THE BIOLOGY OF ERYTHRONEURA (ZYGINA) PALLIDIFRONS, EDWARDS.

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Introduction.

The association between insects and virus diseases of plants and the suspicion which at present rests on JASSIDAE, amongst others, may result in members of this family becoming of increased importance as potential vectors of virus diseases of crop plants. In America leaf-hoppers are already serious pests of cereals and of grape-vines, and in the cotton-growing area of Central and South Africa a Jassid forms one of the most important obstacles to the successful cultivation of this crop, so that in these countries a considerable amount of attention has been demanded by this group of insects. In this country, however, the leaf-hoppers have only been regarded as of minor importance, though in recent years increasing interest has been taken in certain species infesting potatoes and glass-house crops. It was suggested to the writer that further knowledge of the biology of these insects was desirable, especially in view of the extreme importance of a nearly related species in many of the African cotton-growing areas, and it was accordingly decided to use the common species infesting glass-houses as a type for investigation with cotton as the food-plant.

Fig. 1. Erythroneura varnula, Boh. (Austria): a, tegmen; b, face; c, dorsal view of head and thorax; d, male pygophore in ventral view; e, lateral view of paramere; f, lateral view of aedeagus. (a, b, c, are from ♀ specimen; d, e, f, are from balsam preparation.)
It was supposed that the majority of the leaf-hoppers infesting glass-houses belonged to two species, *Erythronoeura (Zygina) parvula*, Boh., and *E. pallidifrons*, Edwards, both of which have been recorded in the open and are therefore supposed to be indigenous to the British Isles, but although the material was collected from several widely separated localities, only *E. pallidifrons* was obtained, so that it seems probable that most of the damage attributed to *E. parvula* is really caused by *E. pallidifrons*. Mr. W. E. China, of the British Museum, states that there is no authentic British male specimen of *E. parvula* on record, and in his opinion also past records of the infestation of glass-houses by this insect are probably due to the fact that *E. pallidifrons* has been mistaken for *E. parvula*.

Fig. 2. *Erythronoeura pallidifrons*, J. Edw. (Cornwall): a, tegmen; b, face; c, dorsal view of head and thorax; d, male pygophore in ventral view; e, lateral view of paramere; f, lateral view of aedeagus. (a, b, and c, are from ♂ specimen; d, e, and f, are from balsam preparation.)

**Methods.**

The work in connection with the present paper was carried out in the Zoological Department, Manchester University, and at the University Experimental Grounds, Fallowfield. The material used was obtained from several different sources: Fallowfield, Wilmslow, and Buile Hill Park, Salford, in the Manchester area; and Kew Gardens and Wisley, in the south of England.

The leaf-hoppers were bred on cotton in one of the glass-houses in the Experimental Grounds of the University, and in the laboratory on cotton, primula and geranium. In the laboratory experiments the adults were confined on leaves under lamp-glasses, and the eggs were hatched and the young nymphs reared under similar conditions; as the nymphs became older they became more active and were transferred with leaves to damp filter paper in Petri dishes where they could be more easily examined.
BIOLOGY OF ERYTHRONEURA (ZYGINA) PALLIDIFRONS.

It was hoped that by using material from different localities the two species, *E. parvula* and *E. pallidifrons*, would both be obtained, but in every case the Jassid proved to be *E. pallidifrons*, and the only examples of *E. parvula* which have been examined are pinned specimens in the Manchester Museum.

I should like to thank Dr. H. W. Miles, who suggested the present work, for his helpful criticism and advice. Thanks are also due to Dr. G. H. Rodman, Kew Gardens, Mr. G. Fox-Wilson, Royal Horticultural Society's Gardens, Wisley, Surrey, and Mr. T. Richardson, Buile Hill Park, Salford, for their kindness in supplying living material from their localities; and to Mr. H. Britten, of the Manchester Museum, for the loan and identification of specimens. I should also like to acknowledge my indebtedness to Mr. W. E. China, of the British Museum, for his kindness in separating the two species of leaf-hoppers and for figs. 1 & 2 which he so kindly prepared.

**Description of Stages.**

**Adult.**

In "The Entomologist's Monthly Magazine" (1924) Edwards\(^3\) describes *Zygina pallidifrons* thus: "Longer and more slender than *Z. parvula* which it otherwise much resembles and having the frons entirely pale. Length 3-5 mm."

For some time it has been considered possible that *E. pallidifrons* is a colour variety of *E. parvula* and not a distinct species. Mr. W. E. China, however, has very kindly made careful preparations of the two insects and these show very clearly that the species are distinct from one another. Figs. 1 and 2, which have been prepared by Mr. China, show these specific differences; and it will be seen that the male genital apparatus of *E. parvula* is very different from that of *E. pallidifrons*, while both the male and the female *E. parvula* have a claval vein in the fore-wing which is not present in *E. pallidifrons*. The colour differences of the head noticed by Edwards still hold good for the two species.

**Egg.**

The egg is elongated, about 0.7 mm. in length and slightly curved. It is white, translucent and without distinctive markings on the chorion.

**First Instar** (fig. 3, a).

The 1st instar nymph is approximately 1 mm. in length; it is white and transparent, except for the eyes, which are reddish at first becoming black later. The head is proportionately large and the antennae long, being at least three-quarters of the length of the body. There is no indication of wings except that the hind borders of the meso- and metathorax are slightly concave.

A feature typical of all the nymphal stages of *E. pallidifrons* is the presence of a number of long setae, clubbed at the distal end. On the dorsal surface of the head of the 1st instar nymph there are six of these setae, four along the anterior border and two behind these near the middle line. There is a pair on each of the three thoracic segments and four on the dorsal side of the third to the ninth (inclusive) abdominal segments. There are also some clubbed setae on the front of the head. In addition to the four setae along the crown, which are also visible from the ventral side, there are two rows of four setae between the bases of the antennae, three pairs down the mid-line of the frons and another row of four setae above the hind limit of the frons. A smaller seta, not clubbed, is present under each eye, and there are a few setae of this latter type (1-4) on the frons, posterior to the second row of clubbed setae. The clypeus bears a varying number, up to fourteen, of the smaller setae.

In the 1st instar all the legs are approximately of the same length, and the tarsi have two joints with well-developed pulvilli but no claws. The middle and hind legs have each one of the clubbed setae on the outer side of the tibiae close to the proximal end.
Second Instar (fig. 3, b).

The 2nd instar nymph is similar to the first. The length is approximately 1.2 mm. The hind angles of the meso- and metathorax are slightly prolonged backwards giving the first definite indication of the wing-pads. The chaetotaxy of the head and abdomen is similar to that of the 1st instar nymph, but on the thorax, in addition to the setae found in the preceding stage, there is a pair of clubbed setae at the anterior angles of the prothorax, a pair at the anterior angles of the mesothorax and one at the posterior end of each of the mesothoracic wing-pads. The posterior tibiae have an increased number of setae, there being four towards the distal end of the segment in addition to the one found at the proximal end of the tibia in the first stage.

The 2nd instar nymph is still white and transparent with no sign of pigmentation.

![Fig. 3. Erythronoeura pallidifrons: a, 1st instar nymph, x 35; b, 2nd instar nymph, x 35.](image)

Third Instar (fig. 4).

The length at this stage is approximately 1.6 mm. The chief difference between the nymphs of the 2nd and 3rd instars is in the length of the wing-pads; in the third instar the metathoracic pads extend back as far as the second abdominal segment. The chaetotaxy of the body is similar to that of the preceding stage, but on the hind tibiae there are now eight of the large setae.

![Fig. 4. Erythronoeura pallidifrons: a, 3rd instar nymph, x 35; b, head of 3rd instar nymph, x about 48.](image)
Fourth Instar (fig. 5).

The 4th instar nymph is approximately 2 mm. in length. The wing-pads are longer than in the 3rd instar. The number of setae on the dorsal surface of the insect has increased; on the thorax, in addition to those found in the earlier stages, a pair of setae is present at the hind angles of the prothorax, a pair at the proximal angles of the wing-pads on the mesothorax, and three setae on the inner border of each of the anterior wing-pads; on the metathorax there is an additional seta on the inner border of each wing-pad. The hind tibiae have now ten setae and the mid-tibiae two.

![Diagram of Erythroneura pallidifrons]

Fig. 5. *Erythroneura pallidifrons*: 4th instar nymph, x 35.

The first sign of pigmentation appears in the 4th instar nymph, there being two patches of dark pigment on the mesothorax, one at the proximal angle of the wing-pads and the other nearer the anterior border of the segment.

Fifth Instar (fig. 6).

The 5th instar nymph is approximately 2·8 mm. in length. The wing-pads are now long and reach about half-way to the posterior end of the abdomen; the pigment on the mesothorax is a little more pronounced than in the 4th instar and the patches of colour are larger, but there is no further pigmentation. There is an additional pair of setae on the prothorax in this stage, on the posterior edge of the segment, and there are now five setae along the inner border of the mesothoracic wing-pads.

In the 5th instar it is possible to distinguish the sex of the insect. The external genitalia of the male nymph consist of a broad basal plate on the ventral side of the abdomen, which bears two short projecting triangular plates from its posterior end. In the female there are two pairs of long pointed plates on the ventral side of the abdomen.
Ecdysis.

At the time of ecdysis the nymphal skin splits along the mid-dorsal line of the head and thorax, and the insect emerges through the slit. The head and antennae are withdrawn first and the abdomen last of all, so that a nymph which has newly moulted can often be found with part of the old skin still adhering to the abdomen. Before the nymph moult the mouth-parts are often inserted well into the leaf tissue to form a firm place of attachment during ecdysis, and because of this the exuviae are frequently found still attached to the leaf. The degree of humidity is of great importance during the moult, for if the old skin becomes too dry, the insect cannot detach itself from it, and if there is too much moisture, the emerging insect cannot harden properly and there is a tendency, especially during the last moult, for it to become stuck to the substratum.

Numerous changes occur at the time of the last moult, which is between the 5th instar nymph and the adult insect. The wings appear, being short at first but rapidly lengthening when the insect has freed itself from the nymphal skin. The clubbed setae, found in all nymphal stages, disappear in the adult, and the antennae are shorter in proportion and the compound eyes larger than in the nymph. At first the imago is colourless, but the pigment begins to appear at once, though it does not develop fully for about 24 hours. In the adult insect the hind legs are very long, being modified for the leaping habit of the JASSIDAE.
Feeding Habits.

*Erythroneura pallidifrons* has a wide range of food-plants and thus tends to become a serious pest in glass-houses. Both adults and nymphs feed on the leaves, never apparently attacking the stem or other parts; they pierce the cell-walls of the leaf and then suck out the cell-content leaving a bleached area. As a rule the insect feeds on the lower side of the leaf, but the stylets are often pushed right through to the palisade tissue, so that the damage done by the leaf-hopper is often first apparent on the upper side of the leaf. The earliest signs of injury are a series of round white spots on the leaf where the chlorophyll has been removed; each of these represents a single puncture by the insect. As the leaf-hopper continues to feed the spots gradually become confluent and irregular white areas are formed, but the injury appears to be mechanical, as normally it does not spread over the leaf from one puncture. When a plant becomes badly infested the leaves are much soiled by the fluid excreted by the nymphs, which causes further damage, as it forms a very suitable medium for the growth of moulds.

In the nympha1 stages *E. pallidifrons* tends to feed on one leaf of a plant only; the first and second stages rarely move when once they have found a favourable place on the leaf. As the nymphs grow the food is used up, so that the older nymphs are obliged to move from place to place on the leaf in search of fresh food. The 5th instar nymphs are fairly active and can run rapidly if disturbed, but even these tend to remain on the same part of the plant.

The adult insects are active, especially in bright weather; they can both fly and leap, though the flights are usually short, from leaf to leaf of the same or neighbouring plants.

Mating and Oviposition.

During copulation the male and female insects lie in the same plane facing in opposite directions.

The eggs are inserted into the leaf tissue of the plant by the saw-like ovipositor of the female. They are almost invariably laid in one of the veins of the leaf on the lower side, though on a very few occasions eggs have been found on the upper side of the leaf. Most frequently the eggs are laid singly, scattered over the leaf, but sometimes they are laid in groups, three to eight eggs being inserted in a row in the same vein. There is no evidence for parthenogenesis and eggs have not been obtained from unfertilised females. Oviposition does not seem to occur often during the day, and as females kept in the dark would not oviposit, it seems probable that most of the eggs are deposited in the early morning or at dusk. The female insects do not begin to oviposit at once after copulation, there being an interval of 7–14 days. After one mating the female leaf-hopper continues to lay fertile eggs for the rest of her life, and on an average lays about 50 eggs.

In this species the oviposition period is very long, from ten days to three months; in most cases it lasted from two to three months, and one female continued to lay eggs at intervals for nearly four months, though in this instance the total number of eggs (10) was very small. The normal rate of egg-laying appears to be from 1–2 a day, though the above-mentioned insect only laid 10 eggs in 113 days, and another deposited 8 eggs in three days. The largest number of eggs laid by one female was 100, which occurred at a constant temperature of 21°C.

At first the egg is not easily visible in the leaf tissue, but as the embryo begins to develop it can be seen as a slight swelling on the vein. The young larva emerges head foremost from the egg, but there appears to be no special mechanism for breaking the chorion and at first the emerging nymph is enclosed in a delicate inner membrane; this membrane usually splits when the nymph is half out of the egg, so that it can generally be found protruding from the empty egg-shell, which remains firmly embedded in the leaf-tissue. The 1st instar nymph begins to feed very shortly after it has emerged from the egg.
Duration of the Life-cycle.

As is common among insects, the life-cycle of *E. pallidifrons* varies in length with the temperature; the following table gives the length of the life-cycle in some of these insects at different periods of the year.

<table>
<thead>
<tr>
<th>Egg laid</th>
<th>Incubation</th>
<th>1st instar</th>
<th>2nd instar</th>
<th>3rd instar</th>
<th>4th instar</th>
<th>5th instar</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>24–27.i</td>
<td>24-27</td>
<td>11</td>
<td>5</td>
<td>10</td>
<td>9</td>
<td>12</td>
<td>71–74</td>
</tr>
<tr>
<td>24–27.i</td>
<td>26-29</td>
<td>11</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>72–74</td>
</tr>
<tr>
<td>24–27.i</td>
<td>36-39</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>17</td>
<td>85–88</td>
</tr>
<tr>
<td>12-14.iv</td>
<td>14-18</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>9</td>
<td>45–49</td>
</tr>
<tr>
<td>13–15.v</td>
<td>20-22</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>40–42</td>
</tr>
<tr>
<td>29–30.v</td>
<td>13-14</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>33–34</td>
</tr>
<tr>
<td>3–4.vi</td>
<td>10-11</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>31–32</td>
</tr>
<tr>
<td>7–10.vi</td>
<td>6–9</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>25–28</td>
</tr>
<tr>
<td>10–11.vi</td>
<td>12-13</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>33–34</td>
</tr>
<tr>
<td>17–18.vi</td>
<td>13-14</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>11</td>
<td>40–41</td>
</tr>
<tr>
<td>24–25.vi</td>
<td>13-14</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>42–43</td>
</tr>
<tr>
<td>10–11.vii</td>
<td>17–18</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>11</td>
<td>45–46</td>
</tr>
</tbody>
</table>

Thus the length of the life-cycle varied from 85–88 days (Jan., Feb., March) to 25–28 days (June, July), after which the time lengthened again to 45–46 days (July, Aug., Sept.). The length of the cycle was fairly constant at each season of the year, though there were isolated abnormal insects, such as one individual which hatched from an egg laid on 5th June and took 62–63 days to complete its development, whereas most of the other insects at the same time took approximately 30 days to become mature.

Although, taking a given period, the total length of the life-cycle is more or less constant, the duration of each instar varies considerably in different individuals. In two insects hatching from eggs laid on 14th June, each of which was 42–44 days before becoming mature, the duration of the different stadia were:

<table>
<thead>
<tr>
<th>Egg</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>Total</th>
</tr>
</thead>
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<tr>
<td>16–18</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>12</td>
<td>42–44</td>
</tr>
<tr>
<td>17–19</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>10</td>
<td>42–44</td>
</tr>
</tbody>
</table>

Another group of insects from eggs laid on 10th July gave the following periods for the different instars:

<table>
<thead>
<tr>
<th>Egg</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>17–18</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>11</td>
<td>44–45</td>
</tr>
<tr>
<td>17–18</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>11</td>
<td>45–46</td>
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<tr>
<td>17–18</td>
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<td>5</td>
<td>4</td>
<td>7</td>
<td>9</td>
<td>45–46</td>
</tr>
<tr>
<td>17–18</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>45–46</td>
</tr>
</tbody>
</table>
Thus the lengthening of one of the nympha! stadia may be compensated for by a decrease in the length of another. The duration of the egg-stage appears to be more directly affected by temperature than the other stages and is usually from a third to half of the total length of the development period.

A certain number of leaf-hoppers were bred at a constant temperature of 21° C., and even under these conditions there is a considerable amount of variation in the length of the stadia and of the life-cycle as a whole, though not so much as when the insects are subjected to changes in temperature. At 21° C. the incubation period varied from 9 to 19 days (usually lasting 14-17 days), the first instar from 2-6 days (average 3-5), the 2nd instar 2-5 days (average 3-2), the 3rd instar from 2-9 days (average 3), the 4th instar 3-6 days (average 4-5), and the 5th instar from 4-8 days (average 6-25); the variation in the length of the complete cycle was from 30-32 days to 41-45 days (average 34-37). This variation at a constant temperature is interesting, especially as it was found that eggs laid in the winter (Nov., Dec., Jan.) took from 34-38 days to 41-45 days to reach the last moult, while the length of the life-cycle in insects from eggs laid later (April, May) only varied from 30-32 days to 35-38 days, which suggests that temperature is not the only factor influencing the length of the developmental period of this insect.

**Sex-ratio.**

In *E. pallidifrons* the female insects slightly outnumber the males, the ratio of males to females being approximately 1:1-3. There seems to be no correlation between the duration of the life-cycle and the sex of the insect.

**Preliminary Notes on the Effect of Food-plant Condition.**

Some preliminary experiments were carried out during the summer of 1930 on the infestation of cotton plants by *E. pallidifrons*. Four blocks of cotton seed (American Upland), each block containing 20 plants in 12 ins. pots, were sown; two blocks, A and B, on 27th March 1930 and the other two, X and Y, on 8th May. A, X and Y, all received 1,000 cc. of water a week, while B only received 500 cc. The soil in the pots belonging to blocks A, B and Y, was left untouched, but the soil in the remaining block, X, was tilled after each watering.

Infestation counts of the Jassids were taken at intervals of seven days. The system used in making the counts was similar to the methods given in other papers dealing with the infestation of cotton by Jassids: that is, the infestation factor is indicated by the number of nymphs on a stated number of leaves in each block; in the present instance 20 leaves in each block were examined at each count.

Infestation counts on blocks A and B began on 5th May, when the cotton plants were about five weeks old. Counts on X and Y began on 23rd June.

The mean infestation factors for the four blocks of plants for the period of the experiments (about 24 weeks) were as follows:—

A. 5-5 nymphs to 20 leaves.
B. 3-0 " " "
X. 1-8 " " "
Y. 1-8 " " "

Block A, planted in March and receiving 1,000 cc. of water a week, has thus a definitely higher infestation factor than block B, also planted in March but only receiving 500 cc. a week. Both these blocks show a considerably higher degree of
infestation than the plants sown in May. The infestation of X and Y is the same, so that tilling the soil appears to have no effect, either adverse or favourable, on the infestation of the plant by *E. pallidifrons*.

The infestation factors for all four blocks of cotton are low, but this is partly due to the fact that the temperature of the glass-house was so high during the early and middle part of the summer that it proved to be unfavourable for the development of the Jassids, and for a time in the middle of the experiments the insects almost disappeared from the plants.

**Parasites.**

Only one species parasitic on *E. pallidifrons* was obtained. This was a Mymarid, not yet identified, which was found to be parasitic on the egg of the leaf-hopper. The parasite has been bred from eggs from two localities, Fallowfield, Manchester, and Wilmislow, Cheshire, but it has not so far been possible to breed it successfully in the laboratory. It is interesting to note that Mymarid parasites, in each case belonging to the genus *Anagrus*, have been recorded from the eggs of leaf-hoppers in Sweden\(^{20}\) and in California and Idaho\(^{19}\).

**Economic Position.**

*E. pallidifrons* and the nearly related *E. parvula* are reported with increasing frequency as pests on plants in glass-houses. They are widely distributed in this country and have a very wide range of food-plants. *E. pallidifrons* will feed on *Chrysanthemum, Gossypium, Fuchsia, Geranium, Nicotiana, Primula* and *Salvia*, while in addition to the above plants, *E. parvula* has been recorded from *Asparagus sprengerii, Calceolaria*, Lemon-scented Verbena, *Salpiglossis*\(^{15}\) and tomato\(^{10}\). The injury to the plant appears to be similar in every case, the leaves becoming covered with bleached patches caused by the removal of the chlorophyll by the insect.

**References.**

3. ——— 1924. On some new or little-known British Cicadina.—Ent. Mon. Mag., lx, pp. 52–58.