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With the Compliments of the Author
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The biology of some Hemiptera-Homoptera (Auchenorhyncha)

(with 24 Text-Figures and 2 Tables)

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I. INTRODUCTION

Going through the literature it was found that very little is known on the biology of the *Hemiptera-Homoptera* (*Auchenorhyncha*). Fox Wilson (1937) attempted to rear *Graphocephala coccinea* (Forst.), but he stated « ... but we so far failed to induce this leaf-hopper to oviposit under laboratory conditions ». Hassan (1939) gave a short account of some points in the biology of *Delphax fairmairei* (Perris). This is possibly due : (1) to difficulties in rearing this group of insects under laboratory conditions; (2) to difficulty in detecting the oviposited eggs, which are not externally visible in some instances, e.g. *Cicadella notata* (Curt.) and *Cicadula quadrinotata* (Fab.); (3) to the wide variation in host preference of the different species and their choice of different plants for oviposition and for feeding, as will be shown in *Tettigoniella viridis* L.; and (4) to the occurrence of some species on a variety of plants, though they mainly feed on particular ones. This demands accurate observations and a test, for the feeding habits as was found in *Cicadella notata* (Curt.) which occurs on several grasses and weeds, but appears to feed on *Hypochoeris radicata* though laying eggs in the weeds, or, again, in *C. quadrinotata* (Fab.) which was observed on different grasses including *Dactylis glomerata*, though the latter is the main host plant.

Delphax fairmairei (Perris) which Hassan (1939) found to feed on grass and lay eggs in the same host under laboratory conditions appears, according to my field observations, to feed on grass but to lay eggs in blackberries in two different ways, the shapes of the eggs varying with the site. There is a serious difficulty in detecting the eggs inside the plant tissues. This was found with *Graphocephala coccinea* (Forst.). Many attempts in the summer of 1947 failed to induce these hoppers to lay eggs under laboratory or outdoor conditions. Later on, it appeared that they lay their eggs in the sepals of the summer-autumn dormant flower-buds of *Rhododendron*, and these buds were not provided during rearing.

The object of the present work was to study the bionomics and life-cycles of those local *Auchenorhyncha* which were found most convenient for detailed observations.

Attention was also paid to their egg-parasites and the parasites of the nymphs and adults, and to the effect of parasitism by *Pipunculids*.

The majority of the nymphal instars of the species studied have been described here for the first time.

II. TECHNIQUE

1. Collecting

For collecting Jassids and Delphacids three methods were tried.

(a) Sweeping the grass with an insect net or fairly small mesh did not give satisfactory results. Jassids drop from plants when disturbed and conceal themselves in the dense bottom layer of grass. Moreover, the ring of the net cannot reach the very bottom stems and leaves. On the other hand, a net was helpful in collecting Jassids from trees and shrubs, excluding those with thorns.

(b) A sucking-tube was found the best for collecting both Jassids and Delphacids from grasses.

(c) A trial was made by spreading a four-feet square white towel on grass. Jassids were pursued towards this sheet and were picked up with the sucking-tube.

a. Under laboratory conditions

2. Breeding methods

(1) A tube (fig. 1) $1 \times 3\frac{1}{2}$ inches was made from a cellulose sheet of 0.4 mm. thickness. The sheet was placed on a graph paper and perforated with a hot pin. The holes were made about one millimeter in diameter. Then the sheet was rolled round two cork stoppers fixed at the ends of the tube and the edge was stuck with a strip of adhesive cellulose tape. One

of the two corks was ¾ inch long to fit a 1 × 3 inches glass specimen tube. A hole was made in the centre of this cork. The cork was split into two longitudinal halves and the two halves stuck together on one side with a piece of the adhesive tape, so keeping the two parts of the cork assembled together, but enabling them to be opened to fit round the stem of the plant. A small plant of grass with a fairly small root was grown in the glass specimen tube by filling it with two inches of soil. The grass was watered and the tube was closed with the ¾ inch cork. The space between the stem of grass and the cork was closed with a small piece of cotton-wool The perforated cellulose tube was fixed to the one inch cork, and its opening at

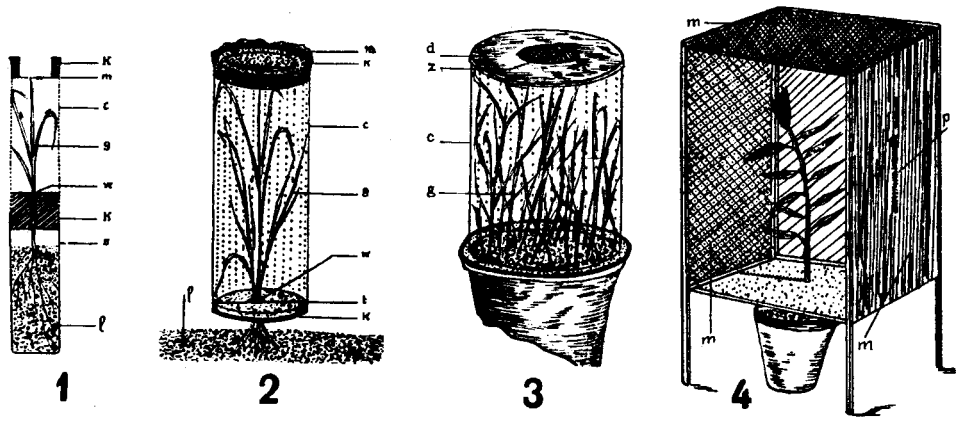


Fig. 1: A cellulose tube fixed to a glass tube (c, cellulose tube; g, grass; k, cork; l, soil; m, muslim; s, glass tube; w, cotton wool), ×¼. — Fig. 2: A cellulose tube fixed to grass (c, cellulose tube; g, grass; k, cork; l, soil; m, muslin; t, slit in cork; w, cotton wool), ×⅓. — Fig. 3: A cellulose cage fixed to a pot (c, cellulose cage; d, tin lid; g, grass; z, wire gauze), ×⅔. — Fig. 4: A muslin cage (m, muslin; p, zipp), ×$^{2}/_{13}$.

the top was closed with a cork having a hole ¾ inch in diameter. The hole was covered by sticking a piece of muslin at the bottom of the cork. This method had the following advantages:

(a) It kept the host plant (grass) green and fresh for over a month. Thus, it saved the trouble of changing the food periodically. Also, it kept the insects under conditions as near as possible to those under which they live naturally.

(b) The method used by Hassan (1939) for rearing Delphacids in specimen tubes, one fifth full of wet sand with four pieces of grass stems planted in it and with the tube covered by a piece of muslin, has been tried for breeding Jassids and Delphacids and was found unsatisfactory. The Jassids dealt with are small and of the macropterous form. The elytra are rather thin and easily stuck to the sides of the glass tube owing to condens-

ation of water-vapour which occurs when the soil is damp enough to keep the plants fresh. Excessive humidity was avoided in the present work by isolating the stem and leaves of grass from the wet soil with the cork at the bottom. Moreover, sufficient ventilation was provided through the perforated cellulose tube, and the muslin fixed to the bored cork at the top.

(c) The study of the incubation period of eggs was possible because the plants kept fresh for a considerable time after the eggs hatched. The parts of grass containing eggs in Hassan's method, when they had been kept for few days, became dry and caused a high mortality among the eggs.

(d) This double-tube method facilitated the microscopical examination of the different parts of grass and of many aspects of the behaviour of the insects.

3. Fixing cellulose tubes to grass growing in a pot

(Fig. 2)

A tuft of grass was cultivated in a pot 13 inches in diameter. Cellulose tubes $1\frac{1}{2} \times 3\frac{1}{2}$ inches were used. These were prepared as already described and fixed to the grass stems. A pair of insects were confined in each one.

4. The stock cellulose cage

(Fig. 3)

A perforated cellulose cylinder 8×12 inches with 2 mm. holes was fixed over some grass growing in a pot 13 inches in diameter. This was covered with a lid which was provided with a disc of wire gauze at its centre. This cage was used for keeping a stock of insects for general study.

5. The muslin cage for rearing Graphocephala coccinea (Forst.)

(Fig. 4)

A big cage was made for the purpose of studying the habits of *Graphocephala coccinea* (Forst.). It had a wooden frame $22 \times 22 \times 47$ inches covered with muslin on all sides except the front which was a transparent sheet of cellulose, through which the insects were watched. A zipp, 12 inches long, was sewn to the centre of the left side of the cage so that insects could be put into or removed from the cage through this opening. A *Rhododendron* plant growing in a 13 inches pot was inserted from the bottom of the cage through a slit made in the muslin. Then the slit was sewn right to the stem leaving no holes in the bottom.

6. Test-cage for host plants

As it was found difficult to discover the species of grass which was the real host plant of a given Jassid a special cage was made for this

purpose. The measurements of the cage were $9 \times 12 \times 10$ inches. The side walls were made of glass, with the bottom 3 inches of wood to hold a layer of soil 3 inches deep. The bottom was perforated to allow drainage, and the top was covered with muslin fixed to a wooden frame. A hole was made in the muslin top through which a glass funnel with a fairly long stem was fixed for watering the grass without opening the cage.

7. The glass specimen tube method

For rearing *Delphax fairmairei* Perris, a glass specimen tube 2×1 inch was used. A pad of wet cotton-wool was put at the bottom of the tube and was covered by filter paper so as to prevent the tarsi of the insects from being caught. The tube was closed with muslin fixed to the opening of the tube by a cork stopper with a hole at its centre. A few pieces of grass stems and leaves were kept in each tube.

Breeding *D. fairmairei* Perris by this method was successful.

8. The glass pot method

A glass pot 2 $^3/_8$ inches in diameter and 1 $^3/_8$ inches high was covered with a glass disc which had a $1\frac{1}{2}$ inches diameter hole at the centre covered with muslin stuck to the glass border by sealing wax. The glass disc was put on the top of the pot and hinged to its side by a cellulose adhesive tape. A piece of wet cotton-wool $\frac{1}{4}$ inch thick covered with filter paper was put at the bottom of the pot. Grass stems and leaves were put in as in the glass specimen tube method.

This method proved to be satisfactory for the rearing of the species dealt with in this paper, with the exception of *Tettigoniella viridis* (Lin.). For *T. viridis* (Lin.) a grass shoot growing in soil in a glass tube $\frac{3}{4} \times 1$ inch was put horizontally into the glass pot just described. Fresh sap provided by actively growing grass appeared to be essential for the successful breeding of this species.

9. Keeping the eggs in cut pieces of stems to hatch

A method was tried for keeping the eggs of *Cicadella notata* (Curt.) laid in the flower stalk of *Hypochoeris radicata*, during the incubation period under laboratory conditions. A piece of flower-stalk containing the eggs was cut obliquely with a sharp razor blade and fixed through a cork. The stalk was inserted into a small glass tube with a cork stopper on its top, having a hole covered with muslin. To the cork at the bottom 4 pins were fixed to allow the whole tube to stand in a small beaker containing a little water (which was changed daily). This method seemed to be satisfactory for keep-

ing the eggs. It delayed the growth of fungus for about 25 days, by which time the incubating eggs were just hatched.

b. Under field conditions

1. Breeding Criomorphus pteridis (Boh.) on bracken plants

A cellulose sheet of the same measurements and description as in No. 3 was rolled round two cork stoppers fixed at either of its ends and the side edge was stuck temporarily with a cellulose adhesive tape. Then the tube was immersed in a hot water-bath to enable it to be moulded into the required shape. The two cork stoppers were bored in the centre, having a hole $^3/_8$ of an inch wide. Each was then split into two halves. Each pair of halves was assembled and stuck on one side with the adhesive cellulose tape. The stoppers were dipped in hot wax for reproofing. The cellulose rolled sheet was fixed round the stem of bracken plant and the split stoppers fixed at each end of the tube opening round the stem of the plant. The side of the tube was stuck with the adhesive tape. Then the corks were removed, and the tube was stapled with two stiches to keep it firmly fixed so as to stand changes in the weather. The cork at the bottom was fixed to the tube and a piece of cotton-wool was wrapped round the stem and the cork inside the tube. Then the insects were put into the tube and the cork at the top was fixed. The opening between the stem and the upper cork was also closed with a piece of cotton-wool. A round cellulose disc acting as a shelter was fixed to the upper cork by making a $^3/_4$ of an inch hole at its centre and a slit running from the centre to the periphery (one side only). Then the disc was fitted round the plant and fixed to the upper cork with two pins. These discs were originally intended to keep off rain but they were also useful as landmarks when fixing the tubes.

2. Breeding Graphocephala coccinea (Forst.)

Cellulose tubes were made in the laboratory and slipped over the tips of the growing shoot of *Rhododendron*. The number of leaves kept in each tube was reduced according to its size. The cork at the bottom of the tube was fixed to it in the way already described. The top of the tube was closed with a perforated cork and muslin.

III. MATERIAL STUDIED

1. Criomorphus pteridis (Boh.)

This Delphacid is found commonly on bracken (*Pteridium aquilinum*) which is its only host plant. In winter some nymphs were collected and fed

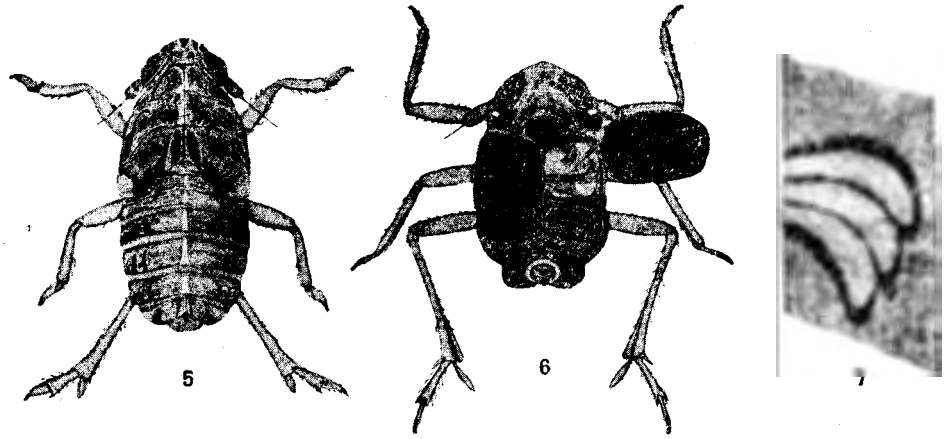
on grass under laboratory conditions with a temperature range of 20°-26° C. The nymphs (fig. 5) became active, but did not feed and died after 2 days.

The insects feed on either side of the leaves though the majority occur on the underside and on the stems of bracken. The punctures caused by their mouth-parts could not be detected easily by the naked eye, when fresh, but later on pinkish spots appear. Also the egg-slits are easily seen scattered in the stem and the midrib of the compound leaf. These slits appear as short lines, pinkish or brown in colour. Adults and nymphs emerge in the first half of June, females being followed by males

The adult

Edwards (1896) gives a description of the adults, but his description was possibly made on old dry specimens because of inacuracy as regards the colour of the legs and the thorax which in fresh adult individuals are coloured as follows:

♂. Fore and mid coxae black; trochanters light brown; femur and tibia light brownish yellow in colour. The first two tarsal segments brown, but the last much darker (nearly black). The tips of the bristles of the hind tibia and those of the spur are dark brown or black. Thoracic sternites nearly black.



Criomorphus pteridis (Boh.)

Fig. 5: Nymph, ×17.5. — Fig. 6: Adult, ×15. — Fig. 7: Eggs in a piece of bracken-stem, ×20.

Macropterous males are scarce, as only three individuals were collected at Silwood Park on June 15th, 1948. In the brachypterous form there is no trace of the articulation of the aborted hind-wings (fig. 6).

♀. Fore and mid coxae are light brownish, but the hind coxae are brown in colour. The rest of the legs are of the same colour as in the male. Thoracic sternites brown.

Copulation

Males face the apex of the female's abdomen. They move slightly forwards and vibrate their elytrae, raising them upwards and downwards in an acute or right angle to the body. The female was seen feeding during this time, and it seemed to be unready for copulation because it refused copulation. It pushed its hind leg backwards at the male, making several strokes. The male made some attempts to excite the female by going round it, walking laterally with its face round the margin of the female's body and vibrating its elytra. When it touched the female, the latter moved its fore or hind legs pushing the male away. After a considerable time the male left the female and wandered about the leaves. Then, it again attempted to excite the female. This was observed repeatedly with different couples. I had no chance to see the pairs in copulation.

Pre-oviposition

Twelve pairs which emerged on May 22nd 1948, were confined in separate cellulose tubes fixed to bracken plants in the field. Five individuals started laying eggs on 5th June, i.e. approximately 14 days.

Oviposition

The female makes an egg-slit with its ovipositor either in the stems of bracken, or in the stalks or midribs of the compound leaves. A single female laid about 100 eggs in 41 egg-slits, either one, two (usually) up to five per slit.

Oviposition took place in the field from the first week of June.

Incubation period

The eggs which were laid on 5th June 1948 hatched out on 22nd July, that is 47 days under field conditions.

The egg

Eggs (fig. 7) are hyaline, whitish in colour, oval in shape, curved, and tapered slightly towards the operculum, about one millimetre in length, and 200 μ in width. They are inserted within the plant in an egg-slit which is made vertically in the direction of the plant veins. The slits are either single or in pairs close and parallel to each other, both on more or less the same level. After some time the slits become brownish pink in colour and later turn black. The cone like caps of the eggs which cover the micropiles sometimes appear on the surface of the slit but in some instances they are covered with a transparent or white gum-like secretion.

In the last week of September 1947, 500 egg-slits were examined to determine the hibernating stage, the arrangement and number of eggs in the slits, and to search for egg-parasites. This examination was really too

late in the season for egg-parasites, but some which had failed to emerge or which left traces of their development were nevertheless found.

270 (54%) of the above mentioned egg-slits were found single, and 230 (46%) paired. 91 (18.2%) of the egg-slits contained one egg, 300 (60%) two eggs, 100 (20%) three eggs, 4 (0.8%) four eggs, and 5 (1%) five eggs. The condition of these eggs at this time of the year was as follows: 641 (62.11%) hatched eggs, 35 (3.39%) alive eggs, 145 (14.05%) dead eggs, and 211 (20.45%) parasitized eggs.

The relative high percentage of hatched eggs induced the author to undertake a thorough search of the nymphs.

Hibernation

In the first week of October, about 400 nymphs were collected. Some were found on the few remaining green plants of bracken and the rest in the thick layer of dead leaves and stems lying on the ground, presumably their proper shelter for hibernation. Another 400 nymphs were collected from the same spot in the third week of December; the majority in the third or fourth instar; none could be seen of the first or last instars. The hibernating nymphs (Fig. 7) were successfully kept alive during winter in cellulose cages with growing moss at the bottom, and a few dry stems and leaves of bracken, being lightly watered every now and then. Some others were kept on growing grass in a plant-pot, the grass being surrounded with a cage.

On 22nd April 1948, bracken buds were obtained by digging from the soil. Some of the hibernating nymphs were successfully fed on these buds, under laboratory conditions. In a few hours some of them moulted.

On 1st May limited number of bracken shoots appeared above soil about a foot in height. Some of the hibernating nymphs started to feed on these new plants. In the third week of May the adults of *C. pteridis* emerged, some of which were collected on 18th of that month.

Number of generations and seasonal occurrence

C. pteridis (Boh.) has one generation a year. The adults emerge in the second half of May and die by the end of July, though six females were collected on 9th August 1947. The eggs were found from the first week of June, decreasing to very small numbers in the last week of September. The nymphs emerged from 22nd July (1948). They pass the winter in the second, third or fourth instar.

Parasites

Anagrus spec. (Mymaridae)

This tiny species has been found parasitising the eggs of *C. pteridis* (Boh.). It seems to quite agree with *Anagrus dilatatus* (E n o c k, i.l.) accord-

ing to Mr. W. D. Hincks, but it is not safe to use this name at the moment. Specimens have been deposited in the collections of the Commonwealth Institute of Entomology and the Manchester Museum. No external symptoms of this parasite indicated its presence before the adults escape from the egg-shells. When the adult parasite emerges, it gnaws its way through the stem making an oblique tunnel which opens to the exterior in a clear-cut round hole located on one side of the egg-slit, when it is a single slit and on the outer side of the egg-slits in the case of a pair of slits. It never comes out straight through the egg-slit of the *Delphacid*.

In some instances a round patch lighter in colour than that of the bracken stem was seen on the outer side of the egg-slit of the Delphacid. This patch indicated the presence of the adult parasite, which was found dead after it had gnawed its tunnel nearly up to the surface of the stem. The emerged adult parasite leaves behind the chewed particles of the stem, a portion of which is left in the egg-shell.

Not more than one adult *Anagrus* spec. was found in each egg. All the eggs of one slit are not always parasitised. I have never seen more than two holes beside the single slit though 20% of the egg-slits contained 3 eggs in each, and not more than 2 holes in each outer side of a pair of slits. The examination of 1032 eggs of *C. pteridis* (Boh.) revealed the presence of 211 eggs parasitised by *Anagrus* spec. (20.45%); but only 48 escape holes were found. In other words the mortality among these egg-parasites is 77.3% which sounds very high. This could be probably attributed to the relation between the date of the adult parasite emergence and the nature of the plant. The plant, while green, has soft tissues but when it is about to die off or is dead, its cortex hardens so that the adult parasites which emerge from the late parasitised eggs of *C. pteridis* (Boh.) may find difficulty in gnawing their way out. The examination of these egg parasites was made late, at the end of October 1947, and all the plants examined were either semi-dry or completely dry.

Pipunculus semifumosus Kow. (Pipunculidae)

On 13th July 1947, thirty females of *C. pteridis* (Boh.) emerged. Three days later five of them were found dead, being parasitised with Pipunculids (Diptera) larvae. These larvae pupated next day but none emerged. On 21st April 1948 three of the hibernating nymphs of *C. pteridis* (Boh.) were collected and found parasitised. The larvae left their hosts on the 24th and pupated the next day. The adult flies emerged on 14th May 1948, and were kindly identified by O. W. Richards as being two females of *Pipunculus semifumosus* Kow. and a male probably of the same species.

It is obvious that Pipunculid larvae found at this time of the year (21st April) must have been in diapause during winter, possibly either in the egg or in the larval stage.

2. Delphax fairmairei Perris

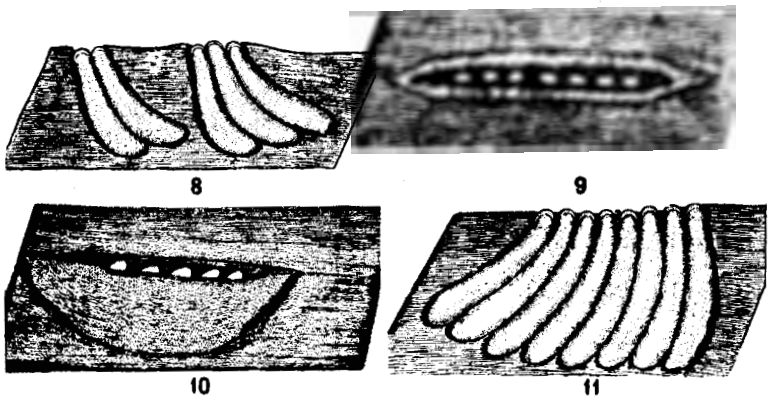
This Delphacid was collected from those parts of the field where blackberries, rushes (*Juncus effusus*) and *Holcus* were in association. It seems that *Delphax fairmairei* Perris occurs more often in wet places than in dry ones. The collections were made on the west side of Silwood Park in wet ground adjacent to a stream.

Hibernation

On 24th March 1948, examination of runner and aerial stems of blackberry revealed the presence of the hibernating eggs of *Delphax fairmairei* Perris. Hassan (1939) refers to the presence of the eggs in the field from the second half of August to the first half of May, in the stems of grasses. In my opinion blackberry is probably the more important oviposition site.

The egg

The egg (fig. 8) is hyaline, yellowish white in colour, oval in shape, and of variable curvature. The egg turns orange when the embryo is about



Delphax fairmairei Perris

Fig. 8: Eggs, ×20. — Fig. 9: Egg-slits (top view), ×20. — Fig. 10: Egg-sac, ×20. — Fig. 11: Egg-slits (longitudinal section), ×27.5.

full grown. It is 800 μ in length and tapered slightly towards both ends (fig. 8).

The blackberry stems contained eggs of *Delphax fairmairei* Perris of two different shapes; further, there were two methods of oviposition, as follows:

(1) Eggs are laid in a semi-hard sac (fig. 9) located underneath the mesophyll layer of the runner stems. Few egg-sacs were found in the aerial stems of blackberry, and none in the petioles. This sac opens to the exterior through an egg-slit 400 to 500 μ long; the margin of the slit is hardened, brown in colour and oval in shape. The eggs are deposited obliquely to the veins of the stems. The sacs show as a prominent tumour which is slightly lighter in colour than the stem. The tumours vary in size according to the number of eggs which they contain. The conical caps covering the micropiles of the eggs protrude from the egg-slits. A gum-like secretion often covers the opening of the egg-slits. It appeared that the egg-sacs are found in rows with from 2 to 11 egg-sacs in each. Single egg-sacs were also found scattered about. The majority of the egg-sacs are located in the edges where the pentagonal sides of the stem meet. The longest row contained 26 egg-sacs and was 37 millimetres long and there were fifteen slits which had no indication of egg deposition. This might have been due to unseccessful attempts at oviposition, as found in several other places in the stem.

From 1 to 5 eggs were found overlapping in the egg-sac, but 1, 2 and 3 eggs per sac were the more frequent numbers. Examination of 200 egg-sacs showed that 37.5% contain single eggs, 51% two eggs, 8% three eggs, 3% four eggs and 3% five eggs.

A piece of runner, 45 cms. long, was examined and revealed the presence of 253 eggs.

(2) Eggs may also be laid right inside the runners, the aerial stems and leaf-stalks of blackberry, being placed perpendicular to the plant surface. Unlike the egg-sacs, here the eggs in slits show no swellings. The eggs look different in shape and length from those laid in the sacs. This might be attributed to the difference in the effect of the plant tissues on the eggs. Those laid in sacs are superficial and lie under a light pressure of the plant cuticle. Whereas, those laid through deep in the stem might be subject to greater pressure. The eggs found in the stems or leaf-stalks are hyaline, oval in shape and tapered slightly towards the operculum. The egg is about 900 μ in length and slightly curved.

The egg-slits (figs. 10 and 11) are parallel to the plant veins and many are found in one line or in several parallel lines. The egg-slit is 1.2 mm. to 3 mms. in length. The slits have a hardened brown edge with the tips of the eggs showing through the opening. This opening is often covered with a gum-like secretion. The eggs are found in rows overlapping each other. The egg-slits contain from 3 to 13 eggs per slit. One hundred egg-slits were examined to show the distribution of eggs in the slits. 10% of the egg-slits contained three eggs, 9% four eggs, 6% five eggs, 16% six eggs, 25% seven

eggs, 16% eight eggs, 15% nine eggs, 1% ten eggs, 1% eleven eggs, and 1% thirteen eggs. Thus, the six, seven, eight and nine eggs per egg-slit were the more frequent.

Adults were reared from eggs in sacs and from eggs in slits and some males of each were submitted to Dr. W. E. China who kindly determined them as *Delphax fairmairei* Perris.

On 10th April 1948, eggs of *D. fairmairei* Perris were removed from the stems and put in a glass pot with wet cotton-wool covered with filter paper. Some of the eggs were in direct contact with the filter paper and the others were kept with small parts of the blackberry stems leaving the eggs exposed on one side. The avoidance of large pieces of plant stems and the removal of the eggs from the stems minimised the trouble caused by fungus infection. Eggs were kept under laboratory conditions with a temperature of 20-25° C. The majority of the eggs hatched out after six days.

Duration of the nymphal instars

Ten eggs of *Delphax fairmairei* Perris hatched on April 16th 1948, 17 on the 17th, 4 on the 18th, and 11 on the 19th. The 51 nymphs were reared under laboratory conditions with a temperature range of 19-25° C.

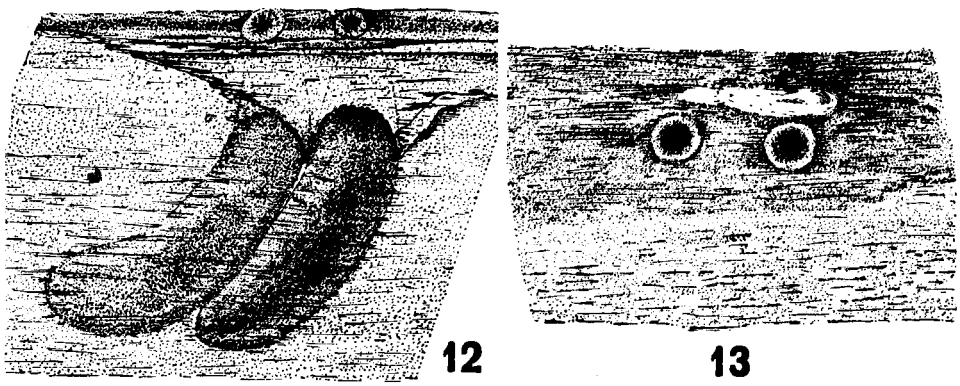
The duration of the 1st, 2nd and 3rd nymphal instars was 3-5 days each. The 4th instar from 3-6 days and the 5th from 6-9 days.

The total duration of the nymphal period was 22-27 days (mean 24.2).

Parasites

Anagrus incarnatus (Hal.) (Mymaridae)

On 24th April 1948, some eggs of *Delphax fairmairei* Perris were found parasitised with *Anagrus incarnatus* (Hal.), kindly determined by Mr. W. D. Hincks. The parasitised eggs are orange in colour with the mecon-



Anagrus incarnatus (Hal.)

Fig. 12: Escape holes (longitudinal section in stem of blackberry), ×50. — Fig. 13: Escape holes (top view).

ium showing through the egg-chorion. The larva and pupa of this parasite rotate inside the egg-shell of the Delphacid egg, when stimulated by light or heat. The adult parasite, when full grown escape through a round hole which it gnaws (figs. 12 and 13). In the case of the eggs which are laid in superficial sacs and just under the cuticle of the blackberry, the parasite usually makes its hole at the posterior end of the egg. Consequently the holes of the parasite in this case are not far from the eggs, unlike those found in the egg-slits where the adults gnaw a tunnel quite a distance from the free extremity of the embedded eggs. The head of the parasite-embryo was usually found at the posterior end of the Delphacid egg, and the parasite breeds singly in the egg.

3. Cicadula sulphurella (Zett.)

The adult female of this Jassid is about 5 mms. long and the male is 4 mms. Both sexes have a distinct sulphur-yellow colour and the crown bears no colour pattern. The venation of the elytra stands out as an even brighter yellow.

Host plants and habitat

This species feeds apparently only on *Holcus mollis* for it was never collected by the author from any other grass. It seems to prefer either semi-dry or wet places in fields where the host plant occurs.

C. sulphurella (Zett.), like other leaf-hoppers, is active and jumps quickly when disturbed. It has a curious habit of lateral movement when walking. Some individuals were watched in a cellulose cage. They never walk in a straight line, but go around the sides of the cage upwards or downwards. This behaviour is similar to that seen in the field on the plants. When they are in danger they immediately retire to the opposite side of the leaves or stems in a quick lateral movement. When they cannot escape the danger they hop to a distance of a foot or fly to a near plant. If they are still disturbed they drop from the leaves of grass and are concealed underneath the mat of grass at the bottom. As to their feeding habits, *C. sulphurella* (Zett.) feed on either side of the leaf of grass or its stem.

All my collecting was made at the Imperial College Field Station, Silwood Park, Sunninghill, Berks.

Nature of injury

As many different species of leaf-hoppers live together with *C. sulphurella* (Zett.), it is rather difficult to appreciate the amount of damage done by this species. However, during my laboratory breeding experiments, a cage was set up for keeping a stock of about 200 individuals of these Jassids and hence considerable damage to the grass was noted. Three days after

having put the adults into the cage, the grass showed a lack of vigour and the leaves had a mottled whitened appearance. A few days later, growth was obviously retarded and the leaves turned yellow, wilted and died.

Hibernation

A weekly collection of *C. sulphurella* (Zett.) was made in 1947 from the beginning to the end of September. 210 females were collected during the first week, 550 females and 3 males in the second week, 120 females in the third week, and 50 females in the fourth week (total 933 individuals). Sixty (6.4%) of these were found parasitized with Pipunculids (Diptera) larvae. No *C. sulphurella* (Zett.) could be obtained in the first week of October.

The figures for the first week of September are not really comparable because the exact locality in which *C. sulphurella* (Zett.) occurred and the favourite host plants were not known to me at that time. From the second week onwards, the decrease in the number of adults is clearly seen. On 6th September 1947 one hundred females were kept in a cellulose cage fixed to some grass growing in a pot. Eight cellulose tubes were also fixed to grass and five females were put in each tube. Most of the individuals were actively ovipositing under laboratory conditions until 15th. They started to die off from the second half of September, and by the end of the month no adults were alive. This agrees with the above data, for the adults were getting scarce in the field at the end of September and none could be seen in the first week of October. Consequently, the eggs appear to be the hibernating stage of this Jassid.

A cellulose perforated cage covering some grass containing eggs and kept indoors, or a cellulose perforated tube fixed to a stem of grass growing in a pot and the tube left lying between other green leaves of grass, were the best methods which allowed to keep the eggs viable during the winter.

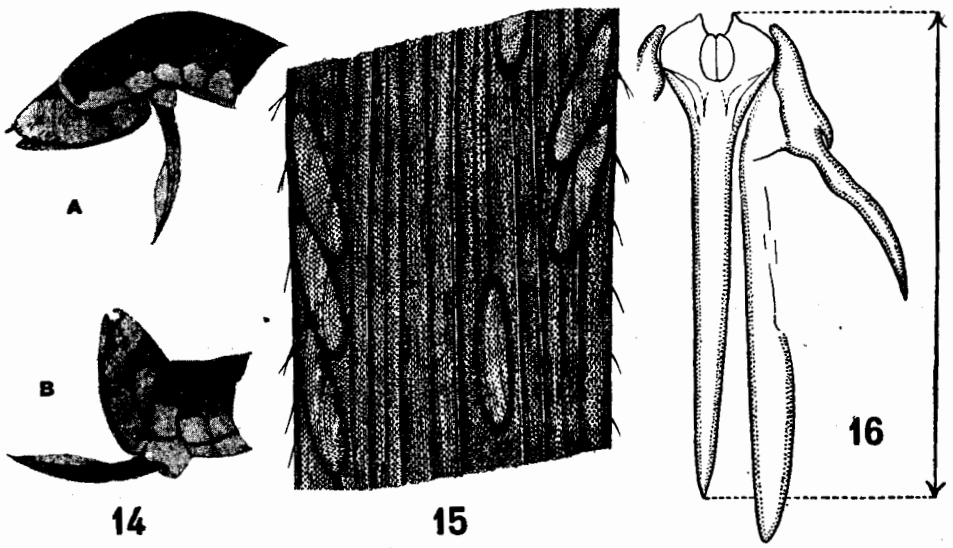
The hibernating eggs were all kept indoors in a partly ventilated room without any heating. The eggs started to hatch on 4th May 1948.

Oviposition

When an adult female begins to lay eggs, it wanders about the leaf of grass, chooses a fresh green part either of the blade or sheath, and feeds before commencing to insert any eggs. It then stops for an instant, getting ready for oviposition. The ovipositor valves exhibit, whilst still horizontal, protrusion and retraction alternately. The saw-like valves protrude from their case downwards, lying perpendicular to the plant surface. In this stage the Jassid slopes downwards in either direction from the point of attachment of the ovipositor and the last sternite (fig. 14).

It then holds the plant firmly with its fore legs, balancing its body as on a tripod, making a third leg with the tip of the saw-like valves. Sometimes, the hind legs exhibit a free movement in the air, keeping away from the leaf or just touching the hairs of the plant. In the mean time the mid legs just touch the leaf surface and are occasionally lifted up. It then begins to force the ovipositor through the tissues of the leaf. The power used in pushing the ovipositor through the cuticle is due to the muscles attached to it, partly to the weight of the Jassid concentrated on this point of the tripod and partly to the upward and downward movement of the saw-like valves which cut the tissues of the leaf. The parts of the serrated pair of valves when in action do not work alternately as in the saw-fly. This is due to their fusion proximally for about a third of their length.

In some instances the Jassid fails to insert its ovipositor in the chosen place. It thus makes several trials, proceeding a step forward each time until it succeeds. When it fails again it bends the ovipositor laterally and



Cicadula sulphurella (Zett.)

Fig. 14: A, first ovipositing site; B, second ovipositing site (×15). — Fig. 15: Eggs in a leaf of *Holcus mollis* (treated with 10 % caustic potash), ×42. — Fig. 16: Length of ovipositor, ×21.

obliquely, usually meeting softer tissues through which the ovipositor can be pushed more easily.

The ovipositor valves exhibit a continuous saw-like movement before laying the egg, clearing a much wider space than that of the egg, in different directions parallel to the leaf surface, either in the cylinder sheath or the flat blade. Clearing a wide space to provide a proper pouch for the egg,

seems to be necessary. The ovipositor is flattened in the same place as the leaf cuticle. Thus, unless a space wider than the egg diameter is cleared, the latter will be squeezed after the ovipositor is withdrawn by contraction of the stretched leaf cuticle. As the Jassid egg appears to be rather soft, squeezing might damage it.

Laying an egg took from one and a half to about ten minutes. The long time for laying an egg in a few cases was due to disturbance by other individuals kept in the same petri dish.

When a pocket has been made the egg runs from the oviduct through the ovipositor and into position. The ovipositor leaves a longitudinal slit of about 0.46 mm. which closes during the growth of the leaf, though some slits in the margins of the leaves were seen open even after the leaf died.

The egg

The eggs of *Cicadula sulphurella* (Zett.) (fig. 15) are hyaline, whitish in colour, oval in shape and tapered slightly towards the operculum. They measure from 1 to 1.33 mm. in length. They are usually laid individually underneath the upper or lower cuticle, either in the blade or sheath of the leaf, whereas in a crowded culture of *C. sulphurella* (Zett.) from 2 to 7 eggs were found overlapping one another. A piece of grass containing eggs was treated with 10% warm caustic potash for a few seconds to remove part of the chlorophyl to show the position of the eggs in the leaf properly (fig. 14). The eggs frequently lie parallel to the leaf veins or occasionally in an oblique position either along the margins of the leaf or elsewhere. Sometimes the egg is found located between two veins and in other instances one of the veins or both run over the egg. With experience, the position of the freshly laid eggs can be told with the naked eye by the swelling blocking the depression between the prominent longitudinal veins of the leaf. But later, the epicuticle or the exocuticle dies leaving a spot lighter in colour than the rest of the leaf.

Variation in colour pattern of nymphs

A range of colour pattern occurs in this species, from a general light yellow colour to a nearly black as in *Cicadula quadrinotata* (Fab.).

Duration of the nymphal instars

From a single egg hatched on 4th May 1948 and reared in the laboratory conditions at 19-24° C., the duration of the nymphal instars can be summarized as follows: first instar (moulted 11th May) 7 days, second instar (moulted 18th May) 7 days, third instars (moulted 23rd May) 5 days, fourth instar (moulted 5th June) 13 days, and fifth instar (moulted 20th June) 15 days.

Parasites

Pipunculus thomsoni Beker

On 3rd September 1947, an adult female of *C. sulphurella* (Zett.) was caught with other Jassids in a sucking tube, and on examination a Pipunculid (Diptera) larva was observed crawling on the walls of the tube. The *C. sulphurella* (Zett.) sample was found dead with the abdomen split open between the third and fourth tergites, all the abdominal contents being eaten. The next day the parasitic larva pupated. During the interval between the first week of September 1947 and the first week of October of the same year, 930 adult females and 3 adult males of *C. sulphurella* were collected. Of this number 60 parasitised individuals were found. Thirty Pipunculid larvae were obtained. Most of them pupated a day after they migrated from their hosts, and a few pupated after two days. The pupae were kept in glass specimen tube with a little soil. Unfortunately most of the pupae failed to emerge next summer. The single adult which emerged was kindly determined by Mr. R. L. Coe of the British Museum (Natural History).

Symptoms of parasitism

The external signs of parasitism in the adult are obvious when the larva of the Pipunculid is in about the last stage. The leaf-hopper shows a distinct swelling of the abdomen which projects behind the elytra. When the parasite is half developed a parasitised adult Jassid could be detected by an experienced eye as follows: (1) the full appearance and roundish cylindrical form of the abdomen of the host, provided the parasitised host is a male, because this might be confused sometimes with the unparasitised female which retains developed eggs; (2) the slightly lighter colour of the abdomen in the parasitised adult; (3) alteration of colour pattern is caused in some cases as will be explained later.

Behaviour of the parasitised host

On 3rd September 1947, eleven parasitised adults of *C. sulphurella* (Zett.) were kept singly in cellulose tubes fixed to glass specimen tubes with growing grass. The behaviour of these parasitised adults was watched when the Pipunculid larvae were about fully developed, and after they migrated from their hosts. The leaf-hopper with a grown Pipunculid larva shows much less activity and tends to settle on grass longer than usual. The parasite, when full grown, devours the contents of the abdomen of the host and exhibits its vermiform movement of alternate contraction and expansion. During this time the host is seen firmly fixing its claws and rostrum to the plant. Through the movements of the Pipunculid larva, waves of pressure are concentrated on the front portion of the abdomen of the

host. In almost all cases (50) the pleura between the third and fourth tergites split open and the Pipunculid pushes its mouth-parts through and makes its way out. Usually the host dies a short time after the parasite migrates from its abdomen.

Effect of parasites on the host

The colour pattern of *C. sulphurella* (Zett.) was examined in a number of parasitised and unparasitised individuals to determine the effect of the presence of Pipunculids. Seventeen parasitised females showed extreme modification, six showed moderate colour changes from the normal, and ten showed slight variation. Two parasitised males showed moderate colour changes.

The degree of colour modification may also depend on the stage at which the host is parasitised. Nymphs show greater modification than adults.

In the extreme cases of colour pattern change, the obvious thin black line extending from the base of each simple eye and marking the suture which separates the frons from the sides of the head (cheek and lora) and continues to the post-clypeus, is missing. The black colour pattern which covers about four fifths of nearly all the tergites is light brown with many irregular yellowish spots, and the coloured areas are reduced to about half. In some instances the colour pattern of the pygophor disappears completely. There is a longitudinal thin black stripe near the lateral margin of each tergite which disappears also in an extreme case of colour change. The more or less black triangle formed on the sixth to the first sternites is also missing but a small light brown spot is left on the fifth sternite in some instances.

Reduction in the size of the adult host

In a few cases the parasites failed to emerge, and their larvae were found in an abnormal position in the abdomen of the host when dissected. The mouth-parts of the parasitic larvae were directed at the caudal end of the host, though it is supposed that they can turn round freely in the empty abdomen of the host at the end of the final larval stage. The parasite attacks the host in its early nymphal stage, and certainly affects its growth, while the Pipunculid larva grows normally. Measurements of the tibae of 50 unparasitised, and the same number of parasitised females were made. Table I shows the frequencies obtained, the difference between the means being significant.

Reduction of the female genitalia

It was noticed that besides the tibia the female genitalia of parasitised individuals were also reduced. Twenty four ovipositors of parasitised and same number of unparasitised adults were measured each from the pointed end of the second valve to the top of its articulation with the valvifer

(fig. 16). The figures for the length of ovipositor in parasitised and unparasitised individuals show the obvious reduction in the latter. Table II shows the frequencies obtained. The difference between means is significant.

TABLE I

LENGTH OF TIBIA (in millimetres)	NORMAL	PARASITISED
2.10	0	0
2.15	0	4
2.20	0	4
2.25	1	4
2.30	6	4
2.35	5	11
2.40	5	8
2.45	10	9
2.50	6	4
2.55	9	2
2.60	7	0
2.65	0	0
2.70	1	0
MEANS	$\overline{X} = 2.463$	$\overline{X_1} = 2.356$
N = 98	t = approx. 4.7	P < 0.001

TABLE II

LENGTH OF OVIPOSITOR (in millimetres)	NORMAL	PARASITISED
1.2	0	4
1.3	0	6
1.4	0	5
1.5	0	7
1.6	11	0
1.7	13	2
MEANS	$\overline{X} = 1.654$	$\overline{X_1} = 1.396$
N = 46	t = 3.50	P < 0.001

4. Cicadula quadrinotata (Fab.)

On 1st June 1948, nymphs and a few adults of this Jassid were collected from grasses at Silwood Park (Ascot). The adults and nymphs are active and quickly drop from the plants when slightly disturbed.

Host plant

Cicadula quadrinotata (Fab.) was only found in places where *Dactylis glomerata* occurred. Consequently, a preliminary test was made to confirm this association. About 500 nymphs and adults were kept in a cage con-

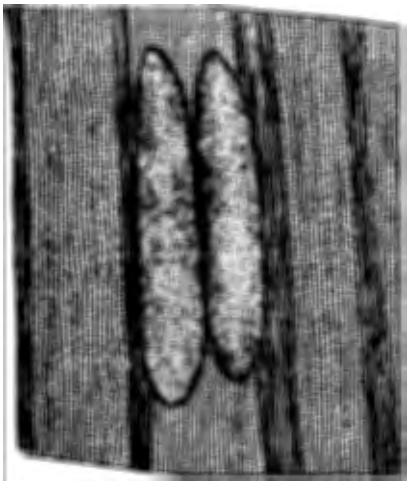
taining *D. glomerata* plants and other grasses collected from the habitat of *C. quadrinotata* (Fab.). The insects were continually watched for several days and it appeared certain that normally they feed on *D. glomerata* only.

Rearing methods

The specimen tube with cotton wool and filter paper was used in rearing the nymphs and appeared to be most satisfactory. This method could not be applied for rearing the adults because their elytra stuck to the moist sides of the tube and the adults died. Consequently, they had to be kept in a small cellulose cage 5 × 9 inches fixed to a plant of *D. glomerata*.

Copulation

The newly emerged adults started copulation after 2 to 4 days. On 10th June 1948, five newly emerged couples were kept, each pair in a glass pot with cut pieces of *D. glomerata* leaves. Three pairs were found in copulation on 12th, one on 13th, and one on 14th June.



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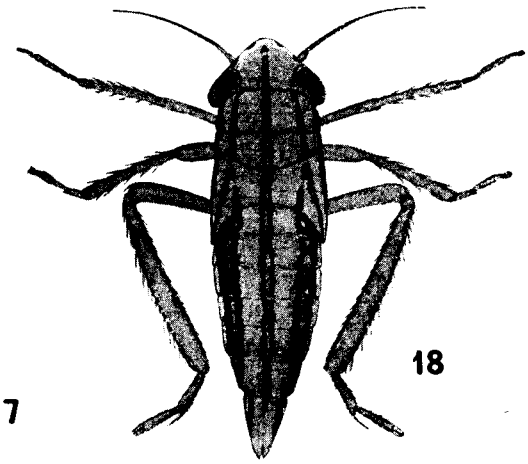

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Cicadula quadrinotata (Fab.)

Fig. 17: Eggs in leaf-spathe of *Dactylis glomerata*, × 52. — Fig. 18: Nymph, × 12.5.

A copulated pair was kept in a refrigerator at 1° C. for 5 minutes and then treated with hydrogen cyanide. This was successful in killing the insects in situ for investigation.

Oviposition

On 24th June, 10 couples of *C. quadrinotata* (Fab.) were kept in glass pots provided with cut pieces of leaves taken from blade. These cuttings were examined daily, but no eggs were found for about a fortnight. The plants on which a stock of adults were kept revealed the egg-site which is

to be found in the cuticle of the leaf-spathe (fig. 17). Eggs are laid parallel to the leaf veins, and are often found singly, though a few are found in pairs. Some of the eggs produce a slight swelling. There is no external indication of the egg-slits made by the ovipositor. When the embryo is full grown its bright red eyes show through the lower or upper thin epidermis. A single female lays about 50 eggs.

Incubation period

On 10th June, 12 eggs of *C. quadrinotata* (Fab.) were laid. Six eggs hatched on 19th, 4 on 20th, and 2 on 21st July, i.e. 9-11, mean 9.7 days.

Leaves containing eggs were kept in direct contact with wet filter paper at a temperature of 13 to 25° C. The filter paper had to be changed during the incubation period when any fungus grew. Some eggs were also removed from inside the leaves and laid on the wet filter paper. This last trial was promising, largely avoiding the fugus infection which usually damages the eggs. Some other eggs left in the growing leaves hatched out without any trouble from fungus.

The egg

Colour whitish; narrow, elyptical and tapered slightly towards the operculum; length 1.1 mm. The egg (fig. 17) before hatching shows the bright red eyes of the embryo through the chorion.

Variation in colour pattern of nymphs

A range of colour pattern occurs in this species from a general light yellow to a nearly black colour. On 24th June 1948, 30 nymphs of the last instar (fig. 18) were collected at random and classified according to three colour grades, light yellow, dark and black. These grades were separated into females and males. The light yellow nymphs amounted to 10 (77%) females and 3 (23%) males, the dark nymphs to 6 (66.7%) females and 3 (33.3%) males, and the black nymphs to 2 (25%) females and 6 (75%) males. From the above figures it appears that the percentage of the males to the female in each group increases towards the darker grades.

Seasonal occurrence

In the second week of May 1948, nymphs of *C. quadrinotata* (Fab.) were available. In the second week of June the adults emerged but some nymphs were still found. On 11th July five nymphs were collected after a long search. The adults were actively laying eggs a few days after emergence. The eggs laid in the middle of June started to hatch out from the third week of July. In the first week of September nymphs were ony found. This suggests that *C. quadrinotata* (Fab.) hibernates as a nymph.

Parasites

Pipunculus haemorrhoidalis (Zett.)

On 26th June 1948, a parasitised nymph of *C. quadrinotata* (Fab.) was collected. The parasitic larva pupated on 27th and its adult emerged on 22nd July 1948. It was kindly identified by O. W. Richards.

Dryinidae

On 28th June 1948, a male nymph of *C. quadrinotata* (Fab.) was found with a Dryinid sac, but unfortunately the adult parasite failed to emerge.

On 30th June 1948, a nymph of *C. quadrinotata* was found with a Dryinid sac and at the same time parasitised with a Pipunculid.

5. Graphocephala coccinea (Forst.)

This Tettigoniellid leaf-hopper is a common North American species which occurs throughout the eastern United States and extends into Canada. It was first recorded in England in 1936, though the labourers in the *Rhododendron* gardens at Windlesham say that it first appeared there in 1931 or 1932. It is also reported from the following localities: Woking (1936), Oxshott (1937), Slough and Langley Park (Buckinghamshire) (1942), Wimbledon (1944), Richmond Park (1945) and the Haslemere district close to the Hampshire and Sussex borders (1947).

In the second week of July 1947, this beautiful bright coloured leaf-hopper was observed in vast numbers on *Rhododendron* bushes at Silwood Park. 50 females and the same number of males were confined in a big muslin cage, but unfortunately after living on *Rhododendron* for a week, 70 individuals died and no eggs were found. Ten days later 25 more died, and the rest perished within the next two weeks, without having laid any egg. On 15th July a fresh lot of 250 adults was confined in 25 cellulose tubes fixed to a *Rhododendron* plant in the field and distributed as 5 females and 5 males in each tube. The tubes were examined on 23rd November. 15 females and 15 males only were still alive, and no eggs were found. The females were dissected and found with fully developed eggs (fig. 19). The failure of oviposition was settled when the insect was provided of its hibernating egg-site consisting of growing plant bearing flower buds.

Hibernation

On 11th July 1947, three nymphs were collected from *Rhododendron* bushes and several nymphal exuvae were found fixed to the leaves. 200 adults were collected weekly from July to the middle of October. In the last week of November, only 7 females were found after a long search underneath

the bushes of *Rhododendron*. The identity of the hibernating stage remained uncertain.

Several other trials were made at the end of autumn 1947 and during the winter to find the hibernating eggs, but unfortunately only one egg was found in a *Rhododendron* leaf.

On 7th May 1948, nymphs were collected from the leaves of *Rhododendron* at the Imperial College Field Station, Silwood Park, Sunninghill, Berkshire. Similar nymphs were also found on weeds and grasses underneath the bushes.

A critical examination of several bushes revealed the site of the hibernating eggs. They were found inserted underneath the thin upper epidermis of the sepals in prominent swellings of the autumn flower buds of *Rhododendron* (fig. 20). Owing to the transparency of the epidermis and the yellow colour of the eggs, the swellings were yellowish in appearance. After the eggs had hatched out the swellings showed dark brown spots and the exuvae of the first nymphal stage protruded from the opening of the egg-slits.

It appears that the first stage nymphs moult as soon as they hatch out, when on their way out of the egg pockets. At the tip of each swelling a short dark line indicates the position of the wound caused by the ovipositing female.

The hibernating eggs are often found in a fan-like arrangement, 2 to 10 eggs being in each group. Such eggs, mostly radiating from the mid-line of the sepals, lie on the circumference of a circle with their axes pointing towards the centre. Other eggs are found singly. Some are partly or completely covered by the outermost sepals.

The hibernating eggs, before hatching out, are oval in shape, flattened, and tapered towards the operculum. They have a rather thin chorion and measure about 1.8 mm. in length.

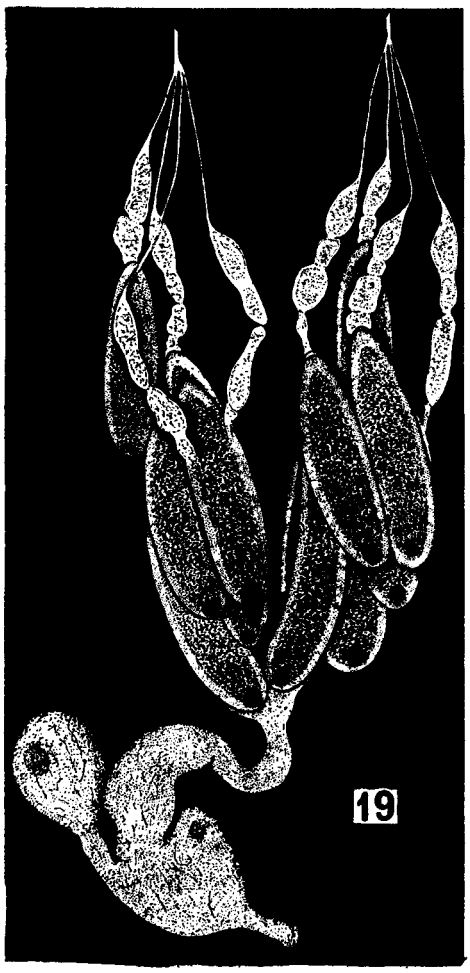
Host plants and feeding habits

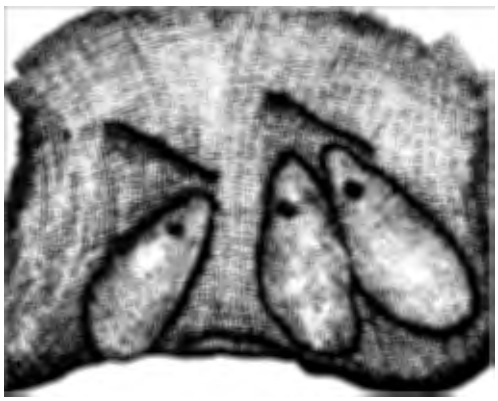
Adults and nymphs of *Graphocephala coccinea* were collected from *Rhododendron* plants, though a few occurred on grass near these bushes. Some adults were also found on holly, ivy, *Viburnum tinus* (*laurustinus*), *Pteridium aquilinum*, *Rumex acetosa*, *Callistephus chinensis* Nees (Chinese Aster), *Robinia pseudacacia* L. (False *Acacia*), *Castanea sativa* L. (Sweet (Spanish) chestnut) and *Tilia sp.* (Lime).

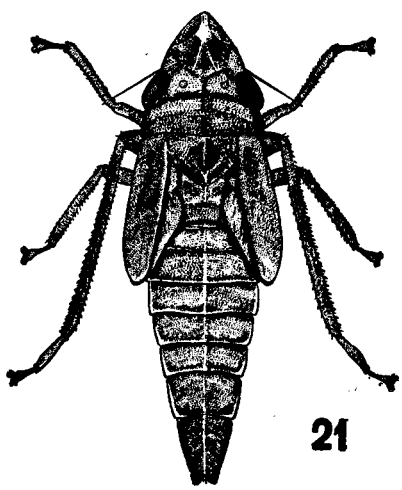
On 20th May, an experiment was set up to investigate the possibility of rearing *Graphocephala coccinea* (Forst.) on the above mentioned plants (but the last four). A cellulose tube was fixed to a specimen of each, and about 10 nymphs were confined in each tube. In the first week of July, when the tubes were examined, all the nymphs were found alive and their

moulted skins were still fixed on the plants. This result shows the possibility of feeding these insects on any of the above plants.

Another experiment was made to indicate feeding preferences of the nymphs for any of these hosts. Nymphs were confined in a big muslin







Graphocephala coccinea (Forst.)

Fig. 19: Female reproductive organs, ×15. — Fig. 20: Eggs in a part of the sepal of *Rhododendron* flower-bud, ×15. — Fig. 21: Last nymphal instar, ×9.5.

cage containing potted *Rhododendron*, grass, *Rumex acetosa*, *Rumex acetosella* and *Hypochoeris radicata*. The nymphs fed mainly on the lower side of *Rhododendron* leaves and a very few on *Rumex acetosa*. None were seen to feed on grass, *Rumex acetosella* or *Hypochoeris radicata*.

On 7th May 1948, when the nymphs emerged, it was thought that they might possibly feed on grass until the new soft leaves of *Rhododendron* appeared. Consequently, an experiment was set up; some nymphs were fed on grass, some on old thick leaves of *Rhododendron* and others on soft ones. All the nymphs grew successfully fed in each case.

Finally, though *G. coccinea* (Forst.) is found mainly on *Rhododendron* in Britain at the moment, in the future it is probable that it will establish itself on other plants in large numbers as recorded in America.

Injury to plants

The injury caused by *G. coccinea* (Forst.) to *Rhododendron* leaves is inappreciable. It is surprising that no apparent damage could be noticed in spite of the vast number of nymphs and adults that swarm on some plants. However, the plant on which about 40 nymphs were reared from the 10th May to 6th July was examined. The upper leaves of the plant near the growing buds only showed noticeable damage. One of the leaves had 42 nymphal skins attached to its lower side. The leaf showed a yellow spotted appearance on its upper side, with a dark green thin stripe on either sides of the mid-rib.

Rearing

It was found that the method applied for rearing *Delphax fairmairei* Perris under laboratory conditions was unsatisfactory in the case of *G. coccinea* (Forst.). On 8th May 1948, 30 nymphs (second instar) were reared singly in 1 × 2 inches glass specimen tubes, each containing a piece of *Rhododendron* leaf, grass, and a leaf of *Rumex acetosa*. The leaves were changed daily. The duration of the second instar varied from 8 to 11 days. 7 nymphs moulted after 8 days, 13 after 9 days, 4 after 10 days, 2 after 11 days and 3 died. The duration of the third instar varied from 4 to 18 days and 14 nymphs died.

Figure 21 shows the last or fifth nymphal instar.

It was remarkable that the nymphs fed mostly on *Rumex acetosa* leaves which is not normally their favourite host. This tendency could be attributed to the leaves of *R. acetosa* being fleshy and containing a good amount of sap. The cut leaves of *Rhododendron* seem to contain much less sap and get dry more quickly than those of *Rumex acetosa*. Thus the nymphs might have preferred *R. acetosa* because they have the habit of fixing their mouth-parts and keeping on pumping the plant juice through one puncture for a considerable time.

Consequently, another method of rearing was tried, in which the nymphs were provided with growing plants.

On 10th May 1948, about 50 eggs of *G. coccinea* (Forst.) hatched out. Some of the nymphs were transferred to three cellulose tubes fixed to

leaves of a potted *Rhododendron* and the rest to the fairly big muslin cage described previously. The nymphs were successfully reared in both ways, and the adults emerged on 6th July 1948. They took 56 days from the hatching of the eggs to the emergence of the adults. These results were obtained from insects kept in an unheated conservatory. The temperature during this experiment varied from 13 to 25° C.

Seasonal occurrence and number of generations

The hibernating eggs of *G. coccinea* (Forst.) hatched out from the first week of May. Nymphs occurred during May, June and July. The adults reared under laboratory conditions emerged on 6th July 1948, but those in the field emerged on 20th July. They were collected from the third week of July until the middle of November, though 7 females were collected on the last week of November 1947 after a long search. The eggs were laid from the first week of September and kept in hibernation until the first week of May. From these observations *G. cocinea* (Forst.) must have one generation a year in Great Britain, and not two as stated by Osborn (1912).

The egg

The egg (fig. 20) is oval flattened and tapered towards the operculum, yellow in colour, and about 1.8 mm. long.

6. Tettigoniella viridis (Lind.)

This Tettigoniellid leaf-hopper was noticed in a damp place by a stream on the west side of the Imperial College Field Station.

The female is about 8.2 mms. long with greenish blue elytra extending to the apex of the abdomen. There are two black pentagonal spots on the crown, located between the two ocelli. A black spot is also found on the above margin of each antennal socket. The male is about 6.3 mms. long with the elytra of a navy blue colour. The elytra extend from about 1 mm. beyond the abdomen.

Host plants

Tettigoniella viridis (Linn.) feeds on *Holcus mollis* which grows vigorously in damp places, the favourite habitat of this insect.

Hibernation

In the sumer of 1947, several attempts were made to induce the females of *T. viridis* (Linn.) to lay their eggs in grass (*Holcus*) under laboratory conditions. Unfortunately no eggs were laid. Another trial was made by fixing a cellulose cylinder 8×12 inches to the soil in the part of the field where *T. viridis* occurrend amongst grass. Many holes were made in this cylinder to provide proper ventilation. It was also covered with a tin lid

having perforations in the centre. Some females and males were confined in this cage and all died after a considerable time. The grass of the cage was examined, and again no eggs were found.

Consequently, in the winter of 1948, it was thought that the eggs might have been laid in certain woody plants that exist in that spot. A considerable number of brambles, and four oak trees were examined without success.

On 13th May, stems of *Juncus effusus* found in the same spot as *T. viridis* (Linn.) were examined, and revealed the presence of the hibernating eggs.

Oviposition

The female makes long slits with its ovipositor in the stems of *Juncus effusus* where the eggs are laid. The egg-slits are 3.5 to 7.5 mms. long and contain 3 to 16 eggs in one row (fig. 22). All of the eggs are found beneath the scale from about 2.5 to 17.5 cms. above soil level, probably because this part of the stem remains green during winter while the upper part of the stem often dies off, and also because it is nearest to the soil and hence the eggs are kept in damp conditions.

The egg-slits are made parallel to the stem veins under the scale leaf, and are difficult to detect unless the scale is removed, though some show

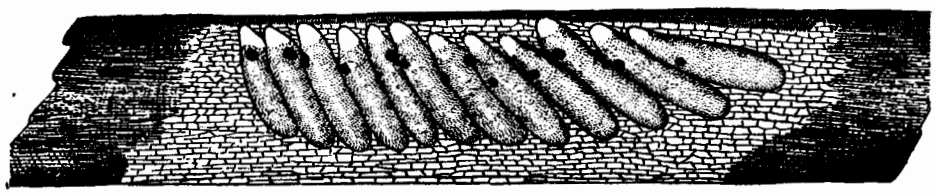


Fig. 22: Eggs of *Tettigoniella viridis* (Linné) in stem fo *Juncus effusus* (longitudinal section in plant), ×12.

prominent swellings. Eggs are located at an acute angle to the plant surface about 0.3 mm. underneath the cuticle of the stem or right through the centre of the pith. Their presence can be detected as follows:

(1) A dark pinkish, thin straight line showing no indication of either a swelling or an opening.

(2) The same dark pinkish line having an opening in the stem with one margin of the slit being folded inwards.

(3) As in 2 but exhibiting a swelling, and the white ivory tips of the eggs (just before hatching) showing through the opening of the slit.

The egg

The egg (fig. 22) is about 1.7 mm. in length. Just before hatching it is yellow with two orange patches laterally, oval in shape with a swelling

in place of the embryo's head and tapered, with an ivory white apex. The dark brown eyes of the embryo show through the transparent chorion as a distinct dark spot on each side of the egg.

Rearing

As *Tettigoniella viridis* (Linn.) occurs in damp places, it was thought advisable to keep the eggs removed from inside the stem in direct contact with the wet filter paper in the pots.

On 13th May 1948, 30 eggs hatched under laboratory conditions. The nymphs were distributed singly in the pots and provided with cut pieces of *Holcus mollis*. Fifteen nymphs died after two days and the rest did not live more than two days longer. After two more trials, replacing the dead nymphs by newly emerged ones, the number of dead insects was still very high.

As leafhoppers tend to keep on sucking the sap of growing grass through one puncture for a considerable time, a certain amount of nymphs were bred on growing grass in pots covered by a $1 \times \frac{1}{2}$ inch glass tube. The nymphs kept alive for 24 days, when the grass ceased to keep healthy.

Another method was tried for rearing first stage nymphs. They were kept in a fairly big cellulose cage surrounding growing grass in a plant pot. The cage was examined every now and then, and as soon as the nymphs moulted they were transferred to another cage fixed to fresh growing grass; this was repeated with all stages. This method proved to be satisfactory, for the nymphs were reared successfully up to the adult stage. In spite of the success, the data obtained were insufficient owing to the late date at which this trial was started. By that time very few eggs were available and consequently very few nymphs were obtained.

Seasonal occurrence and number of generations

Eggs of *T. viridis* (Linn.) were found on 13th May 1948 in the stems of *Juncus effusus*. A few of them had already hatched by that time. Other eggs, very few, were found in the first week of June in another spot. As to the adults, they appeared in the field in the first week of July, and became very scarce in the fourth week of September. Egg-laying occurred in the fourth week of August (24th) and the eggs hibernated until the first week of May. Consequently, *T. viridis* (Linn.) has one generation per annum.

Parasites

Anagrus incarnatus Hal.

Some eggs of *Tettigoniella viridis* (Linn.) collected on 13th May 1948, were found parasitised by *Anagrus incarnatus* Hal. (Hymenoptera: Mymar-

idae). Each egg contained from 3 to 11 parasites, while in *Delphax fairmairei* Perris there is never more than one parasite per egg.

On 1st June 1948, 80 egg-slits were examined. They contained 979 eggs, thus an average of 12.2 per slit. 46 eggs (4.7%) were found alive, 318 (32.5%) were already hatched, 38 (3.9%) were found dead, 122 (12.5%) were parasitised. 455 eggs (46.5%) were killed through a mould (*Acrostalagnus* spec.), kindly identified by Mr. R. K. S. Wood, of the Botany Department, Imperial College, England.

7. Cicadella notata (Curt.)

This leaf-hopper belongs to the family Typhlocybidae and is characterised by its pronotum bearing five short longitudinal lines (a median at the centre of the front margin, one on either side at the posterior angles, and one on each side between the median line and the postero-lateral ones), the abdominal sternites which are yellow in both sexes with the exception of the eighth sternite (before the sub-genital plate) black in the male, the pygophor of the female, and the outer valves of the ovipositor, are black.

Cicadella notata (Curt.) occurs amongst grasses, and almost always in spots where *Hypochoeris radicata* grows.

The adults exhibit the same general habits as do most Jassids, but the nymphs differ in some respects. Unlike the nymphs of Jassids, those of *C. notata* (Curt.) are inactive and show a tendency to settle on the leaves unless they are disturbed. They do not hop and prefer the shaded side of the leaf.

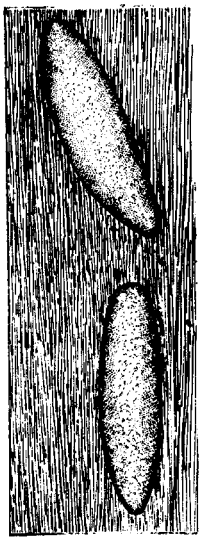
Symptoms of infestation

The infested leaves of *Hypochoeris radicata* exhibit white mottled patches with brown and yellow scorched areas. 10 adults were fed on a healthy plant and produced the same symptoms of infestation as had been found in the field. The flower stalk fed on by this leaf-hopper exhibited the same diseased appearance.

Oviposition

Six females were kept singly after copulation, but unfortunately the exact date of oviposition was not known because of the difficulty of finding the eggs inside the tissues of the plant. The eggs (fig. 23) are rather small (400 μ long), whitish in colour, more or less of the same colour as the tissues in which they are inserted (the thick fleshy midrib of the leaves which is prominent on the lower side of the leaf, and also in the flower stalk), and tapered slightly towards the operculum. They are often laid horizontally in the midrib or perpendicularly into its surface. Some of them were found underneath the epidermis of the midrib which exhibited a slight swelling. Eggs found in the flower stalk were either underneath the outer epidermis,

which shows a slight swelling, or inserted inside the tissues without any sign of their presence. In the older flower stalks, which have a cavity inside, a few eggs were found just covered by the innermost thin tissue, showing a swelling towards the inner cavity. The eggs are laid either singly or in pairs.



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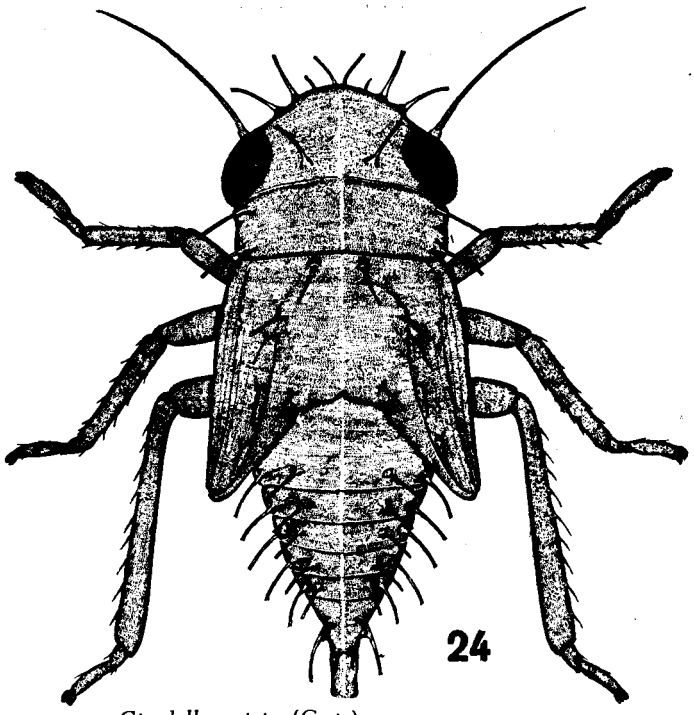

24

Cicadella notata (Curt.)

Fig. 23: Eggs in flower-stalk of *Hypochœris radicata*, ×80. — Fig. 24: Fifth or last nymphal instar, ×22.

There is no indication of the oviposition slit where the eggs are laid. This is probably due to the nature of this plant, which is juicy, the wounds healing quickly without leaving any trace.

Incubation

On 26th June 1948, some females of *Cicadella notata* (Curt.) were confined in a cellulose tube round a flower stalk of *Hypochoeris*. They laid few eggs. The stalk containing the eggs was cut and kept under observation. The eggs hatched on the 20th July, i.e. after 25 to 27 days under laboratory conditions, with a temperature of 13 to 25° C.

Copulation

Some adults emerged on 25th June 1948 were found in copulation after three days and others after four days.

Seasonal occurrence, hibernation and number of generations

C. notata (Curt.) nymphs (fig. 24) were difficult to find in the first half of May 1948, but a few were collected in the third week. In the last week some nymphs of the last instar (fifth) were collected.

The adults appeared in the first week of June. Those which emerged in the third week started to lay eggs after a few days. The eggs which were laid on 26th June hatched on 20th July. The duration of the nymphal instars is about 25 days. The adults emerged in the last week of July and the first week of August. Some of them started laying eggs in the beginning of August and adults emerged in the second week of September. These observations were made from laboratory rearing, but were confirmed in the field. Collections made on 28th September 1947 yielded 30 adult females, 24 adult males, and 2 nymphs. A search for adults and nymphs during the winter was unsuccessful. Hence it seems that *C. notata* (Curt.) hibernates in the egg-stage, and has three generations per annum, the third occurring in late autumn. This does not quite agree with Ribaut (1936) who states that usually there are two generations in Typhlocybidae, the second one occurring before winter.

Duration of the nymphal instars

C. notata (Curt.) has 5 nymphal instars, the combined duration of which is about 25 days under laboratory conditions with a temperature of 13 to 24° C.

On 5th July 1948, 10 eggs hatched and the nymphs were reared singly. Though some nymphs varied in the duration of their instars, yet the adults emerged on nearly the same date (8 on 30th, and 2 on 31st July).

The duration of the nymphal instars summarises as follows: first instar, eight nymphs six days, two seven, mean 6.2 days; second instar, two nymphs four days, seven five, one six, mean 4.9 days; third instar, two nymphs two days, six three, two four, mean 3 days; fourth instar, four nymphs six days, six seven, mean 6.6 days; and fifth instar, eight nymphs four days, two five, mean 4.2 days.

Parasites

Chalarus spurius (Fallen)

Chalarus spurius (Fallen) (Diptera: Pipunculidae), identified by O. W. Richards, emerged on 13th July 1948 from a parasitised nymph of *C. notata* (Curt.) collected on 11th June 1948. The full grown parasitic larva migrated from its host on 13th June and pupated next day.

IV. SUMMARY

(1) Several methods using different types of cellulose tubes and cages were satisfactory for rearing *Jassids* and *Delphacids*, providing proper ventilation, reasonable humidity and a supply of fresh plants.

(2) The *Delphacids* dealt with were *Criomorphus pteridis* (Boh.) and *Delphax fairmairei* Perris. Their life-history and bionomics are recorded. *D. fairmairei* hibernates as eggs in aerial stems and runners, and in the leaf stalk of blackberry in either egg-sacs or egg-slits. Eggs were found parasitised by *Anagrus incarnatus* (Hal.).

(3) A few Pipunculidae (Diptera) were found in diapause as eggs or larvae in the hibernating nymphs of *C. pteridis*.

(4) The *Jassids* dealt with are : *Cicadula sulphurella* (Zett.), *Cicadula quadrinotata* (Fab.), *Graphocephala coccinea* (Forst.), *Tettigoniella viridis* (Linn.), and *Cicadella notata* (Curt.). Their life-history and parasites are given.

(5) The oviposition site of *C. quadrinotata* was found to be the leaf spathe of *Dactylis glomerata*.

(6) The hibernating eggs of *G. coccinea* were found beneath the sepals of the dormant flower buds of *Rhododendron*. The nymphs were successfully reared on several hosts. *G. coccinea* has one generation per year in Britain.

(7) The hibernating eggs of *Tettigoniella viridis* were found in the stems of *Juncus effusus*. The eggs are parasitised by *Anagrus incarnatus* Hal. From 3 to 11 parasites were found in single eggs. The eggs are also attacked by *Acrostalagnus* spec., a white fungus.

(8) *Cicadella notata* was found to feed on *Hypochoeris radicata*. The eggs are laid in the midrib of the leaves and in the flower stalk. The nymphs and adults are parasitised by *Chalarus spurius* (Pipunculidae).

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