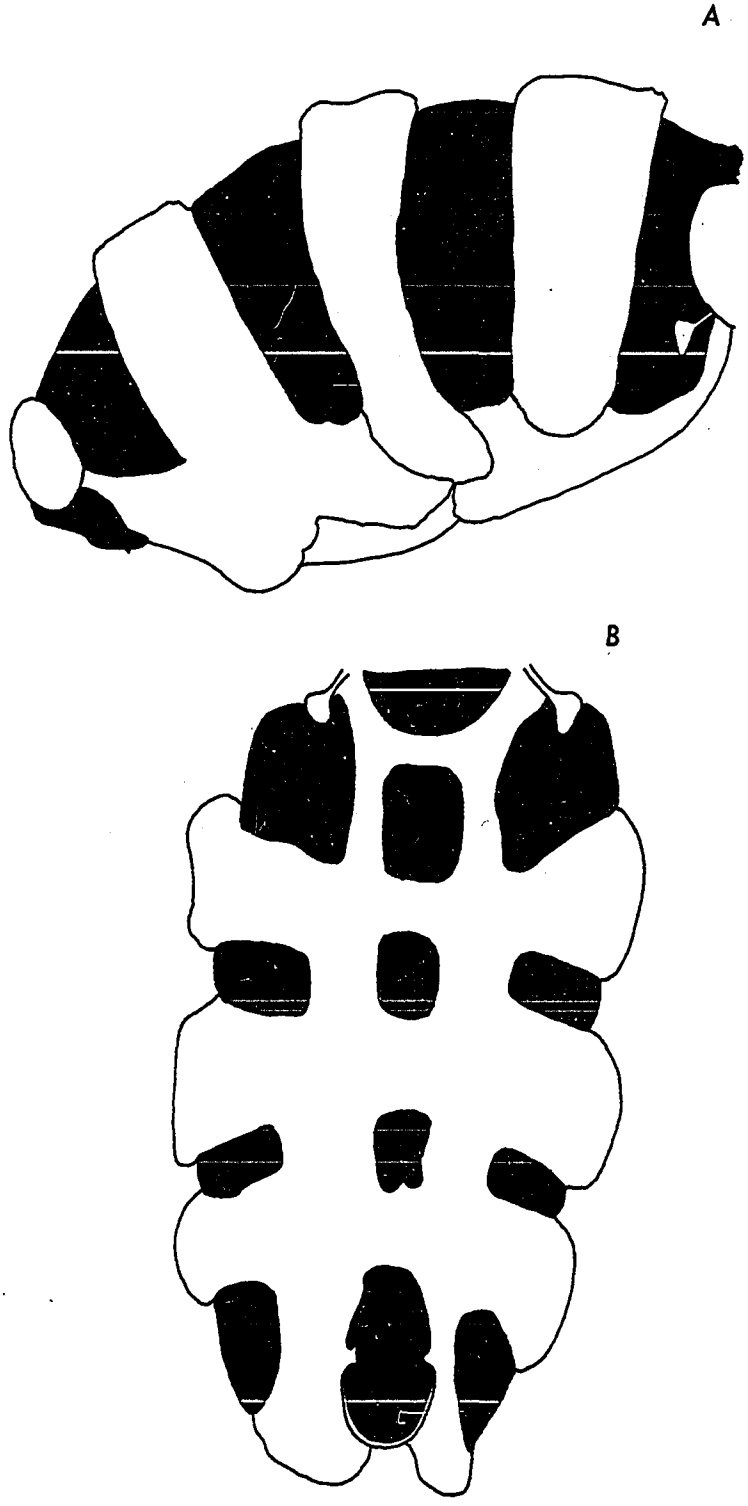


Fig. 16

Adult P. rudis killed by the fungus E. muscae and showing the characteristic distention of the abdomen. In this specimen the proboscis was also protracted.

Fig. 17

Abdomen of P. rudis distended by the fungus E. muscae.
(A) Lateral and (B) ventral view of the abdomen.


A
B

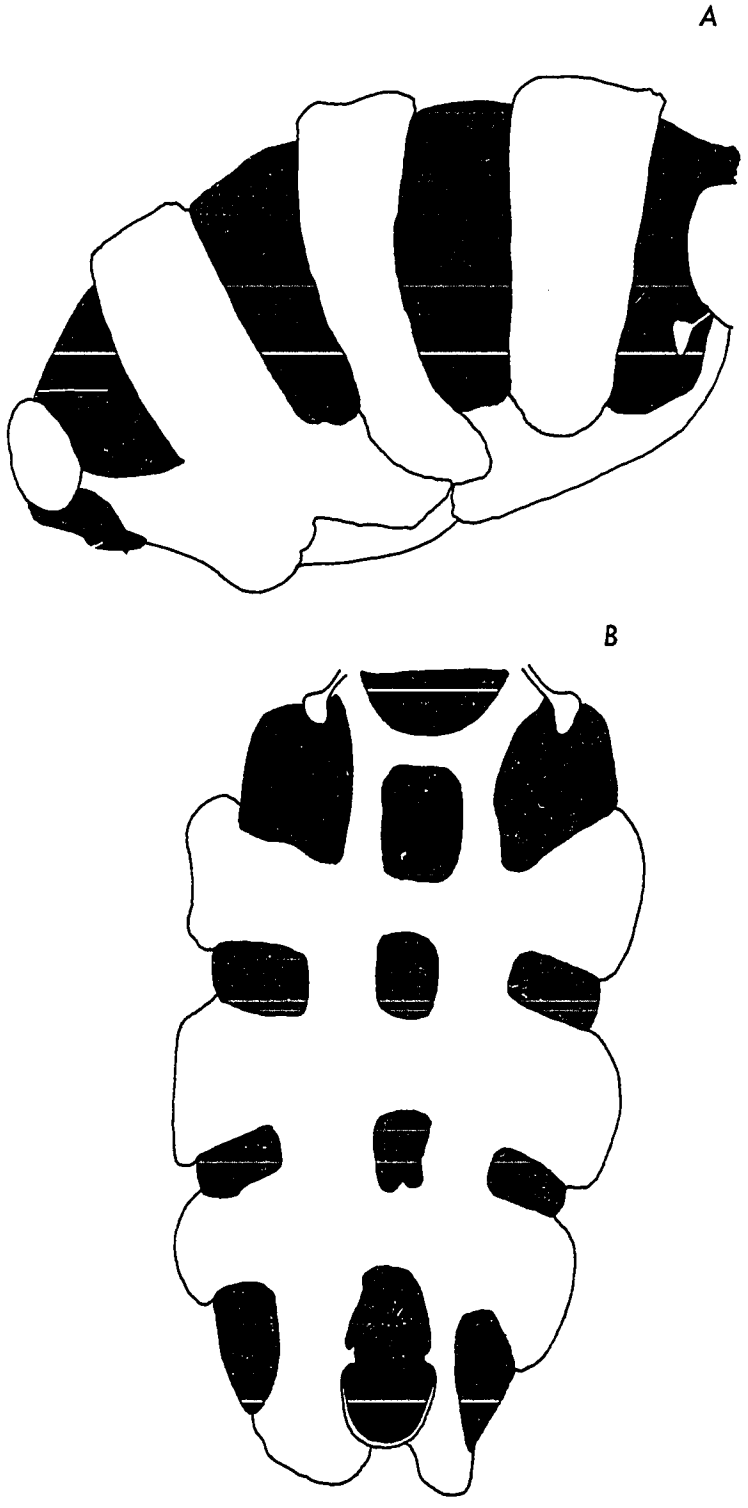

A
B

Fig. 18

Percentage mortality of *P. rudis* at 4°C.

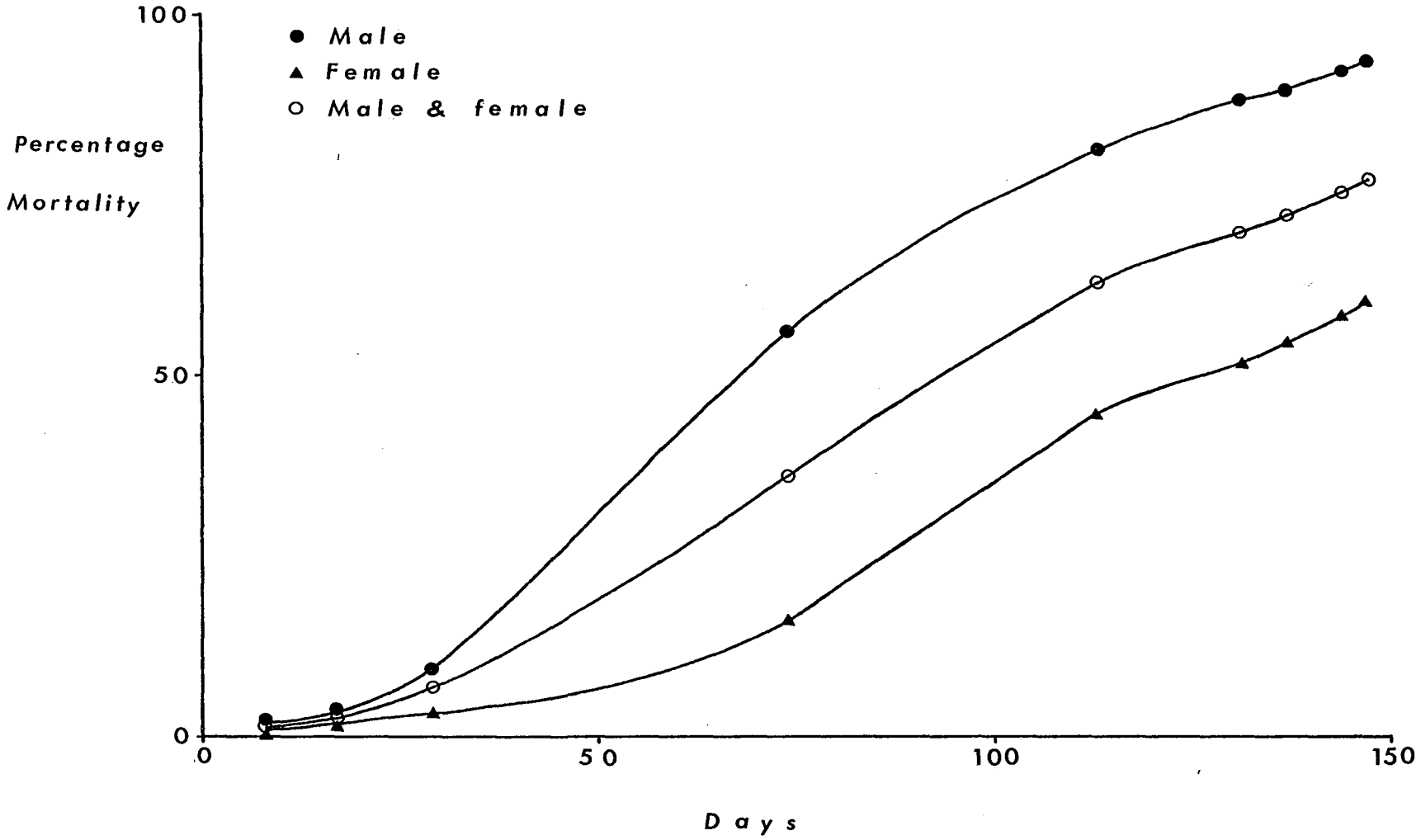
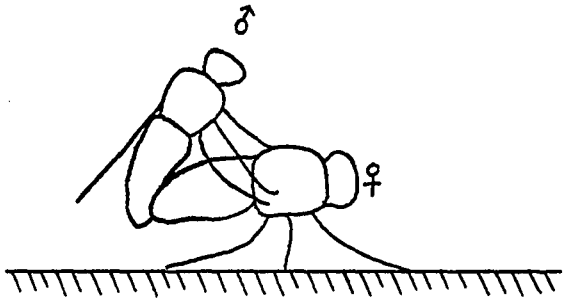
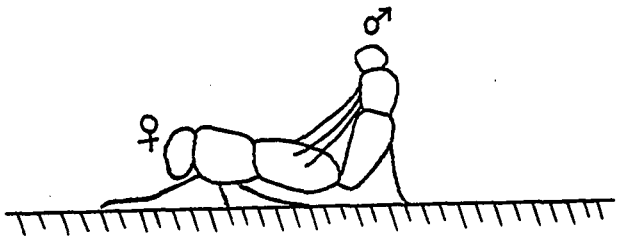

100
50
0
Male
Female
Male & female
Percentage
Mortality
0
50
100
150
Days

Fig. 19

Postures adopted by three pairs of copulating *P. rudis* in the laboratory.





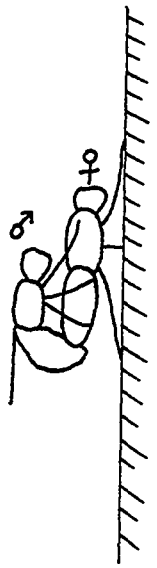


Fig. 20

Lateral view of the ovipositor of P. rudis as seen in specimens mounted on glass capillaries.

AL anal leaflet, AS abdominal segment, S sternite, T tergite.

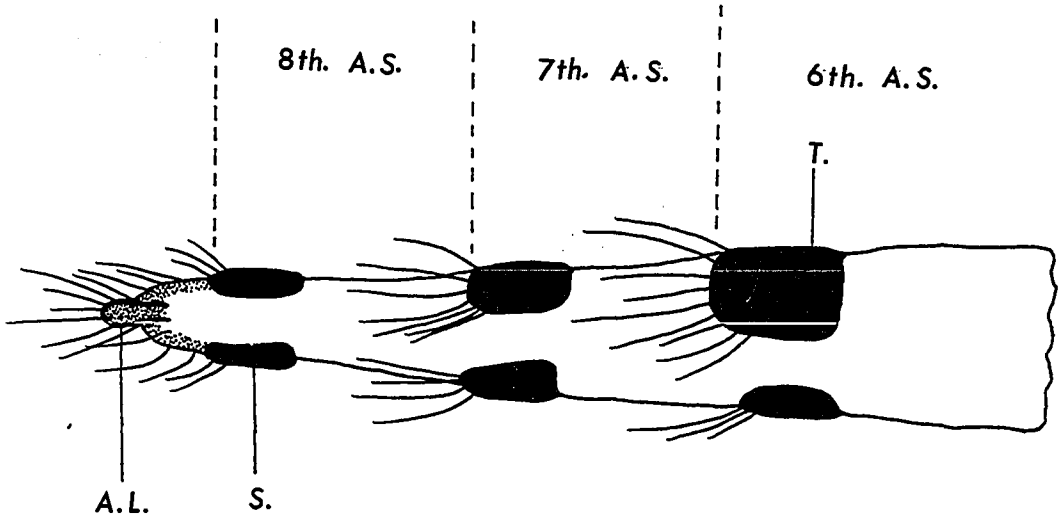

8th. A.S.
7th. A.S.
6th. A.S.
T.
A.L.
S.

Fig. 21

Latero-dorsal view of the posterior end of the ovipositor of P. rudis. X 230

Fig. 22

Two peg-like structures on the outer surface of an anal leaflet of P. rudis which may have a chemoreceptory function. X 1960.

Fig. 23

Pollenia rudis ovipositing in moist cotton wool.

Fig. 24

Egg of *P. rudis* in dorsal (A) and lateral (B) view.

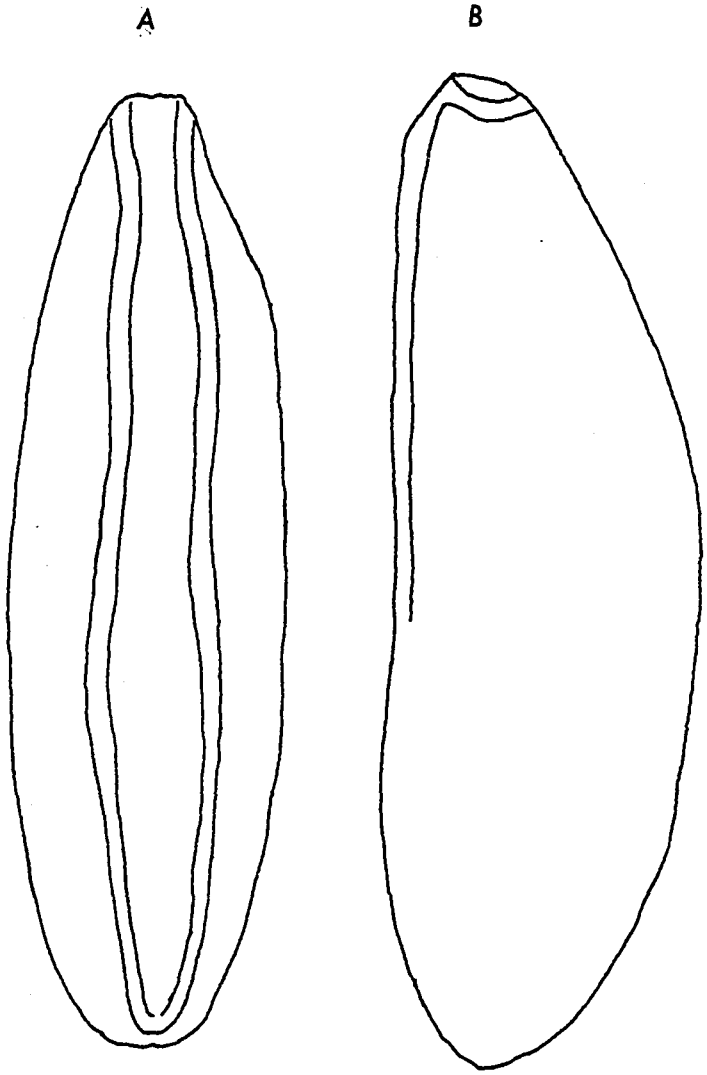

A
B

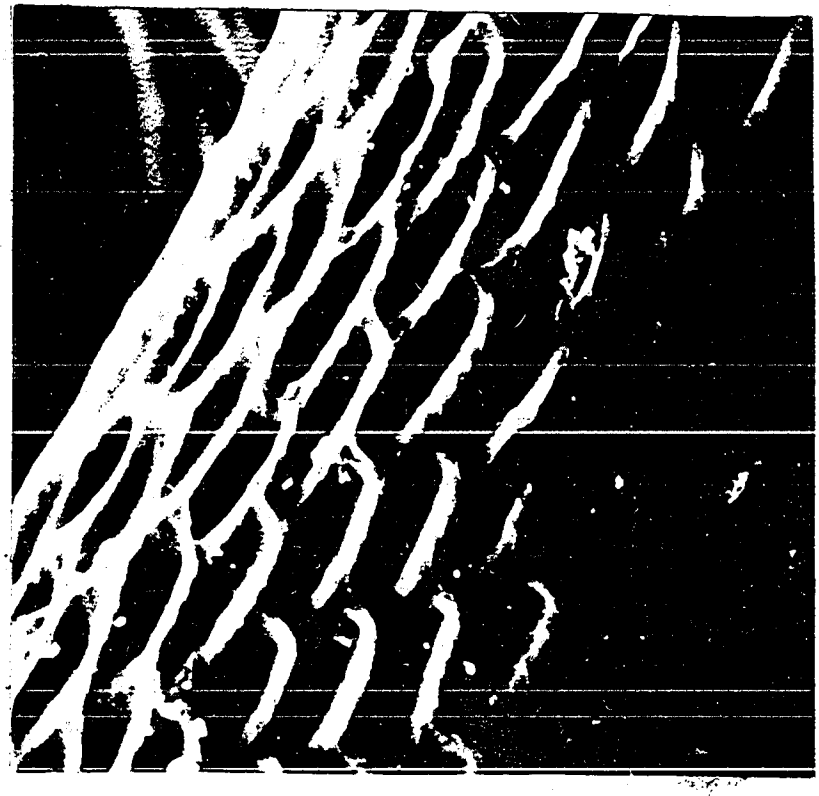
Fig. 25

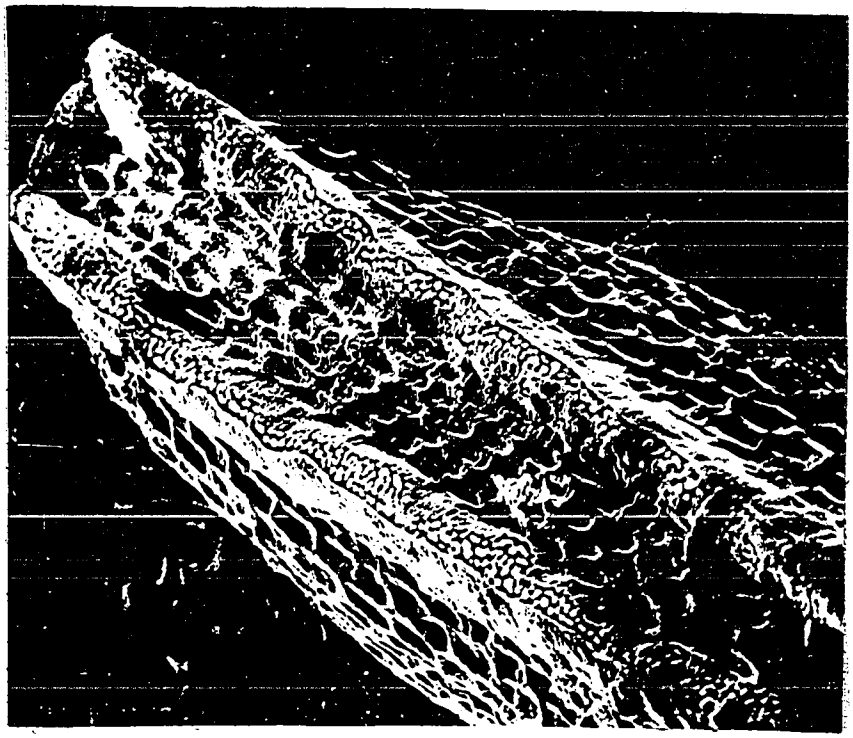
A portion of the external surface of the egg of P. rudis showing the sculpturing of the chorion outside the area between the longitudinal ridges. The white-coloured speckles represent surface contamination with dust and soil particles.

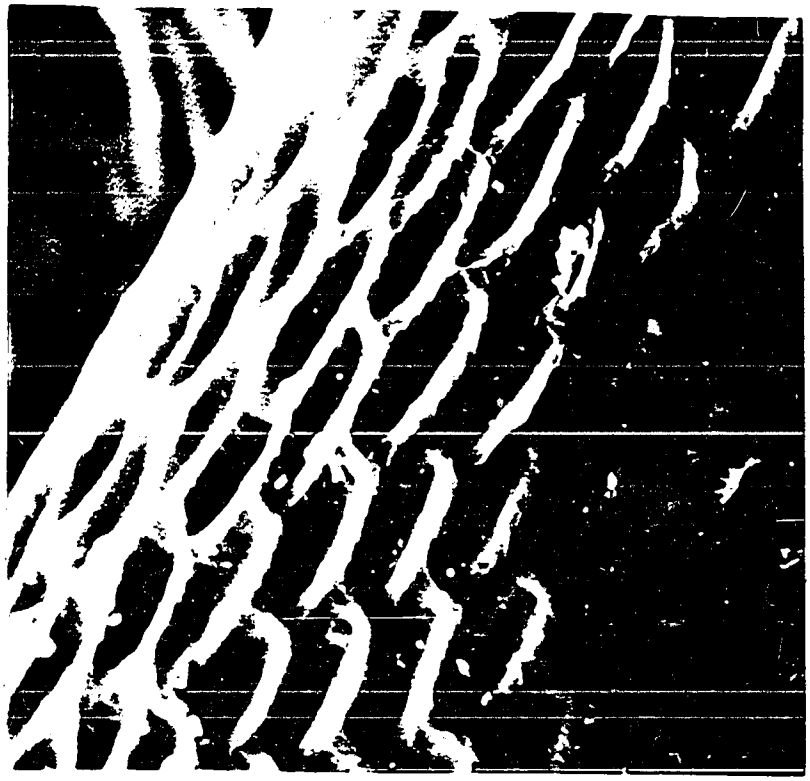
X 455.

Fig. 26

Dorsal view of the anterior half of the egg of P. rudis showing the micropyle and the area between the longitudinal ridges. X 185.







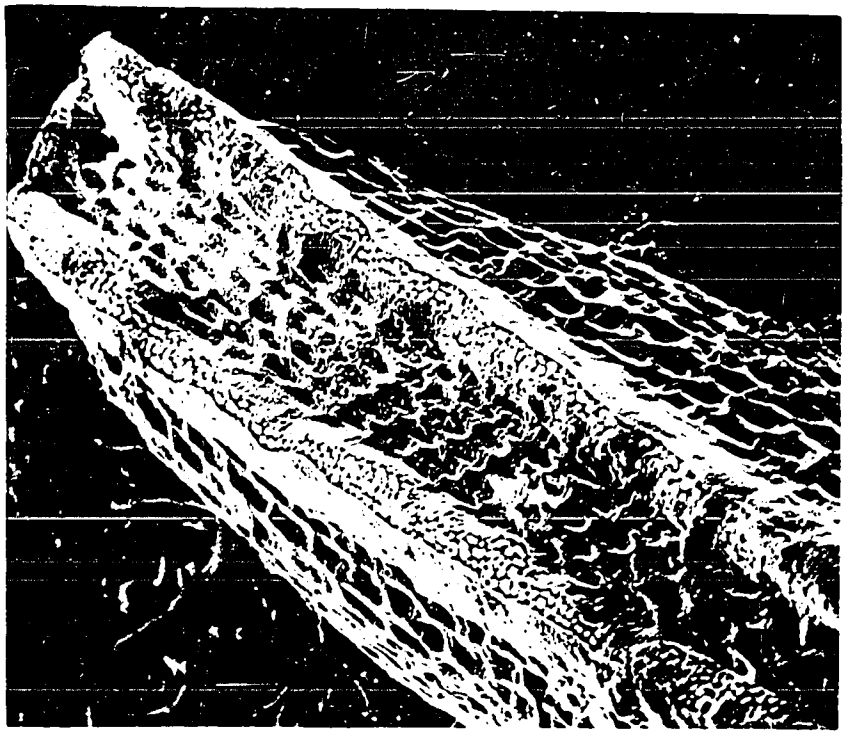
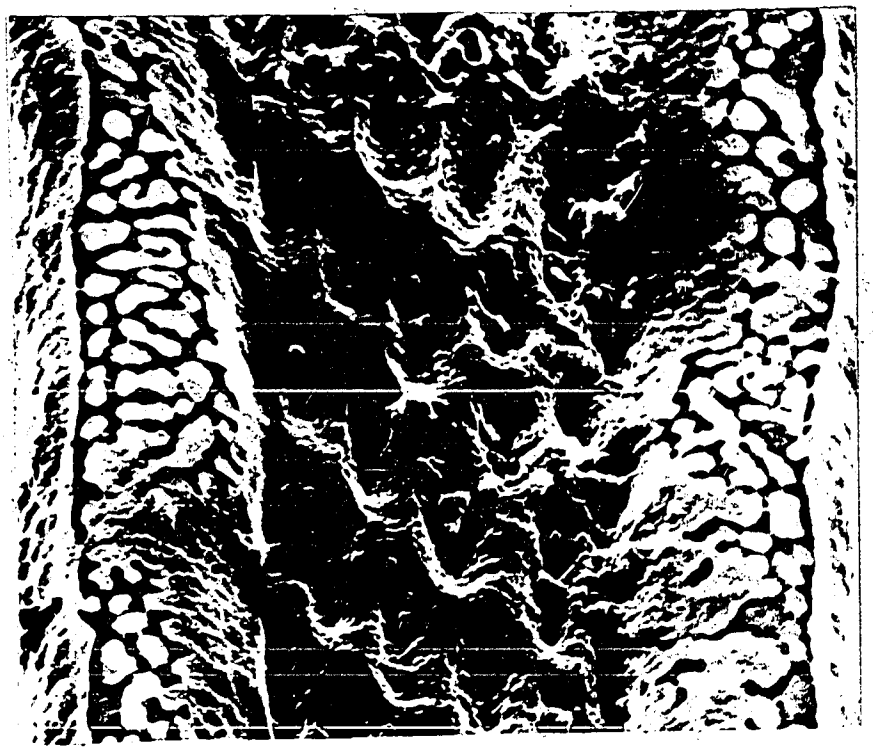


Fig. 27

A surface view of the area between the longitudinal ridges of the egg of P. rudis. X 455.

Fig. 28

A surface view of part of the plastron network of the egg of P. rudis. X 1365.



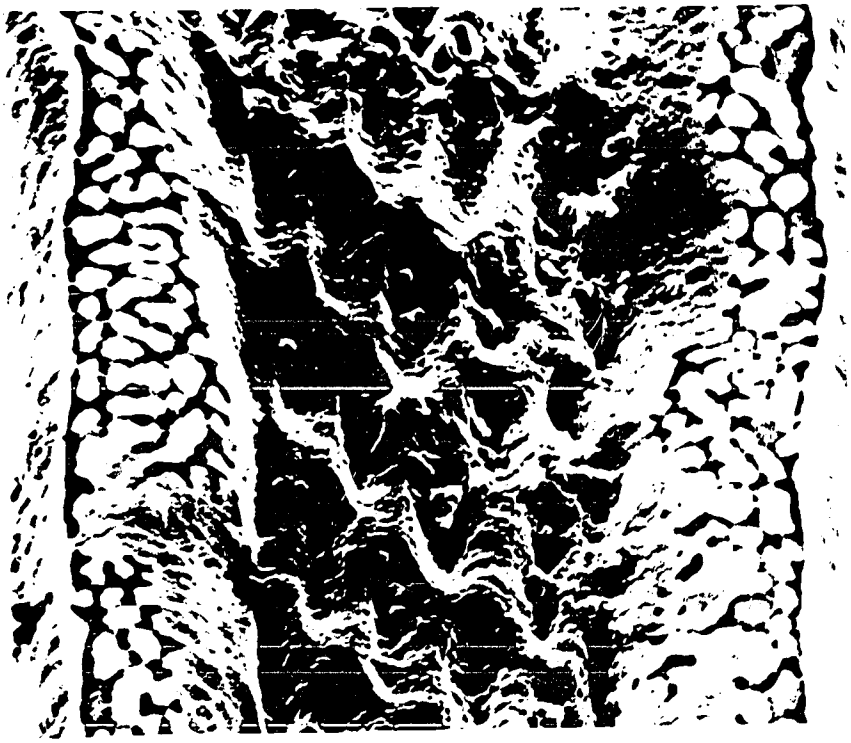


Fig. 29

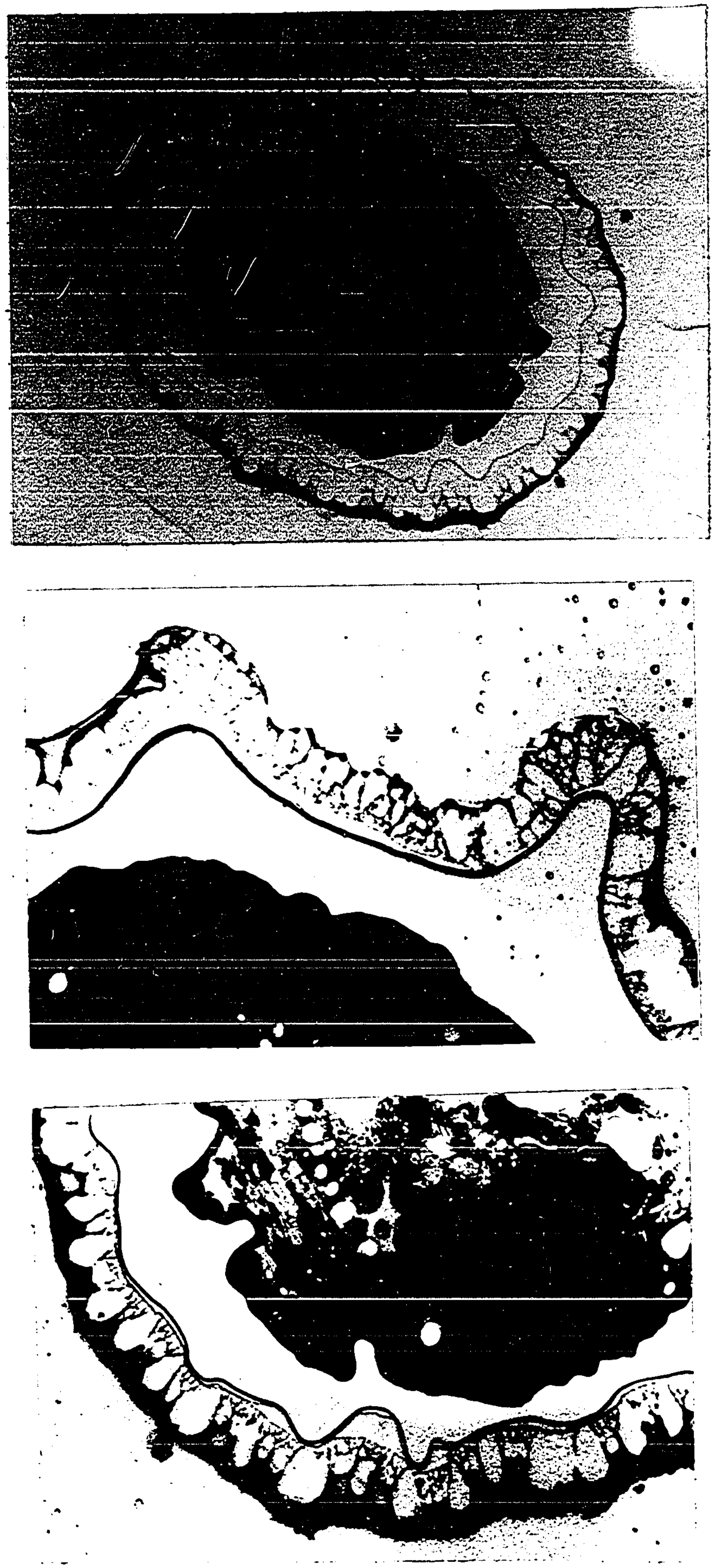
Transverse section through the mid-region of the egg of P. rudis. X 350

Fig. 30

Transverse section through the longitudinal ridges of the egg of P. rudis. X 700

Fig. 31

Transverse section through the chorion, outside the longitudinal ridges, of the egg of P. rudis. X 700



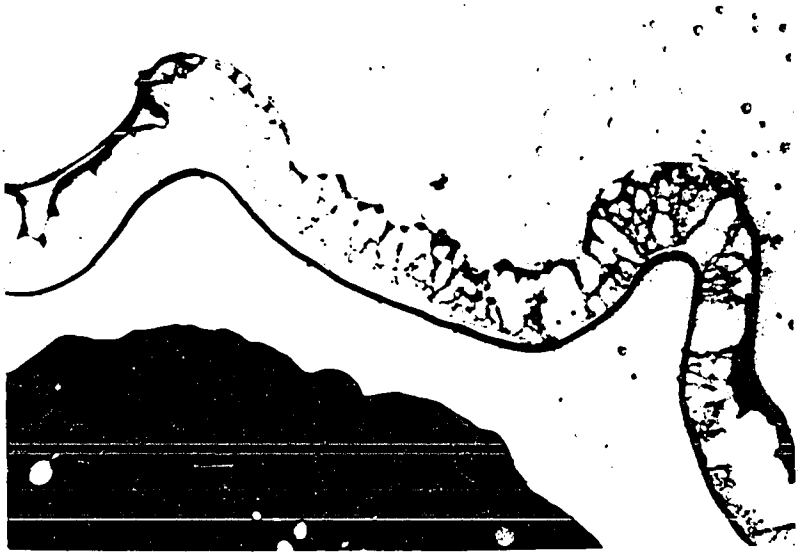


Fig. 32

Dorsal view of the posterior end of the first instar larva of P. rudis showing the posterior abdominal spiracles, the main longitudinal tracheae and the rings of forwardly directed hooks.

H hooks, LT longitudinal tracheae, PAS posterior abdominal spiracles.

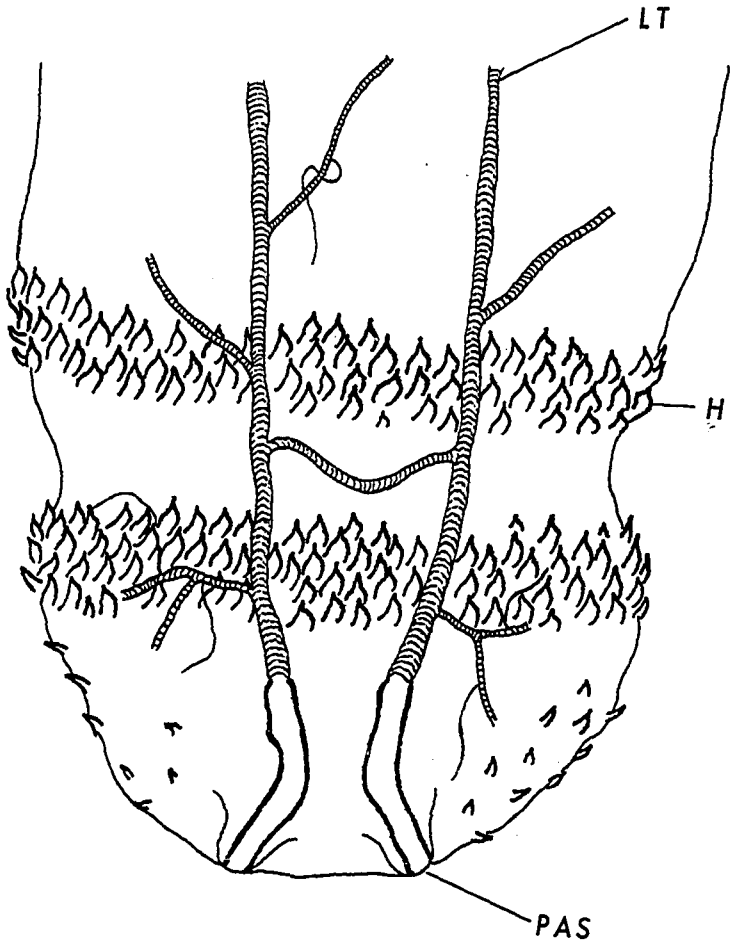

LT
H
PAS

Fig. 33

Posterior end of A. chlorotica showing gut partly evaginated from anus.

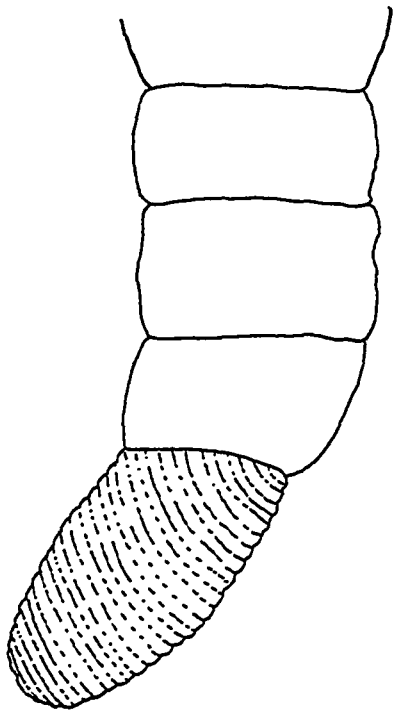


Fig. 34

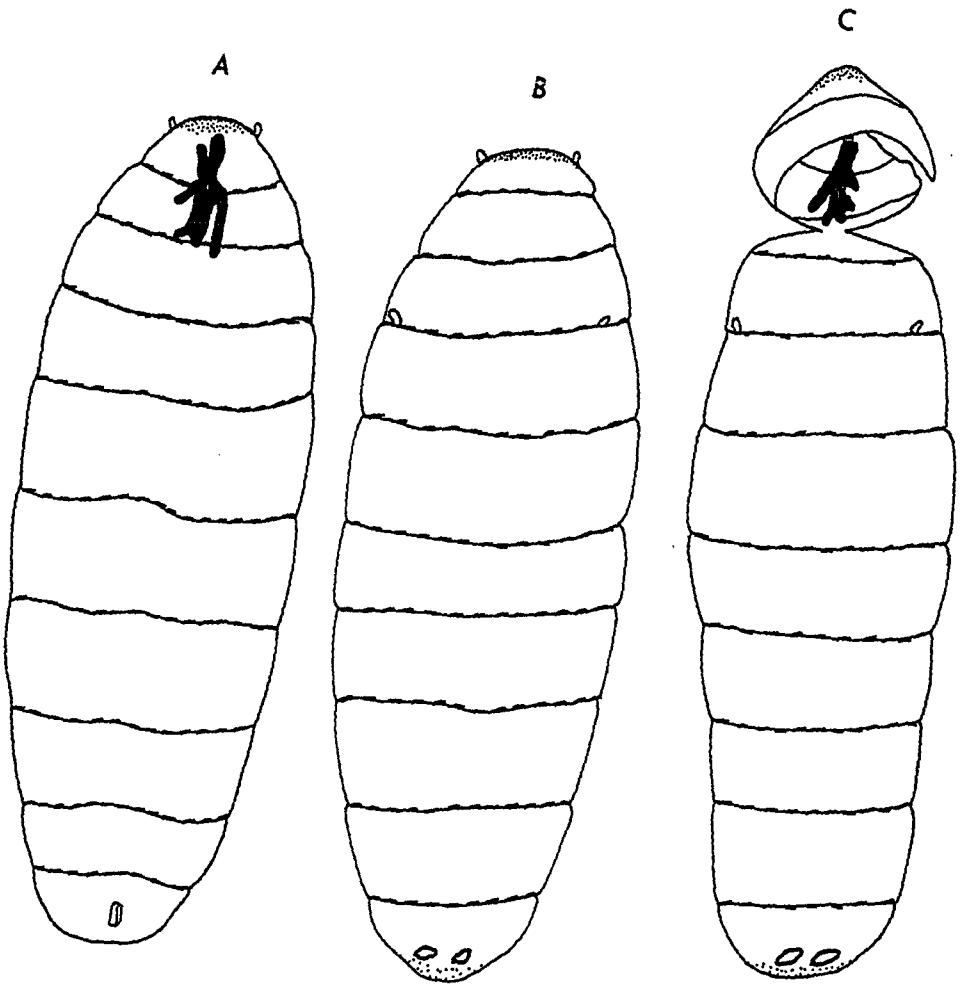
P. rudis.

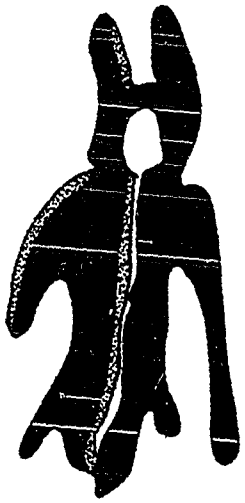
(A) Ventral view of the pupa.

(B) Dorsal view of the pupa.

(C) Dorsal view of the puparium following emergence of the adult.

(D) Enlarged ventral view of the cephalopharyngeal skeleton in (A).





D

Fig. 35

Newly emerged adult of P. rudis, showing the everted ptilinal sac and the unexpanded wings.

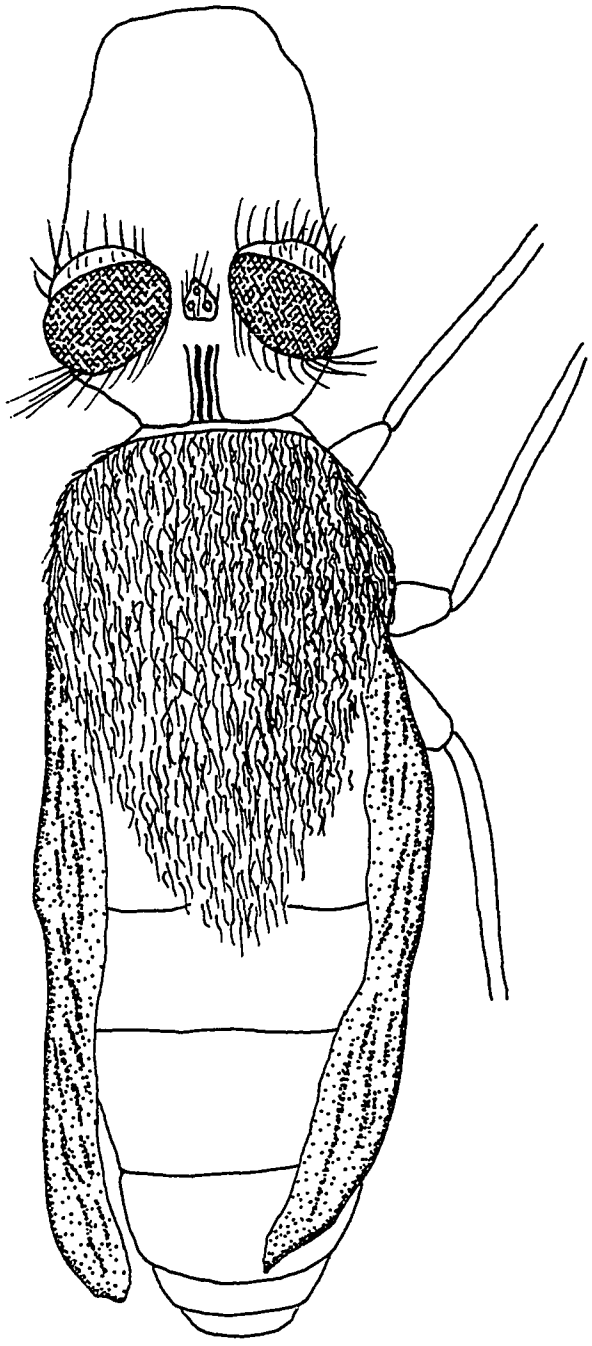


Table 1

Questionnaire on the types of buildings invaded by *P. rudis*.

A. (a) Occupied by people all year round
(b) Seasonally
(c) Occasionally

B. (a) Brick
(b) Stone
(c) Clapboard
(d) Log
(e) Other (state)

C. No. of stories

D. Overall outside colour of building

E. (a) Flat roof
(b) Sloping roof

F. (a) Wood-shingled roof
(b) Asbestos-shingled roof
(c) Tarred roof
(d) Other (state)

G. (a) In isolated area
(b) In built-up area

H. (a) On an elevation
(b) On the level
(c) On a slope

I. (a) Surrounded by a large area of clipped grass
(b) Surrounded by a large area of unclipped grass
(c) Surrounded by a large area of shrubbery

J. (a) Shaded by trees
(b) Not shaded by trees

K. (a) Wood frame windows
(b) Aluminium frame windows
(c) Other (state)

L. (a) Attic
(b) Crawl space

M. Any particular plant growing in abundance nearby

N. (a) Fences nearby
(b) Wood piles nearby
(c) Sheds nearby

O. (a) Accoustic tile ceiling
(b) Other type of false ceiling

Table 2

Number of P. rudis adults net-captured in the open in the Morgan Arboretum during the period May-August, 1970.

	May	June	July	August	Total
Females	2	24	20	85	131
Males	10	9	41	78	138
Total	12	33	61	163	269

Table 3

Sex ratios of live P. rudis adults collected from inside the chalet in the autumns of 1970 and 1971.

Year	Males	Females	Total	Males : Females
1970	341	346	687	49.6 : 50.4
1971	1589	1636	3225	49.2 : 50.8
Total	1930	1982	3912	49.3 : 50.7

Table 4

Live insects found on the inside of windows in the chalet in the autumn of 1971.

Order	Family	Species
Coleoptera	Coccinellidae	Coleomegilla maculata lengi Timberlake
		Adalia bipunctata L.
Diptera	Calliphoridae	Phormia regina (Meigen)
		Pollenia rudis (Fabricius)
		Protomorphia terraenovae (R-D)
	Muscidae	Musca autumnalis DeGeer
		Muscina assimilis Fallen
		Muscina pabulorum (Fallen)
		Muscina pascuorum Meigen
		Spilogona sp.
Hemiptera	Jassidae	Macrosteles sp.
Hymenoptera	Vespidae	Polistes fuscatus laurentianus Beq.
		Polistes fuscatus pallipes Lep.
		Vespula maculifrons (Buyss.)
		Vespula vidua (Sauss.)
		Vespula vulgaris (L.)

Table 5

Spiders found in the chalet in autumn 1971.

Family	Species
Araneidae	Araneus diadematus Clerck
	Araneus sericatus Clerck
Agelenidae	Agelenopsis potteri (Blackwell)
Theridiidae	Steatoda borealis (Hentz)

Table 6

Number and distribution of nymphs of *Carpoglyphus* sp. on the thoraces of *P. rudis* adults caught in the chalet on October 19, 1971.

Fly	Sex of fly	Position and numbers on thorax
1	Male	Mesothorax 2, metathorax 1
2	Male	Prothorax 1
3	Female	Prothorax 2
4	Female	Prothorax 9, metathorax 9
5	Female	Prothorax 2, mesothorax 1

Table 7

Numbers of live P. rudis adults collected from inside the windows of the chalet in the spring of 1971.

Date	Females	Males	Total
17.3	3	3	6
8.4	3	9	12
19.4	32	3	35
20.4	10	0	10
6.5	2	0	2
Total	50	15	65

Table 8

Incidence of phycomycosis in P. rudis adults collected from the floor of the dome of the McGill Radar Weather observatory on October 4, 1971.*

	No. of flies	No. infected	% of infection
Females	117	65	55.5
Males	208	52	25.0
Total	325	117	36.0

* All flies collected within 48 hours of death.

Table 9

Results of a questionnaire on the cluster fly problem completed by nine pes

Building	Geographical location	In isolated or built-up area	Topographical position	Occupied by people	No. of stories	O c b
1	Wheaton, Illinois	Built-up area	Level	All year	2	R
2	Oak Brook, Illinois	Built-up area	Level	All year	22	W
3	Spokane, Washington	Built-up area	-	All year	2	
4	Elizabeth Town, Pennsylvania	Built-up area	-	All year	1	
5	Paxton, Massachusetts	Built-up area	Elevation	All year	2	
6	Omaha, Nebraska	Built-up area	Elevation	All year	9	Wl
7	Los Angeles, California	Built-up area	Level	Seasonal	2	Gl
8	St. Louis, Missouri	Built-up area	Level	All year	2	Re
9	Kialua, Hawaii	Built-up area	Level	Seasonal	1	Wl

y nine pest control operators in the United States in 1971.

o. of tories	Overall colour of building	Major construction material of building	Flat or sloping roof	Construction material of roof	Construction material of window frames	Type c ceilir
2	Red	Brick	Flat	Tarred	Steel	Accous
22	White	Brick	Flat	-	Steel	Plaste
2	-	Wood	-	Wooden shingle	Wood	-
1	-	Brick	Sloping	Asbestos shingle	Wood	False ceilin
2	-	Clapboard	Sloping	Wooden shingle	Aluminium	-
9	White	Stone	Flat	Tarred	Aluminium	Plaste
2	Grey	Brick	Flat	Tarred	Aluminium	False ceiling
2	Red	Brick	Sloping	Wooden shingle	Wood	False ceiling
1	White	Wood	Flat	Corrigated iron	Wood	-

Type of ceiling	Attic or crawl space	Surrounded by grass or shrubbery	Shaded by trees	Any particular plant growing in abundance near by	Fences, wood-piles or sheds near by
Accoustic	Crawl-space	Asphalt car park	No	No	-
Plaster	-	Clipped grass	No	No	No
-	Attic	Shrubbery	No	-	-
False ceiling	Crawl-space	Clipped grass	No	No	No
-	Attic	Clipped grass	No	No	-
Plaster	Crawl-space	Clipped grass	No	No	No
False ceiling	Both	Shrubbery	No	No	No
False ceiling	Attic	Clipped grass and shrubbery	No	No	No
-	Attic	-	No	No	No

Table 10

Laboratory history of three pairs of adult P. rudis up to and including copulation.

Pair	No. of days at 4°C.	No. of days at 27°C. after which copulation was observed.	No. of minutes over which copulation was observed.
A	130	3	3
B	150	8	5
C	150	5	5

Table 11

Length and width in mm of 50 eggs of *P. rudis*.

	Length	Width
Mean	1.026	0.302
Range	0.98-1.06	0.26-0.32
S.D.	0.103	0.013

Table 12

Length and width in mm of 25 first instar larvae of P. rudis.

	Length	width
Mean	1.335	0.266
Range	1.12-1.50	0.20-0.34
S.D.	0.119	0.035