THE CONTROL OF THE GREENHOUSE WHITE FLY (*ASTEROCHITON VAPORARIORUM*) WITH NOTES ON ITS BIOLOGY[1].

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(With 5 Text-figures, 2 Diagrams and Plates I and II.)

CONTENTS.

1. INTRODUCTION.

THE classification of the Aleyrodidae has been recently revised by Quaintance and Baker(1) who have referred *Aleyrodes vaporariorum* Westw. to the genus *Asterochiton* Maskell. The insect, popularly known as the Greenhouse White Fly, or Snow Fly, is thought to be a native of Brazil, but is now widely distributed. Its fecundity and polyphagous habit have rendered it one of the worst greenhouse pests and it is responsible for the loss of large sums every year in the British Isles.

2. ACCLIMATISATION.

In England it breeds freely in the summer out of doors on a wide variety of plants, shrubs and trees in the neighbourhood of infested greenhouses. The vast swarms found around these in the summer and

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autumn owe their origin mainly to the adults which are continually passing out of the greenhouses and, to a less extent, to those which have been fostered in cold frames over the winter. At the same time it is highly probable that the insect can survive mild winters out of doors in the south of England and it can certainly do so in the Channel Islands where it is a more serious pest than in the Lea Valley. In the winter of 1919–20, when the insect was being bred for the purposes of this study, the adults could be found around the experimental house throughout, especially on *Althaea rosea* and *Aquilegia*. The first emergence of the

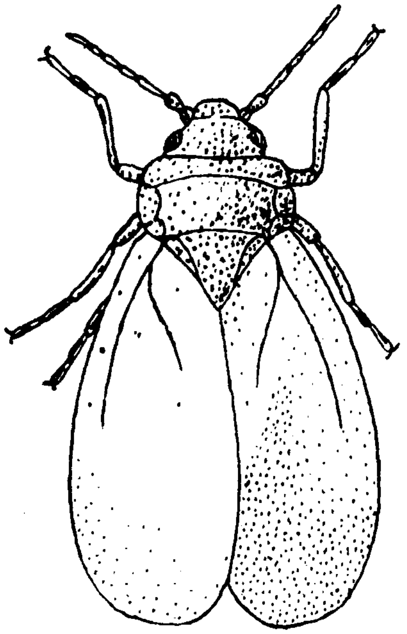

Fig. 1. Adult *A. vaporariorum* (× 100).

adults of the insects breeding outside was observed on July 1. Through the summer and autumn they were excessively numerous in the garden and became a serious pest on runner beans. At the beginning of December the greenhouses and cold frames were free from the pest but the adults were still to be found on *Digitalis* and *Althaea* where a batch of recently laid eggs was seen. Unfortunately the leaf which held these perished. In early December there was a week of snow with 23 degrees of frost on one occasion. Two adults were seen alive after this. The latter half of the month was cold and wet and no more of the insects were found in the garden till the end of May when a few adults were seen on *Althaea* and *Philadelphus*. The Station houses were still quite free from the pest and the nearest infested greenhouse was 200 yards away from the garden. These were probably, though not certainly, survivors from the heavy infestation of the previous year.

Experiments carried out in the winter 1919–20 afford evidence that the insect may survive a mild winter out of doors in small numbers in the Lea Valley.

An *Urtica dioica*, heavily infested with all stages of the pest, was enclosed in a capacious muslin sleeve and placed outside on January 15. The adults became gradually reduced in numbers until on April 13 only 12 survived and the young foliage held numerous eggs. All the scales on the plant were dead.

A second nettle plant, heavily infested with all stages, was cleared of adults, enclosed in muslin, and placed outside on February 2. Seven adults emerged between February 13–20, and eight more between March 9 and April 13. On the latter date oviposition was occurring, but there were no intermediate stages between egg and adult. On May 20 the plant held a few adults, eggs and first stage larvae only.

A *Lamium* was subjected to a massive infestation of adults on January 14; the following day, when it was well covered with eggs, the flies were cleared from it and it was sleeved and placed outside. The eggs commenced to hatch after 87 days on April 10 and continued to do so until May 10, 117 days after oviposition.

Adults were placed in muslin-covered glass vessels containing moist soil with and without cut foliage and placed in the shade outside in January. It was found that where no foliage was enclosed they died in less than a month, January 15 to February 9 (25 days) being the longest period that one survived. In one case a *Lamium* leaf was enclosed and this kept curiously green and fresh for nearly three months. Seventeen adults were placed with it on January 15 and lived an average of 36 days, five survived 50 days, and the last one died on April 6, the 82nd day.

The outside shade temperatures during this period will be found in Table I. Although the winter was a mild one all the insects concerned in these experiments experienced frost and the adult which survived 82 days was subjected to frost on 25 nights. It is therefore clear that both the eggs and the adults are able to withstand considerable cold, but that the intermediate stages are less resistant. Both the resistant stages are dependent on living foliage; as the adult, when subjected to the alternate cold of night and warmth of day, requires food, and the eggs on foliage severed from the plant shrivel and die. Even were this not the case the larva has not that power of movement enabling it to pass on to living plants.

In *Al. citri* the wintering stage is the pupa (2) and the phenomenon of partial brooding, such as is familiar in the case of many Lepidoptera, occurs, some of the pupae going into the wintering condition quite early in the season and the proportion which so delay emergence increasing as the cold weather approaches. No such partial brooding occurs in *Ast. vaporariorum* and its dependence on living foliage shows that it is not fully adapted to a temperate climate where the occasional occurrence of severe winters, when all foliage except that of leathery evergreens is cut down, must exterminate it out of doors.

Table I. *Showing shade temperatures (degrees F.) in greenhouse and outside during investigation.*

	Outside		Greenhouse	
	Mean	Range	Mean	Range
1919				
December	41·2	24–53	60·6	48– 76
1920				
January	39·2	21–54	62·9	50– 87
February	41·4	23–54	63·2	45– 83
March	46·0	26–73	66·3	43–100
April	50·5	29–71	66·8	44–101
May	55·2	27–86	74·7	51–101
June	59·9	33–87	71·5	47– 96
July	60·0	41–84	71·1	53– 92
August	58·2	41–83	70·4	49–100
September	57·7	36–80	—	—
October	49·0	23–76	—	—
November	42·2	20–58	—	—
December	39·9	9–53	—	—

3. FOOD PLANTS.

The insect has a wide range of food plants but those which suit it best have rather thick sappy leaves and among its most favoured hosts may be mentioned the following: tomato, potato, cucumber, vegetable marrow, French beans, tobacco, hollyhock, calceolaria, dahlia, heliotrope, stinging nettle. On these plants practically every egg laid produces an adult under favourable circumstances. On a number of hard leaved plants it can breed successfully but the mortality of the larvae is great and the plants do not frequently become massively infested. Such plants are the grape vine, various fuchsias, *Calla*, begonias, geraniums.

On the younger foliage of the tuberous begonias none of the scales survived the first moult and on the older leaves scales at the extreme periphery alone reached maturity. A similar thing occurred on fuchsias of the Mrs Marshall type where frequently a leaf was found with a complete fringe of mature or empty scales while on the rest of the leaf all the scales were dead. On chrysanthemums breeding was free on old foliage but not common on young growth. On two weeds strongly favoured by the adults, *Solanum dulcamara* and *Lamium purpureum*, no scale was ever found to mature, all dying either before or just after the first moult. On narcissus, tulip, hyacinth and various grasses eggs were often laid, but no larvae passed the first moult. Mature scales have been found rarely on elder and hawthorn and rather frequently on elm. This list by no means exhausts the food plants of the insect which were noted, but is merely indicative of its range.

4. HABITS OF ADULTS.

The adults usually mate on the leaf on which they emerge and frequently commence oviposition there. Later they seek younger foliage. Outside, when there is a perceptible wind, they are very reluctant to take flight, but on warm still days they may sometimes be seen hovering in numbers over their host plant. In the tomato houses they often remain very localised until the infestation on a few plants has become massive. Trimming the plants and the consequent disturbance aids their dispersal. They are distinctly gregarious as the following figures show, the counts being made in each case on foliage on which no adults had emerged.

On July 8, large bushy *S. dulcamara* growing under staging in the greenhouse, 260 leaflets all young and tender, plant held 90 flies distributed on 35 leaflets and of these 15 (16·6 per cent.) were on one leaflet and 9 (10 per cent.) on another.

On July 16, 10 plants, *Trifolium sativum*, growing in a box in the greenhouse held 242 flies distributed as follows: 7, 4, 35, 79 (33 per cent.), 16, 11, 3, 0, 53, 34.

On July 20 the top 40 leaves of an *Al. rosea* held 129 flies of which 55 (43 per cent.) were on the 22nd leaf from the top.

On August 27, a young *Urtica* held 32 flies of which 22 (68 per cent.) were on one leaf and the others distributed over the remaining 11 leaves.

This gregarious habit has possibly originated for the better protection of the scales from parasites. If a healthy scale is watched under a moderately high power of the microscope and in bright sunlight, the "honey dew" excreted at the anus in the base of the lingula is seen to form into bubbles which swell up very suddenly and burst, distributing the dew as a fine spray. The mechanism of the bubble formation has not been made out. There is at the caudal end of the vasiform orifice a small trumpet-shaped organ and the tip of the lingula frequently touches the mouth of this. The trumpet-shaped organ lies at the end of the furrow running from the caudal air channel of the scale to the vasiform orifice. No actual air channel was followed, and time did not permit of any exhaustive examination of structure. A large number of scales blowing bubbles in this way would form a continuous shower of a sticky spray and it seems reasonable to suppose that this would be a deterrent to the small parasitic hymenoptera. Bubble formation is well known in another group of the Hemiptera, certain Cercopidae, the well-known "froghoppers" which form the "cuckoo spit."

The adults exhibit a remarkable colour reaction, being strongly attracted to yellow, and to green and orange in proportion to the amount of yellow these colours contain. The experimental work on this subject will be recounted elsewhere.

(1) *Length of life.* A study of the length of life of the adults, their fecundity and parthenogenesis was carried out with newly emerged females, alone or with single males, on small plants growing in muslin covered beakers. In this way daily observations could be made without disturbing the insects and these could be transferred to fresh uninfested plants before their offspring attained maturity. Unfortunately *Lamium purpureum*, a plant which thrives well under these artificial conditions, was used in a number of the earlier experiments and as none of the young matured these were largely wasted.

The average life of 16 females, including three which came by accidental deaths, was 40 days. The longest life recorded was 104 days, on *Lamium*. The average life of 10 males was 25 days, the longest being 46 days, also on *Lamium*.

(2) *Fecundity.* The average number of eggs laid was 130 per female and the rate of oviposition averaged about three eggs a day. The largest number laid was 534 giving an average of slightly more than five a day. There appeared to be some variation in fecundity in accordance with the food plant, such as Morrill and Back (2) describe for *Al. citri*, but the experiments were insufficient for this to be certain. Oviposition began on the second to fifth day after emergence in most cases. The high mortality of the young, which occurred several times on suitable foods, was due to the difficulty of keeping all the foliage healthy under conditions ensuring that no invading insects could contaminate the experiments.

Table II. *Showing the length of life, fecundity, and sex of offspring of* A. vaporariorum, *mated and unmated.*

Experiment No.	Date commenced	Plant	Condition of female	Life in days: Male	Life in days: Female	Number of eggs	Offspring: Males	Offspring: Females
5	20. I.	*Ranunculus*	Virgin	—	9 + (escaped)	4	3	0
6	26. I.	*Lamium purpureum*[1]	,,	—	71	186	—	—
		Urtica dioica[2]				85 (271)	76	0
8	26. I.	*Lamium purpureum*[1]	,,	—	77 + (escaped)	147	—	—
		Urtica dioica[2]				150 (297)	107	0
9	26. I.	*Lamium purpureum*[1]	,,	—	17	82	—	—
21	6. II.	Tomato	,,	—	46	110	73	—
40	12. IV.	*Urtica dioica*	,,	—	22	88	8	—
7	26. I.	*Urtica dioica*	Mated	8	55	191	33	123
10	27. I.	*Lamium purpureum*[1]	,,	46	104	534	—	—
11	27. I.	*Senecio vulgaris*	,,	7	20	12	0	1
20	6. II.	Tomato	,,	34	39	74	16	12
22	6 II.	*Trifolium pratense*	,,	45	47	83	14	13
25	18. II.	*Urtica dioica*	,,	33	33	102	11	11
26	18. II.	,,	,,	13	14	28	15	8
33	12. III.	,, (out of doors)	,,	40	95 + (drowned)	95	No record	
39	12. IV.	*Solanum dulcamara*[1]	,,	5	13	49	—	—
41	20. IV.	*Urtica dioica*	,,	16 + (killed)	16	63	2	8

[1] Food plant unsuited to larvae. [2] Transferred to this plant.

(3) *Mating.* Mating occurred soon after emergence and it is the habit of the male to rest quietly by the side of the female and to effect impregnation repeatedly. In one case coitus was observed between the same pair on five occasions between January 27 and February 26 and probably also on March 6. Notes were made of their relative positions

on 37 days and on 23 of these they were close together. This repetition appears to be unnecessary as in one case when coitus occurred on January 29 and the male died on February 3 the still isolated female continued to oviposit until March 19 and the effect of the fertilisation was evident to the end in the sex of her offspring, the eggs laid from January 30 to March 2 producing 82 females and 21 males and those laid from March 2–19 producing 41 females and 12 males.

(4) *Parthenogenesis.* Morrill first noted parthenogenesis in Aleyrodidae and in conjunction with Back (2) found that unfertilised eggs of *Ast. vaporariorum*, *Al. citri* and *Al. nubifera* always gave rise to male offspring. Hargreaves (3), working in England, found just the reverse, and bred two generations of females of *Ast. vaporariorum* in the absence of males and states "out of the hundreds of flies that I examined I did not encounter a single male." Williams (4) found several colonies of the insect in England consisting entirely of females or in which this sex largely predominated. In his experiments in breeding he obtained from mated females small families in which the sexes were equal but none of the offspring of his virgin females reached maturity. This author and later Schrader (5) discuss the genetics of the insect and the suggestion is made that the parthenogenetic female producers in England may have arisen by mutation from the American parthenogenetic male producers of America and that the occurrence of some males in England may be due to fresh importations.

In the greenhouses in the Lea Valley the sexes occur in approximately equal proportions, counts giving in July out of 305 insects a male percentage of 52·8 and in October out of 118 a male percentage of 46·6. The breeding experiments show that the strain agrees with the American race in this important point, as the data in Table II show. Five virgin females produced offspring totalling 267 all of which were males. Seven mated females produced offspring also totalling 267 and of these 91 (34 per cent.) were male and 176 female.

5. DEVELOPMENT.

(1) *Egg.* The eggs (Fig. 2) (Plate I, fig. 1) are laid in circles on smooth leaves, but on hairy leaves like those of the tomato they are scattered in groups. A firm attachment to the leaf is gained by means of a short stalk which rests in a cut made by the female. Like all the other stages of the insect they are covered with wax. At first they are greenish yellow in colour but darken in two or three days in warm weather and during the greater part of the incubation period they are quite black.

They are almost invariably placed on the undersides of the leaves. As indicated above the incubation period may be very prolonged in cold weather outside. The varying incubation periods were recorded on a series of plants from December to August and the results are summarised in Table III. The longest period observed outside was 117 days and the shortest 13–16 days in August, mean temperature 58° F. The incubation period outside in August is little more than half that recorded in the greenhouse in December, though the mean temperature in the latter case was two degrees higher and is approximately the same as that in April under glass with a mean temperature of 67°. This seems to show

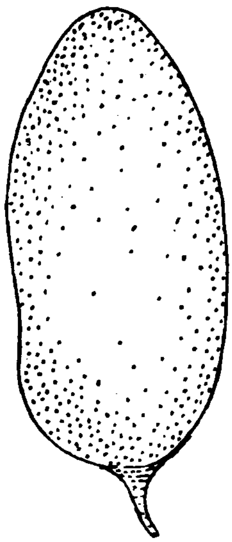

Fig. 2. Egg of *A. vaporariorum* (× 350).

that sun heat is more stimulating than artificial, the sunshine hours in the three months being: December, 27; April, 87; August, 158.

(2) *Scale.* The characteristics of the four scale stages are described by Hargreaves (3). The first larva (Fig. 3*a*, *b*) moves about on the surface of the leaf but usually only a sufficient distance for it to grow without coming in contact with others from the same batch of eggs. The movement was usually confined to a few hours and once only was one seen to move the day after hatching. On one occasion a larva was seen walking on the stem of a plant, a very small *Trifolium pratense*, the leaves of which were overcrowded with scales. When cut foliage heavily infested with hatching eggs was placed on the soil around the stems of *Urtica*

and beans no migration of the larvae from the dead leaves to the living plants occurred. When eggs were hatching in numbers on the unsuitable foot plant *Lamium*, and it was particularly desired to preserve the larvae, an *Urtica* was planted by the side of the former and the leaves of the two were stitched together. No larvae passed from the unsuitable to

Table III. *Showing the duration of the egg and scale stages of* A. vaporariorum *on various plants in a heated greenhouse and outside.*

	Plant	Date of oviposition	Date of hatching	Duration of egg stage (in days)	Date of emergence of adults	Duration of scale stage (in days)	Number emerged
In heated greenhouse	Tomato	3–4. XII.	23–29. XII.	20–25	20–28. I.	28–30	Many
	Urtica	3–4. XII.	23–29. XII.	20–25	21–28. I.	29–30	,,
	Anemone (St Brigid)	14–16. I.	1–4. II.	17–21	9–18. III.	37–43	28
	Bean	28–30. I.	14–19. II.	17–20	18–31. III.	33–41	260
	Tulip	20–23. II.	11–15. III.	20–21	—	—	0[1]
	Bean	23–24. II.	13–15. III.	19–20	7–17. IV.	25–38	49
	Begonia (tuberous)	2–3. IV.	16–19. IV.	14–16	—	—	0[2]
	Urtica	2–3. IV.	16–18. IV.	14–15	12–18. V.	26–30	87
	Potato	23–25. IV.	5–8. V.	12–13	26. V.–4. VI.	21–27	270
	Tomato	12–13. V.	21–22. V.	9	8–18. VI.	18–27	870
	Bean	9–10. VII.	17–19. VII.	8–9	3. VIII.?	17–?	Many
Outside	*Lamium*	12–15. I.	10. IV.–10. V.	87–117	—	—	0[1]
	Urtica	5–8. III.	28. IV.–14. V.	54–67	—	—	0[3]
	Urtica	2–3. IV.	14. V.–20. V.	42–48	—	—	0[3]
	Urtica	5–19. IV.	20. V.–1. VI.	43–45	29. VI.	40	5
	Bean	—	8–10. VIII.	—	7. IX.–?	30–	Many
	Bean	2–3. VIII.	15–18. VIII.	13–15	15–20. IX.	30–33	Many

[1] Food unsuited to larvae. [2] Young begonia foliage unsuited to larvae.
[3] All infested leaves shed.

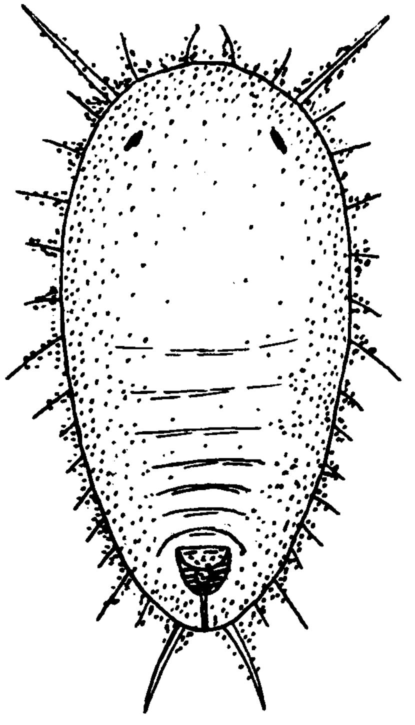

Fig. 3 *a*.

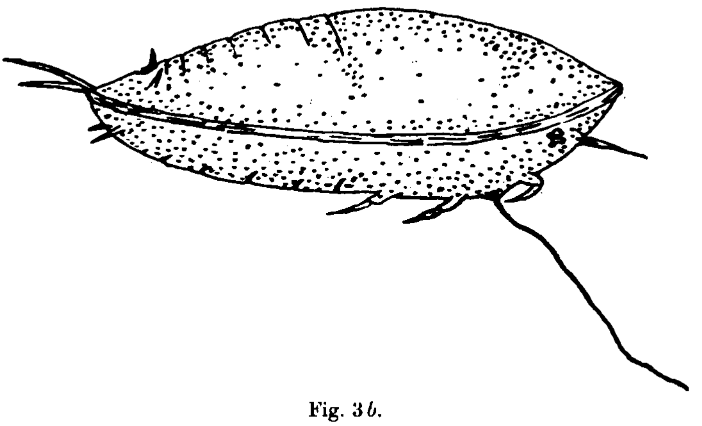

Fig. 3 *b*.

Fig. 3. First stage larva of *A. vaporariorum*, recently hatched (× 300). *a*. dorsal view, *b*. lateral view.

the suitable food. The movement of the larvae is therefore not a migratory one and when the eggs are laid on an unsuitable plant or the foliage holding them is severed from the plant, they cannot survive. Eggs and feeding larvae on severed foliage shrivel up and die with the drying of the foliage which holds them.

All the larval stages are distinctly flat after the moult and the growth in each stage is in depth only. The first three become very turgid towards the moult and the skin splits at the junction of the thorax and abdomen by a T-shaped orifice. Through this the larva protrudes the head and thorax and forces itself forward till it can grasp with its legs the leaf in front of the old skin. It then elevates the posterior end of the body thus tearing the old skin away from the leaf. This is heavy through being filled with the "honey dew" and when it is released it falls clear of the leaf as a rule. Walking subsequent to a moult has not been observed but when the scales are crowded a revolving motion is often seen while the larva feels for a clear space. Overlapping of the scales, however, is common in heavy infestations. When the adult emerges from the mature scale the empty shell is left attached to the leaf.

The fourth stage of the scale (Fig. 4) is always referred to in the literature of the Aleyrodidae as the pupa, but at the beginning of the instar it is as much a larva as the preceding stages. Its dorsal skin becomes somewhat heavily chitinised and leathery and in its growth this is elevated entire from the leaf, a corrugated palisade of wax forming as the elevation proceeds. The stout waxen case is continued entirely over the ventral surface and the mouth stylets protrude through it. Respiration takes place at folds where the otherwise translucent wax remains opaque white and porous. These breathing folds are the same depth as the palisade and are situated one median posterior and two antero-lateral in the region of the thorax. The dorsal surface carries a marginal fringe of short tooth-like waxen processes arising from bosses. These short spines curl downwards. There is also a system of longer waxen processes standing upright from the scale. Hargreaves mentions and figures eleven pairs of which seven pairs are marginal. In the specimens examined during this work only four pairs could be distinguished from the marginal teeth, viz. one anterior, one over the lateral breathing folds, one posterior to this pair at the level of the first abdominal segment, and one caudal, while in the typical form those on the disc agreed with Hargreaves' description, viz. one pair cephalic, one thoracic, one on the third and one on the fourth abdominal segments. In a few of the specimens mounted from tomato the fifth and sixth abdominal segments also bear spine bosses, and in one case there is an asymmetrical one on the fifth segment. Where these additional ones are not developed, minute hairs can be seen replacing them, evidently vestiges.

This instar becomes quite opaque early in its development and it is therefore not possible to tell by the movements of the pharyngeal pump how long it continues to feed. After the eyes and other organs are well developed, if it is removed from the leaf its mouth stylets wave to and fro as though they were still functional. Considerable growth in depth also takes place after the adult eyes are distinct. If it is removed from

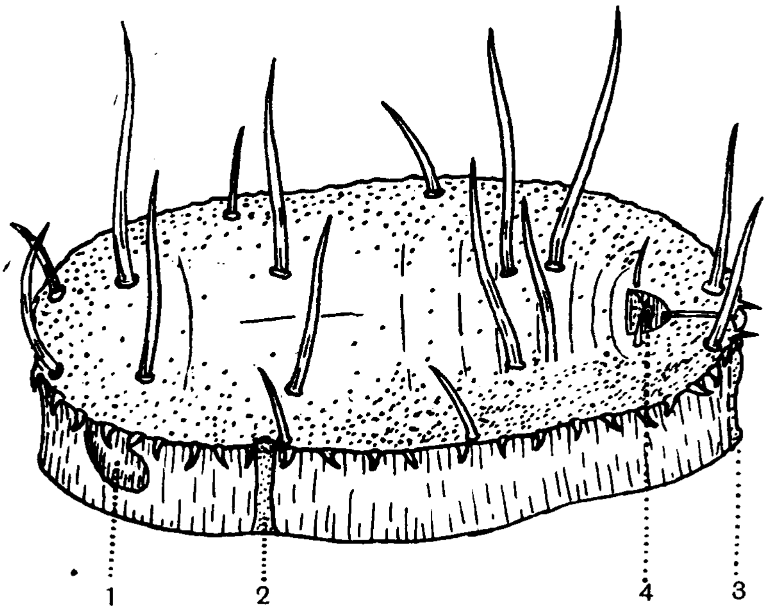

Fig. 4. Mature scale (pupa) of *A. vaporariorum* **(× 130). 1. adult eye, 2. thoracic breathing fold, 3. caudal breathing fold, 4. vasiform orifice.**

the leaf shortly before emergence the mouth stylets break off short by the case and have evidently ceased to function except as an anchor. About this time a copious excretion of honey dew takes place and the insect then lies tolerably free inside the old larval skin.

The duration of the scale stage was noted on a variety of plants which were examined before use to ascertain that they were free from the pest. They were then heavily infested with the fly for one or two days. After this the fly was cleared from them and they were enclosed in muslin sleeves. The hatching of the eggs and the emergence of the adults were noted. The limits of the scale stage in the greenhouse were found to vary from 45 days in February to 17 days in July and bore a close correspondence to the temperature (see Tables I and III). There was however some variation with the different species of plants, since in one experiment when a variety of plants were infested on April 23–25 and the eggs on all hatched from May 5–8 the duration of the scale stage was on fuchsia 26–31 days, on thick-leaved zonal geranium 24–30 days and on tomato, potato, calceolaria, and thin-leaved variegated geranium 21–29 days.

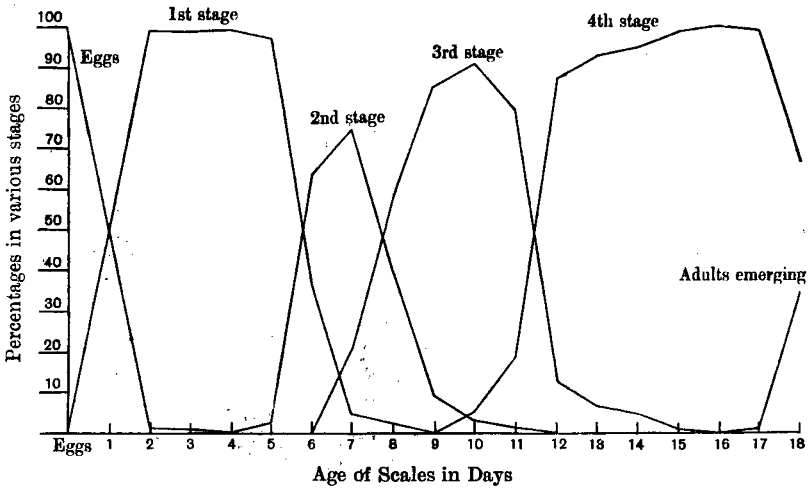

Diagram I. Showing the time spent in the four larval stages by *A. vaporariorum* on French beans at optimum temperature (mean 74° F.). The maximum number moult where the curves cross at 50 %.

In July young bean plants, known to be free of the insect, were taken one each day for 19 days and exposed for 24 hours to a large number of adults. These were then cleared off and the plants were kept in a fly-free muslin cage. When emergence of adults commenced on the plant first infested the series was stopped, each plant holding developmental stages of the same age from egg to adult. A portion of each plant holding 200–450 scales was then examined and each scale was assigned to its particular instar, the condition of 4900 scales being thus noted. The percentages in the various stages on each plant are shown in Diagram I. The mean temperature during the experiment was 74° F. with a range of 54–193°. Hatching began on the 8th day after oviposition and was practically complete by the 10th day. The figures showed that on the average the duration of the first stage was 5 days, the second 2 days, the third 3 days, and the fourth stage 8 days. On *Ranunculus* in February and March with a mean temperature of 64° (range 45–94°) the duration in days of the four stages in four scales was: 1st, 6–7; 2nd 4–6; 3rd 8–11; 4th 16–19. On beans in March and April, with a mean temperature of 67° (range 47–101°), the average duration in days of 49 scales was: 1st, 7; 2nd, 3; 3rd, 6; 4th, 12. These instances sufficiently show the proportion of the larval life which is spent in the various instars.

The emergence of the adults appeared to be always in the early hours of daylight.

6. OCCURRENCE OF *A. SONCHI* KOTINSKY IN ENGLAND.

A second form of pupa appeared in the greenhouse where the main culture of *A. vaporariorum* was kept (Plate I, fig. 2). This scale differed from the typical form in the absence of dorsal tubercles and processes and the greater development of the marginal waxen processes which stuck out parallel with the leaf surface. It was first seen on a small *Acer* which had been brought in to test its susceptibility to the fly and had been in the greenhouse for some weeks; later, on *Brassica oleracea* which had been introduced for the same purpose. Both these plants were thought to be clean at their introduction and the typical scales never developed on them. It was also found on *Polygonum aviculare* and *Sonchus oleraceus* which had grown from seed in the chamber. Outside it was found on *Acer*, *Sonchus*, *Clarkia*, *Tropaeolum indicum* and *T. canariense*. Its incidence in numbers in the Station garden corresponded to that of the typical *A. vaporariorum*, the experimental greenhouse being the focus. The same scale was seen in Guernsey in October massively infesting *Sonchus* in the greenhouses, again in association with *A. vaporariorum*. A *Polygonum* which, after pocket-lens examination, was believed to hold the atypical form only was cleared of all adults and placed in a muslin cage with three tomato plants which were uninfested. This cage was unopened for a month during my absence from the Station, watering being done through the muslin. At the beginning of October when the cage was opened there had been time for one generation to breed through. The tomato plants were found to be massively infested with typical *A. vaporariorum* in all stages. It was then thought possible that the two scales belonged to the same species as no differences in the adults could be detected. Material from the cage and from outside was therefore submitted to Mr Laing of the British Museum who reported:

"The absence of dorsal tubercles gives the form found on *Acer*, *Tro-*

pacolum and also to a certain extent on *Polygonum aviculare.* This form may be that originally described by Barensprung as *complanatum*, but his description is totally inadequate. It almost certainly is *sonchi* of Kotinsky from Hawaii, and the absence of the two tiny caudal spines would make it *tentaculatus* Bemis, from California. On *P. aviculare* I find in my preparations both typical and atypical pupa cases, but on the tomato the typical form seems to be present alone. Is it not possible that the two forms were present at the beginning and that only the typical form developed on the tomato? The case would then be very similar to Morrill's experiment when he separated *packardi* Morrill from *vaporariorum*. In addition to the absence of the dorsal tubercles in the atypical material there are other minor differences and seeing the material without knowing anything of the experiment I should unhesitatingly have called the two forms distinct species."

It was intended to do further work with the atypical form in the present summer but circumstances have prevented this. Its wide distribution, Hawaii, Guernsey, the Lea Valley, and possibly California, and its apparent association in two of these with *A. vaporariorum* make it a very interesting form.

7. ECONOMIC IMPORTANCE.

Financial loss caused by *A. vaporariorum* results mainly through its attacks on tomatoes, beans and potatoes grown under glass. The two latter suffer less than the former because they are brief crops and the insect does not have the same opportunity of causing massive infestations on them for this reason. The damage is partly direct through loss of sap, but is mainly due to the layer of honey dew which soon covers the foliage and fruit of the infested plants. In this medium sooty moulds grow, forming a black felt over the foliage which keeps away sunlight, while all fruit from infested plants must be wiped before it can be marketed. The fungus growth on the tomato plants was examined by Dr W. F. Bewley, who found it to consist of *Penicillium* sp. predominating, together with *Cladosporium herbarum* and *Fumago vagans*, all saprophytic forms.

In order to estimate the damage done by an unchecked attack on tomatoes, 34 young plants in 12-inch pots were lightly infested with about ten adults each on May 6 and placed in a chamber in the greenhouse. On half of them the pest was allowed to develop unchecked while the others were removed about once a fortnight to another chamber and fumigated with hydrocyanic acid gas in order to keep the infestation under control. Apart from the fumigations the plants received the same treatment. The infested plants were practically dead on August 24 and the last fruit was picked from them. Their total yield was 29 lbs. 14 oz. The fumigated plants were still vigorous at the last fruit picking on October 8 and their total yield was 66 lbs. 8 oz. or about 4 lbs. of fruit per plant. Not uncommonly tomato plants in trade nurseries are as badly attacked as these and it may be stated fairly that if the plants are infested early and the infestation is not checked a loss of more than half the crop will be the result.

Such a condition only obtains when the grower deals in mixed crops keeping his houses occupied during the winter. The grower who only grows tomatoes has his houses empty for several months and nearly always commences the season free from the pest. Invasion by the insects is liable to occur in May and June and it is not until the late summer that fumigation becomes necessary.

Although the cucumber was mentioned above among the favourite foods of the insect, trade growers of this crop do not recognise it as a pest in the Lea Valley. It is sometimes present in the houses early and late in the year, but generally disappears when the weather becomes warm. In the tomato houses it was observed that when the temperature of the air approaches 100° F. the flies become restless and flutter up to the glass, many escaping through the laps. It was found by experiments in thermostats that they are stupified when the temperature rises to 105°. Fifty flies so stupified by 40 minutes' exposure to 102–106° nearly all recovered by the second day after the experiment. One out of 20 recovered after 5 minutes' exposure to 104–110°. It was clearly impracticable to effect control of the pest in the tomato houses by so raising the temperatures so no further details of the series of experiments will be given, but they showed that it is the atmospheric conditions of the cucumber houses which often rise above 100° that prevent the white fly from becoming a serious pest there.

8. CONTROL.

The spread of the insect is greatly aided by the culpable negligence of some nurserymen who make a business of the sale of young plants. Bedding plants such as geraniums and salvias are often sold infested with the pest, and even young tomato plants are sometimes sent out in a similar unclean state. Probably only legislation could stop this dangerous practice, but growers may be advised to ask for a guarantee of cleanliness in this respect for any plants they purchase for gardens around the nurseries, and especially for young tomato plants. It is always advisable to raise tomato plants from seed rather than to buy them from mixed growers. Propagation of the new season's crop from cuttings taken from old plants has also led to very serious infestations and though this is not a common practice it is well to warn against it.

Growers should realise that they are themselves responsible for the heavy infestations outside the nurseries, and they should prevent these by never allowing conditions inside to get bad. Very many of the insects pass out of the houses of their own accord but still larger numbers are taken out on trimmings and on the plants at the end of the season. The pest should be kept under such control that the trimmings are never heavily infested and if the plants are still infested when they are cut out at the end of the season, they should be cyanided before removal. It is a common practice to burn sulphur in the houses before the plants are removed, but this is not a good fumigant against the white fly.

The grower of mixed crops should free his nursery from the pest during the winter by fumigations of all the occupied greenhouses and cold frames. A greenhouse may be easily cleaned without fumigation by completely emptying it and digging it over to bury any infested weeds or leaf fragments holding pupae, leaving it empty with the heat on for a week to starve any adults that remain and then reoccupying it with clean plants. Much of the trouble with this pest, especially in Guernsey, is caused by propagating tomatoes in houses containing infested potatoes or beans. A small separate propagating house would prevent this early infestation of the seedlings. Attacks of white fly are often caused by sheltering some ornamental plants such as fuchsias in the greenhouses. The specialist in tomato growing should not permit this practice.

9. FUMIGATION.

Spraying is of little use against white fly, while properly applied fumigants give excellent results. Special attention was given to four fumigants, viz. naphthalene, tetrachlorethane, tobacco preparations and hydrocyanic acid gas, and these will be discussed in turn.

(1) *Naphthalene.* This substance forms the basis of a number of proprietary articles sold as exterminators of white fly and attention was given to it for this reason. Naphthalene is sold in various forms as "pure flake" which is a sublimed form; "crude naphthalene," a dark material containing carbon as an impurity and from which most of the tarry acids have been removed; "drained salts" or "whizzed naphthalene," a damp oily product containing a very variable amount of the tarry acids; "undrained salts" or "unwhizzed naphthalene" which

contains relatively larger quantities of phenols. The effect of these varies greatly, but in the proportions in which it is safe to use them they are toxic only to the adults and this makes them unsatisfactory and excessively costly owing to the necessity for repeated applications.

From 50 to 200 adult white flies on foliage were placed in half-gallon glass-stoppered jars and small quantities of pure naphthalene, cresylic acid and phenol, alone and in various combinations, mixed with ash were introduced on watch glasses. Notes were made of the rate at which the insects were stupified and after an hour the fumigants were removed and the jars were left with muslin covers. A count of the mortality was made the day after the fumigation. The results of a small series of fumigations are given in Table IV. It will be seen that the mortality was slight where naphthalene alone was used, heavy with cresylic acid or phenol, but almost total in most cases (10 out of 12) when naphthalene was used in combination with the tarry acids. The rate of stupifaction was in the same proportion as the final mortality, being slow when naphthalene alone was used. A similar series was carried out with various grades of naphthalene, 0·25 grm. in 0·75 grm. of ash being used and the fumigation lasting 70 minutes at a temperature of 66° F. The mortality was as follows:

1. Naphthalene, pure flake		killed	4/65 = 6·1 %
2. ,,	high grade white (Crow & Co.)	,,	1/57 = 1·7
3. ,,	crude (carbon impurities)	,,	1/35 = 2·9
4. ,,	,, (another sample)	,,	2/60 = 3·3
5. ,,	drained salts (Crow & Co.)	,,	50/62 = 80·7
6. 1 grm. containing 75 % destructor refuse and 25 % volatilisable naphthalene containing some tarry acids (proprietary remedy)		,,	15/89 = 16·8

Table IV. *Showing the percentage mortality of adult* A. vaporariorum *obtained* in vitro *with pure naphthalene alone and with tarry acids, fumigations lasting one hour. Temperature* 69–72° F.

	Naphthalene grms.					
	0	0·1	0·2	0·3	0·4	0·5
No tarry acids	—	—	—	—	—	3·5
	—	—	—	—	—	3·0
Cresylic acid ("pale straw") 0·1 grm.	79	—	—	—	62·6	95
	64	—	—	—	—	—
Pure phenol 0·1 grm.	66	100	99	99	98	97
	39	—	—	—	100	98
	76	—	—	—	—	—
Cresylic acid 0·1 grm. + phenol 0·1 grm.	78	—	—	85	—	100
	75	—	—	—	—	100

It is clear that the effect of naphthalene on white fly depends on the presence of the residue of tarry acids. The finding was checked by fumigations of an infested greenhouse with the various grades, but as it is at best a poor remedy these will not be detailed. The materials give an unpleasant flavour to the fruit and it must be realised that the introduction of an unknown amount of carbolic acid among growing plants is a risky proceeding. The vendors of naphthalenes state that the crude forms contain a very variable amount of tarry acids in the different samples, but they are unable to guarantee the strength. This would make it impossible to standardise a treatment.

(2) *Tetrachlorethane.* This liquid has been occasionally used for greenhouse fumigation during the last two years at the Experimental Station, and gives good results against white fly. Its use is simple as it is merely poured down the centre of the house in the evening and this is kept closed for as long as possible on the following day. As it is not a very poisonous substance it may be used in conservatories opening into dwellings where the employment of cyanide is undesirable and it has a future as a fumigant in very small greenhouses where the measurement of the small quantity of cyanide required is a difficulty. As it costs about ten times as much as cyanide fumigation the trade grower should take little interest in it.

Its action on adult *A. vaporariorum* is doubtless toxic, but it appears to kill the scales through the effect of the vapour on the wax as considerable numbers of the flies attempt to emerge subsequent to the fumigation and die when partially free from the pupa cases. It has no effect on the eggs. It has been used for a wide variety of plants including tomatoes and no damage has resulted except in one case when the foliage of three young sycamores (*Acer pseudoplanatus*) growing in pots turned brown the day after the fumigation and was subsequently shed. It may be therefore that some greenhouse plants would suffer from it. Daylight during the fumigation did not tend to damage and no preparation of the plants appeared to be necessary.

The liquid should be used at the rate of about half a pint to 1000 c.ft. of space and the fumigation should be repeated as with cyanide. The complete success of the fumigation depends on its duration, and the limiting factor to this is the weather as the house can be kept closed longer in dull than in sunny weather. A dull period should therefore be chosen when possible. The mortalities obtained in four experiments, with varying amounts of tetrachlorethane and varying durations, when in-infested plants were sleeved after the fumigations and kept under observation for two to three weeks, are shown in Table V.

Table V. *Showing the mortality of* A. vaporariorum *obtained with tetrachlorethane.*

Capacity of greenhouse	Amount per 1000 c.ft.	Duration	Temperature	Mortality: Adults	Mortality: Scales
2500 c.ft.	1 pint	15 hours	61–85° F.	100%	(343/350) 98%
4500 ,,	⅔ ,,	12 ,,	65–70	100	(585/699) 83
2500 ,,	½ ,,	18 ,,	62–65	(28/29) 97	(65/67) 97
2500 ,,	½ ,,	40 ,,	51–68	100	100

(3) *Tobacco preparations.* It was recently stated by a correspondent in a trade journal that some twenty years ago when white fly first started to give trouble to nurserymen in this country it was only necessary to burn a little tobacco in the greenhouse in order to control it, but that now such preparations only stupify it. Whatever they were once, they are at any rate at present of very little use against the pest as they drive enormous numbers of the insects outside and many of those which fall are merely stupified. They have no appreciable effect on the young stages. The various tests made will not be discussed in detail. They included the burning of "shreds" at five times the strength recommended by the maker, fumigations with a proprietary nicotine and camphor fumigant, also with pure nicotine at the rate of ⅛ oz. per 1000 c.ft. and ⅜ oz. with ⅜ oz. camphor per 1000 c.ft. In each case less than a 50 per cent. mortality of the adults was obtained. These preparations have also become almost prohibitory in cost to the commercial grower.

(4) *Cyaniding.* Fumigation with hydrocyanic acid gas or, as it is generally called, "cyaniding" is the most effective method of controlling the pest and is the only one known sufficiently economical for use in trade nurseries. High grade sodium cyanide, 98 per cent. purity (often described as 130 per cent. in reference to the strength of pure potassium cyanide), is employed, and the gas is generated by means of sulphuric acid. Potassium cyanide and phosphoric acid are sometimes used as alternatives, but they have no advantages and are more costly. The proportions in which to employ the materials are: 1 oz. of sodium cyanide in 1½ fluid ozs. of sulphuric acid diluted with 3 fluid ozs. of water. An error which had become almost universal among Lea Valley growers and in other parts has led to most of the failures in the use of these materials in the past. Fear of the poisonous nature of the gas has led the users to drop the cyanide into the acid enclosed in a sealed envelope or some other type of paper packet. When the acid enters the packet and evolution of the gas commences the pressure prevents the free access of the acid and the heat of the reaction chars the remaining cyanide.

Later, when the packet breaks down, the acid will no longer act on the charred mass. The cyanide should be dropped free into the acid so that the reaction may be brisk and unimpeded. A so-called "Safety Cyanide Package" is on the market and this consists of a metal container the side of which is made of thin zinc foil. An additional amount of sulphuric acid is used and the zinc dissolves away completely so that the acid has free access to the cyanide. There is no scientific objection to this container. There is, however, ample time for the operator to drop loose cyanide into the acid and to move on to the next jar at a slow walking pace without detecting the slightest odour from the gas.

A series of eighty fumigations with this gas was carried out in an experimental greenhouse 18 ft. long by 20 ft. wide, height 11½ ft. to the ridge and 4 ft. to the gutter, capacity 2500 c.ft. The recommendations finally made were checked in blocks of tomato houses in trade nurseries and in greenhouses of mixed plants. Temperature, humidity, duration, time of day, size of dose, and the condition of the plants were all varied. Tomato plants in pots were always included, and some of these were of large growth growing in 12-inch pots, to study the effect of the gas on normal plants. Others, tomatoes or beans, were heavily infested with white fly in all stages and were enclosed in muslin sleeves at the end of the fumigation and were examined every day or two for two or three weeks in order to estimate the effect of the gas on the insect. In general three infested plants were included and placed in different positions and at different heights, but it was found that position made no appreciable difference. A fumigation chamber with a capacity of 350 c.ft. was also constructed, but it was found that results obtained in a chamber are useless when applied to a greenhouse owing to the difference in leakage and its use was abandoned except for a few special experiments.

Temperature. The results confirmed the work of other investigators that a somewhat low temperature (below 60° F.) renders the plants less liable to damage, but in practice as the fumigation of tomato houses is most often done in summer and early autumn the operation has generally to be carried out at a somewhat higher temperature than this. On 30 evenings from May to July fumigations were commenced at dusk and on only two occasions was the temperature of the house below 60° though artificial heat was cut off in nearly every case, and on 11 occasions it was above 65°. As will be shown presently it is possible to counteract the harmful tendency of high temperature by withholding water from the plants. It is exceedingly difficult to make any definite recommendation about temperature as, in the case of tomato plants, very severe damage with the same amount of cyanide has occurred at a temperature of 57° with unprepared plants and none at all at 69° with prepared plants of a similar soft growth. The best advice that can be given to the grower is that he should have his houses cool for the fumigation and carefully prepare the plants beforehand as described below.

The toxicity of the gas for the insect was not found to vary within the mean temperature limits of 47° and 66°, total mortalities being obtained with both at the correct dosage.

Time of day and duration. Every writer on the fumigation of greenhouses with this gas mentions the importance of not commencing the operation till dusk, but growers in many cases persist in starting several hours before sunset. Damage which means practically the death of the plant results. All tissue on which the sunlight falls is seared as though with flame, the growing points are killed and the buds and flowers cut off. The materials are always blamed for this and the operation discredited. Moreover the gas is less toxic in sunlight as the following cases show. A fumigation with $\frac{1}{8}$ oz. cyanide per 1000 c.ft. commenced four hours before sunset and lasted $13\frac{1}{2}$ hours gave a mortality of less than 50 per cent. for adults and negligible for the scales, as contrasted with a usual mortality of 90 per cent. for adults and 75 per cent. for scales in fumigations with this quantity commenced at dusk and lasting 8–11 hours. A fumigation with $\frac{1}{4}$ oz. cyanide per 1000 c.ft. commenced three hours before dusk and lasted 12 hours gave an almost total mortality for adults and 70 per cent. for scales, as contrasted with a usual total mortality for adults and total, or almost total, mortality for scales with the same quantity commenced at dusk and lasting 8–11 hours.

It has generally been the custom to recommend relatively large doses of cyanide with short exposures rather than small doses with long exposures. Sasscer and Borden (6) using $\frac{1}{2}$–$\frac{3}{4}$ oz. cyanide per 1000 c.ft., exposure one hour, obtained with this pest a mortality which was total except for eggs and late pupae. In the course of this work $\frac{1}{2}$ oz. cyanide, 1000 c.ft., exposure one hour, gave 95 per cent. mortality for adults, had practically no effect on late pupae, and destroyed about half the younger scales. The same amount, $1\frac{1}{2}$ hours' exposure, gave 100 per cent. mortality for adults and about 90 per cent. for scales. $\frac{1}{3}$ oz. cyanide, 1000 c.ft., exposure three hours, gave 100 per cent. mortality for adults and a poor result for scales. In the two last cases tomato plants were damaged, the temperature being 57° and 62° respectively. To control the infestation by these means at least three fumigations would be necessary as against two when the smaller doses with long exposures are used. The former at the present price of materials would cost about £12 per acre and the latter about £4. Provided that the houses are opened up at dawn there appears to be no more risk to the plants with the long exposure and small dose than with the short exposure and large dose, and the former should always be employed.

Toxicity of the gas. The following account of the toxicity of the gas for the insect deals only with exposures of 8–11 hours' duration.

The eggs are unaffected and the adults are rather more susceptible than the scales. A large proportion of the adults fall to the ground directly the gas reaches them and unless there is a sufficient concentration many of these recover during the following day or two and regain the plants. Whenever the mortality of the adult was total that of the scales was always more than 90 per cent., generally more than 95 per cent. and often 100 per cent., so that if all the flies are killed the effect of the fumigation is known at once to be good, if not perfect. The results obtained on heavily infested plants sleeved after the fumigations will be given briefly under the various dosages. The study of the life-history was carried on at the same time and showed that the emergences recorded were after intervals too brief for them to have been in the egg condition at the temperatures ruling at the season when the particular fumigation was done.

½ oz. cyanide per 1000 c.ft.; 4 tests; mortality for adults always total; mortality for scales in three cases total; small numbers of adults emerged on one plant beginning on the 18th day after fumigation.

⅓ oz. cyanide per 1000 c.ft.; 6 tests; mortality for adults always total; mortality for scales in three cases total and in three cases very small numbers emerged beginning on the 13th, 16th, and 17th days respectively.

¼ oz. cyanide per 1000 c.ft.; 14 tests; mortality for adults always total except in one case when three out of 500 recovered; mortality for scales in seven cases total; in three cases a single scale survived out of hundreds, the flies emerging on the 8th, 14th and 15th days respectively; in four cases emergence occurred in very small numbers (one to three a day) commencing once on the 10th, twice on the 14th, and once on the 17th days respectively.

⅕ oz. cyanide per 1000 c.ft.; 10 tests; mortality for adults always total except in two cases, 1 and 9 surviving respectively, in each case out of many hundreds; mortality for scales in six cases total; in two cases emergence occurred in small numbers after the 12th day, in one case two flies emerged on the 5th and no more to the 10th day; the remaining case was an unexplained failure, only 75 per cent. of the scales being killed.

⅙ oz. cyanide per 1000 c.ft.; 9 tests; mortality for adults total in five cases, and in the remainder over 95 per cent.; mortality for scales total in three cases; emergence in the other cases in very small numbers began on the 2nd, 5th (twice), 6th, 7th and

10th days respectively. In one case where an exact count was made after a fumigation lasting 9 hours on six tomato plants holding scales from 9 days old to mature pupae the mortality was 91 per cent. (2900 out of 3184).

The fact that the small numbers surviving these fumigations were apparently young for the most part at the time of treatment is difficult to explain as, when smaller doses of cyanide were used, it was found, as other workers have stated, that the pupae, which would give rise to adults in two or three days' time, were the most resistant forms. Series of plants were prepared as described above so that in each series one plant held scales representing one day's development from egg to adult;

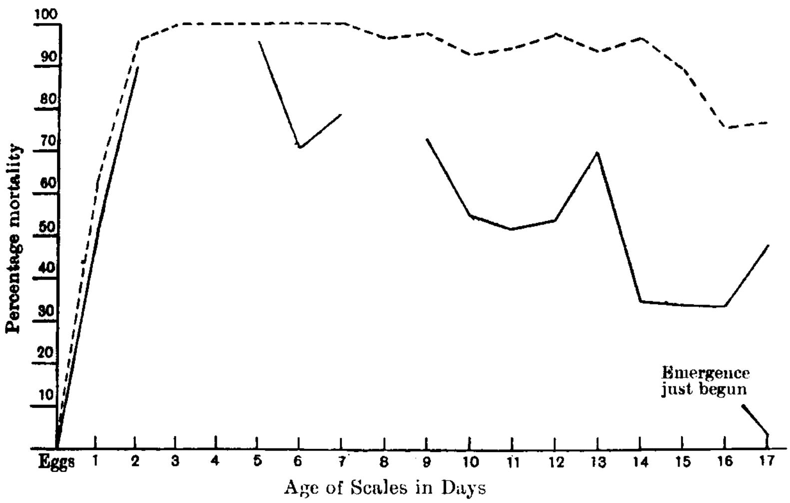

Diagram II. Showing percentage mortalities of scales of *A. vaporariorum* of various ages obtained with small doses of cyanide, long exposures. Compare with Diagram I. The gaps on the lower curve are due to the death of three plants. ⅛ oz. cyanide per 1000 c.ft. 1/7 oz. cyanide per 1000 c.ft.

i.e. at one end of the series was a plant holding only eggs, due to begin hatching, and at the other end was one holding mature scales from which emergence of flies had just commenced. Two series were cyanided as follows: (1) 18 tomato plants representing complete development except that three plants died from stem rot and caused gaps; fumigated with ⅛ oz. cyanide per 1000 c.ft., 9 hours' duration; (2) 19 bean plants representing complete development, fumigated with 1/7 oz. of cyanide per 1000 c.ft.; 9½ hours' duration. After the treatment the plants were kept for a week and a count was then made of the living or emerged scales and the dead ones, which had by this time turned brown and dried up.

The smallest count made on any one plant was 140 and the highest 970, while the average number dealt with was 460. The mortalities on the several days reduced to percentages are shown in Diagram II. The mortality on a tomato plant uncyanided but otherwise similarly treated was 29 dead out of a total of 900 scales, or 3 per cent., while the natural mortality on uncyanided beans was also negligible. If these two curves, and especially the lower one given by $\frac{1}{8}$ oz., are examined in relation to Diagram I which shows the proportion of the scales which would be in the different stages on each day, it will be seen that there are very suggestive drops in the mortality which correspond roughly with (1) the first moult on the sixth day after hatching; (2) the second moult on the eighth day, seen only in the upper curve; (3) the third moult on the tenth to twelfth days, and (4) the time of true pupation just before emergence begins. The mortality of the adults given by these small doses varied with $\frac{1}{7}$ oz. from 95–100 per cent. (average of five tests 98 per cent.), and in 10 tests with $\frac{1}{8}$ oz. from 88 per cent. to nearly 100 per cent., but was never total with the weaker charge.

After these experiments it appeared possible that a very good result could be obtained with two fumigations with a small charge on successive nights, and two heavily infested tomato plants were treated with $\frac{1}{8}$ oz. cyanide per 1000 c.ft. On the following morning one of them was removed from the fumigation greenhouse while the other was treated again the next night with the same charge. The mortality of the scales in all stages, on the first plant was 75·8 per cent. (805 out of 1045) and on the plant treated twice 91·8 per cent. (903 out of 1013). The combined effect of the two thus gave a less satisfactory result than would have been obtained with $\frac{1}{6}$ oz. in one fumigation.

The very small charges will clearly give a moderately good check to the pest, though they will not exterminate it, and it is at times advisable to use them on soft sappy tomato plants which for one reason or another cannot be brought into a proper condition to withstand the normal dosage.

Dosage. From these experiments and tests made in commercial houses it was concluded that in an isolated greenhouse in a moderate state of repair $\frac{1}{4}$ oz. of cyanide per 1000 c.ft. could be relied on to give practically total mortality for all stages except the eggs, if the fumigation lasted through the night. In a block of greenhouses in decent repair which communicate with one another a dose of this size is not required as the proportional leakage is less and $\frac{1}{5}$ oz. per 1000 c.ft. is a sufficient quantity, or when the houses are new and in very good repair even $\frac{1}{6}$ oz. gives almost total mortality.

The amount of cyanide which should be put into one jar depends on the width of the houses which vary in the Lea Valley from 12 to 30 feet. A good rule to follow is to so arrange the jars that the distance between two is approximately the width of the house as this arrangement gives an even distribution of the gas. Quarter ounce charges are recommended for houses up to 14 ft. wide, half ounces for houses 14–20 ft. wide, and ounces for wider ones. It is not wise to use a larger charge than this in tomato houses as the concentrated gas evolved so close to the plants is liable to cause damage.

The use of liquid hydrocyanic acid has recently been advised by Quayle (7) for the fumigation of fruit trees as an alternative to the jar method of generation, but the difficulties of distribution make this impracticable in large greenhouses.

Repetition of fumigation. The fumigation should be repeated when all the eggs have hatched but before any of the young can become adult. A reference to Table III shows that at any temperature there is an interval of a few days between these periods in heated greenhouses. The most suitable days for the second fumigation are shown in the poster "Cyaniding Tomato Houses."

Effect on plants. While the doses of cyanide mentioned above may be applied without hesitation to most greenhouse plants, very considerable caution is required in applying them to tomatoes, whether growing in pots or in borders, as this plant is particularly susceptible to damage by the gas. Hard growing wiry tomato plants resist the gas much better than soft sappy ones, but in trade nurseries the plants are usually of the latter type (Plate I, fig. 3).

The damage to which they are liable consists of burns on the foliage which may develop at once or several days after the fumigation. The damage is symmetrical on the leaflets and in moderate cases is confined to the basal half on each side of the midrib. Leaves which are fully grown are much less liable to damage than the younger ones. In mild cases the leaflets of the younger leaves crinkle up without any browning. On several occasions the only damage which has occurred has been a scorch on the underside of the petioles of two or three leaves which causes a permanent dwarfing of the leaf. The leaflets develop normally but become very crowded, while sometimes the leaf coils spirally round the main stem. The growing points and stems and trusses are only damaged by exaggerated carelessness such as fumigating in daylight or by the use of excessive doses. Faulty setting of the fruit could never be associated with fumigation.

By taking continuous measurements of the growth of very vigorous plants by means of a Farmer auxanometer it was found that when the fumigation commences a distinct check in growth occurs when doses of $\frac{1}{4}$–$\frac{1}{6}$ oz. per 1000 c.ft. are used, even if no subsequent lesions develop. After a day or two a normal rate of growth is resumed. One of these growth records is reproduced in Fig. 5. The plant from which this was taken was young, about $2\frac{1}{2}$ ft. in height and of a moderately soft nature, with the second truss setting. One pint of water was given daily. The thread was tied close behind the growing point and the pointer was reset at noon each day. The actual growth on six successive days was as follows, the fumigation lasting on the third period from 9.0 p.m. to

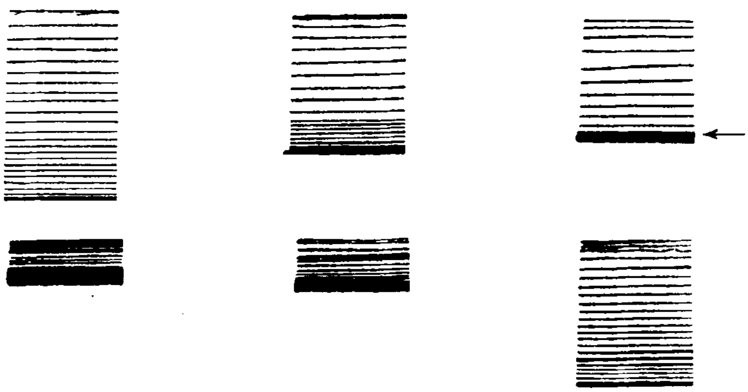

Fig. 5. Record of daily growth of tomato plant measured by Farmer auxanometer, showing check and recovery in growth after fumigation with hydrocyanic acid ($\frac{1}{4}$ oz. cyanide per 1000 c.ft., duration 9 hours). Instrument set to record double the growth. The gas was introduced on the third day at the point marked by the arrow.

6.0 a.m.: (1) 1·25 mm., (2) ·9 mm., (3) ·8 mm., (4) ·3 mm., (5) ·35 mm., (6) ·95 mm. Very slight damage to the foliage followed the fumigation. A similar check in the growth of the length of the leaves also occurs though unaccompanied by any obvious damage.

A natural assumption is that the gas causes damage by entering the leaf through the stomata but this is not necessarily the case. In this connection two experiments suggested by Prof. V. H. Blackman were carried out. Two tomato plants were placed in a dark chamber 5 hours before dusk, while four similar plants were kept in the light. At dusk all the plants were placed close together and fumigated with $\frac{1}{4}$ oz. of cyanide per 1000 c.ft., duration $9\frac{1}{2}$ hours, temperature 69–60°, relative humidity 97 per cent. The experiment was repeated with a plant kept in the dark 6 hours before dusk and then fumigated with a control plant of similar nature; $\frac{1}{4}$ oz. cyanide per 1000 c.ft., duration $9\frac{1}{2}$ hours, temperature 61·5–53°, relative humidity 81 per cent. The plants kept in the dark would presumably have had more opportunity to close the stomata but were in no way protected against damage thereby as in each experiment precisely similar burns developed on all the plants in each test. The second experiment consisted in cutting with scissors the laminae of the leaflets parallel to the chief lateral veins, and in cutting off the tips of some of the leaflets. Four plants were treated in this way immediately before fumigation so that the gas had free access to the raw tissue. Although moderate burns developed no damage could be associated with the cuts and the injury was much the same on cut and uncut plants. After these experiments Prof. Blackman agreed that no simple explanation of the mode of injury could be given and it is not proposed to discuss it further.

It was abundantly clear, however, that after daylight the most important factor in fumigating with this gas was the turgidity of the plant. An idea prevailed among the growers, and had found expression in a tradesman's circular, that flaccid plants were very liable to damage. For this reason flaccid and very turgid plants were repeatedly fumigated side by side and in each case the foliage of the former escaped injury while that of the latter was damaged (Plate II, figs. 4–7). On four occasions series of five to eight large tomato plants in 12-inch pots were prepared by withholding water from them on successive days till one or two were flagging and one was excessively turgid while the remainder were in intermediate conditions. On two occasions the test consisted of the fumigation of two plants only, one flaccid and one turgid in each instance. The fumigation greenhouse was heavily saturated with moisture, except in one case, and the plants were then treated with $\frac{1}{4}$ oz. cyanide per 1000 c.ft., duration 9 hours. Flaccid plants and those approaching flaccidity escaped any damage under the following conditions of temperature and relative humidity: (1) 60–54°, 97 per cent.; (2) 66·5–61°, 88 per cent.; (3) 67–59°, 67 per cent.; (4) 69–60°, 97 per cent.; (5) 58–55°, 90 per cent.; (6) 65–52°, 85 per cent. In each case turgid plants side by side with the others were badly damaged, the injury being always proportional to the turgidity. The two following experiments carried out under still more adverse conditions illustrate the same point:

(1) Two plants with four trusses set, one plant turgid and one flaccid, were fumigated with the excessive dose of $\frac{1}{2}$ oz. cyanide per 1000 c.ft., duration 9 hours, temperature 64–59°, relative humidity 86 per cent. The turgid plant had its foliage

very severely burnt while that of the flaccid one was undamaged but its buds and flowers were injured.

(2) Two young plants with first truss in flower, growing in 8-inch pots, one turgid and one flaccid, were fumigated in a chamber (350 c.ft.) at the rate of ¼ oz. cyanide per 1000 c.ft., the equivalent of at least double this charge in a greenhouse; duration 2½ hours, temperature 90–72°, relative humidity 80 per cent. Even at this excessively high temperature the flaccid plant was undamaged while the top of the turgid one was killed and the whole plant very severely scorched.

Nothing in this experimental work afforded any evidence that the humidity of the atmosphere of the greenhouse was a factor which needed to be considered in the fumigation and when plants were sprayed with water immediately before the operation no damage could ever be associated with this. Previous workers have disagreed about the importance of this factor (8) and it is probable that some have failed to dissociate the moisture of the air from that of the soil, the latter being all-important. It is fortunate for the tomato grower that air humidity is not a factor as the tomato house has necessarily a very moist atmosphere when it is closed down.

It is not, of course, practicable to allow tomato plants on which the fruit is setting to flag as the crop would be thereby damaged, but the principle has a practical application in that the grower may be advised to get the roots of the plants as dry as possible without harming them. It is a common practice in the Lea Valley to drench the borders heavily before planting (in one rather exceptional case to the equivalent of a 9-inch rainfall) so that the plants can grow for two or three months without heavy watering. (This makes the plants throw deep roots.) When the houses are in this condition there is clearly no control over the turgidity of the plants. Those who grow in pots usually keep the soil very wet while the first four trusses are setting. Under these circumstances it is advisable to use only half the quantities of cyanide recommended above which will give a very fair check to the pest and prevent it from getting out of control. Later the plants in borders are watered periodically according to the character of the soil, generally once a week, and older plants in pots do not suffer if they are allowed to dry until the "pot rings hollow." The fumigation with the full amount of cyanide may be given the night before the periodical watering is due or when the soil in the pots is dry. The day after the fumigation the plants may be watered freely.

It is not possible to give any guarantee that with these doses no damage to the foliage will occur, but an assurance may be given that if all the rules are followed any injury will be negligible in proportion to that caused by an unchecked infestation of the pest.

(5) *Summary of Cyaniding.* A poster giving the essential instructions on the cyaniding of tomato houses has been issued from the Lea Valley Experimental Station. The foregoing instructions are summarised there and reference is made to several important points which are well recognised and do not require discussion.

10. SUMMARY.

The insect exhibits partial adaptation to a temperate climate, the egg and adult being resistant to considerable cold.

The wide range of its food plants is indicated.

The adults are gregarious and show marked colour reactions. The life is long and the fecundity great. Parthenogenesis occurs and only male offspring result from this; mating is the rule and produces offspring of both sexes.

The incubation period of the egg varied from 8 to 117 days according to temperature, and the duration of the scale stage from 17 to 43 days.

The occurrence of *A. sonchi* Kotinsky in England was noted.

The attacks of the pest on tomatoes mainly make it of great economic importance.

Specialisation in tomato growing to the exclusion of other crops is a useful precaution and other precautionary measures are indicated.

Fumigation is the only effective method of treating infested plants. Naphthalene and tobacco preparations give little relief. Tetrachlorethane is a good fumigant, but is too costly for trade growers.

Cyaniding is the best method of treatment. The dose of sodium cyanide varies from one-quarter to one-tenth ounce per thousand cubic feet of greenhouse space, according to the type of greenhouse and the condition of the plants. Long fumigations with these small doses are more effective than short fumigations with larger quantities.

The precautions necessary to avoid damage to the plants are given, avoiding daylight during fumigation and having the roots of the plants dry being the most important.

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EXPLANATION OF PLATES I AND II.

PLATE I.

Fig. 1. Underside of leaf of zonal geranium showing circles of eggs of *A. vaporariorum.*

Fig. 2. *A. sonchi* Kotinsky, on *Sonchus oleraceus* in a Lea Valley tomato house.

Fig. 3. Three tomato plants cyanided side by side and photographed a fortnight after the fumigation. The hard plant was not damaged while the two soft plants show a severe scorch and crinkle of the foliage, the damaged leaves continuing to function partially. The plants are growing away from the damage.

PLATE II.

Two tomato plants photographed immediately before (Figs. 4 and 6) and a week after (Figs. 5 and 7) cyaniding together, ¼ oz. cyanide per 1000 c.ft., duration 9 hours, temperature 60–54° F., relative humidity 97 per cent. Fig. 4 represents a plant well watered and turgid, and the severe damage it received from the gas is shown in Fig. 5. Fig. 6 represents a plant which was not flaccid but required water, and Fig. 7 shows that it was undamaged.

(*Received July 27th*, 1921.)

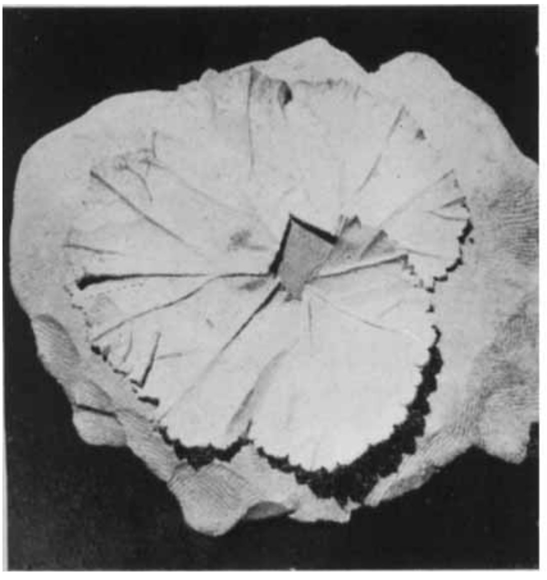

Fig. 1.

Fig. 2.

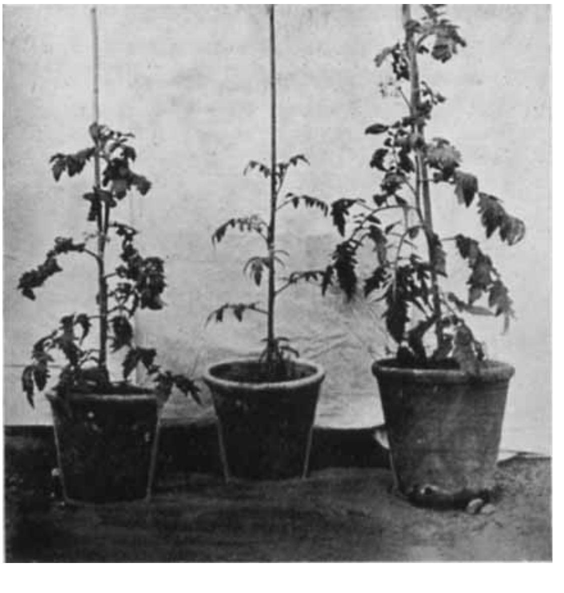

Fig. 3.

Fig. 4.

Fig. 6.

Fig. 5.

Fig. 7.