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## Studies on the Rush Saw-Fly, *Tomostethus juncivorus* Rohwer.

By

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### I. Introduction.

The rush saw-fly which is one of the injurious insects of economic importance for the cultivation of the rush, *Juncus effusus* L. *var. decipiens* BUCH., in Japan is considered in the present report.

The larva of this insect is known as "*i-no-hōjō*" or "*i-no-aomushi.*" The species found in Okayama Prefecture is a new species according to S. A. ROHWER[1] of the United States National Museum and recently he described the species as *Tomostethus juncivorus.*

There is another saw-fly which is injurious to the cultivated rush in Hyogo Prefecture. This species resembles *Tomostethus juncivorus* ROHWER closely, and it made the author think that it might be the same species as the rush saw-fly.

A third species of saw-fly, the larva of which is known as "*hojo*" in Fukuoka Prefecture, injures the cultivated rush. Although the name given to the larva is similar to that of *Tomostethus juncivorus* in Okayama Prefec-

1) S. A. ROHWER, Jour. Washington Academ. Scien., Vol. 14, (1924), pp. 150—214.

ture, it is a quite different species.

The rush saw-fly, *Tomostethus juncivorus*, more or less appears every year in Okayama Prefecture. Occasionally it appears so abundantly that it causes a great damage on the cultivated rush. The rush plants in the nursery are especially liable to be attacked by this insect, and often seen turning white and dry as a result of the attack.

A characteristic of the injury brought about by this insect is its abundant occurrence in scattered and limited areas. In other words, it does not appear uniformly and abundantly over a great rush field.

*Tomostethus juncivorus* has been found in no other country but Japan up to the present time. Although the distribution in Japan has not been definitely ascertained yet, it is likely to be found in the following Prefectures besides Okayama: Hyōgo,[1] Hiroshima, Shimane and Fukushima.[2]

Although *Tomostethus juncivorus* is an important injurious insect for the cultivation of the rush, the knowledge on its bionomics and its control is still meager. The author, therefore, undertook the study of this insect several years ago, and published a preliminary report in 1920.[3] The study was taken up again in 1923. The present paper contains all the results that the author has obtained thus far.

## II. Description.

### i) *Adult.*

A technical description of *Tomostethus juncivorus* ROHW. has been published by S. A. ROHWER in the Journal of the Washington Academy of Sciences, so that the author does not wish to repeat it here. However, he wishes to add a few remarks in regard to the coloration of the adult.

There are two broods of this insect in a year in Okayama Prefecture. The female of the second generation (autumn generation) somewhat differs in coloration from that of the first generation (spring generation).

In the spring form the thorax is black on all sides while in the autumn form all the upper surface is dark yellowish red. However, some of the females which appear in the autumn are not colored as above. Intermediate forms between the spring and the autumn form, in which the middle triangular area of the mesonotum and sometimes some parts of the metanotum are black, appear in the spring as well as in the autumn generation.

There is apparently no difference of character between the males of the first and the second generation.

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1) 渡邊清, 藺葉蜂驅除法. 明治三十六年七月.

2) 小貫信太郎, 藺葉蜂驅除試驗. 農商務省農事試驗場報告, 第三十號, 明治三十七年三月, 67--70頁.

3) 春川忠吉, 藺ノ葉蜂ニ就イテ (豫報). 病虫害雜誌, 第七卷, 大正九年, 4—15頁.

ii) *Egg.*

The egg is whitish and translucent. It is almost spindle-shaped, slightly curving to one side, and somewhat thickened towards one end. It measures about 350—385 $\mu$ in width and 758—844 $\mu$ in length.

The mature and the immature eggs in the ovary can be distinguished by dissecting the female under a dissecting microscope. The former are always spindle-shaped while the latter are almost ellipsoid even when they are fairly developed.

iii) *Larva.*

The full-grown larva is green; its head is pale yellowish brown; its body segments consist of several annulets; and its thoracic segment bears a pair of thoracic legs, and the second to eighth and the tenth abdominal segment bear a pair of prolegs.

The larva becomes pale bluish green after the last moulting. The body measures about 15 to 21 mm. in length.

iv) *Pupa and Cocoon.*

The cocoon is made by combining soil particles together, sometimes small plant debris are also mixed with them. The inside of this earthen, elliptical cell is lined with a brown secretion. The cocoon measures about nine mm. in length and five mm. in width.

The pupa is a *pupa libera* which is usual in Hymenoptera. Its head and thorax are black; its antennae, its wing-sheaths and its palpi are pale grayish green; and its abdomen and its legs are green.

When the time of emergence of adult approaches, the pupa changes in coloration. The head and the thorax are black; the legs and the abdomen are yellow; and the wing-sheaths are grayish. In the male pupa the tip of the abdomen is also black.

The pupa measures about six mm. in length.

## III. Seasonal History and Biological Notes.

i) *Field Observations.*

The adult begins to appear toward the end of April or the beginning of May, and the number of emerging adults increases up to about the middle or the twentieth of May. Then, it decreases gradually, and the emergence ends usually by the tenth of June.

The larvae of the first generation pass the summer in a dormant state, and their adult insects begin to emerge usually by the middle of September. The emergence continues till about the tenth of October. The time of maximum emergence comes usually about the twenty-fifth of September.

The approximate dates of the beginning, the maximum and the end of emergence of adults are shown below in tabular form according to the observations in the field.

Table I.

**Time of Emergence of Adults in the Field.**

| | | 1919 | 1920 | 1923 | 1924 |
|---|---|---|---|---|---|
| Spring Generation | Beginning | — | May 5 | April 29 | May 7 |
| | Maximum | May 15 | „ 15 | May 14 | „ 21 |
| | End | „ 31 | June 8 | „ 20 | June 10 |
| Autumn Generation | Beginning | Sept. 15 | Sept. 13 | — | Sept. 18 |
| | Maximum | „ 25 | — | — | „ 24 |
| | End | Oct. 10 | — | — | Oct. 10 |

The results of observations regarding the time of appearance of larvae are shown in Table II.

Table II.

**Time of Appearance of Larvae in the Field.**

| | | 1919 | 1923 | 1924 |
|---|---|---|---|---|
| Spring | Beginning | May 15 | June 1 | June 4 |
| | Maximum | June 10 | „ 10 | „ 20 |
| | End | July 10 | July 7 | July 16 |
| Autumn | Beginning | Sept. 25 | Oct. 10 | Oct. 10 |
| | Maximum | Oct. 20 | Nov. 10 | Nov. 5 |
| | End | Dec. 5 | Dec. 10 | Dec. 15 |

Usually the appearance of the adult in the spring ends about the tenth of June and all the larvae of the first generation go into the soil by the fifteenth of July as will be apparent from the data in Tables I and II. In 1919, however, the author observed in the field as late as July tenth a few adult flies and small larvae which seemed to have just hatched. This seems to be an exceptional case because the author has never seen adults so late in the season except in that year.

ii) *Emergence of the Reared Adults in the Spring.*

The author reared a good many larvae of the second generation in 1918 in an outdoor breeding cage and let these larvae overwinter in it.

The adults of these larvae began to appear on May fourth in 1919 and the emergence ended on May twenty-third. The record on emergence is shown in Table III.

Table III.

**Emergence Record.**

| Date | Number of Males | Number of Females | Sum of males and Females |
|---|---|---|---|
| May 4 | 4 | 0 | 4 |
| 5 | 1 | 0 | 1 |
| 6 | 1 | 3 | 4 |
| 7 | 0 | 3 | 3 |
| 8 | 4 | 0 | 4 |
| 9 | 12 | 6 | 18 |
| 10 | 10 | 5 | 15 |
| 11 | 20 | 9 | 29 |
| 12—13 | 5 | 1 | 6 |
| 14 | 22 | 12 | 34 |
| 15 | 0 | 1 | 1 |
| 16 | 0 | 0 | 0 |
| 17 | 13 | 5 | 18 |
| 18 | 6 | 19 | 25 |
| 19 | 0 | 5 | 5 |
| 20 | 0 | 5 | 5 |
| 21 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 |
| 23 | 1 | 2 | 3 |
| Total Number | 99 | 76 | 175 |

The results in the table above seem to indicate that the emergence of the male precedes that of the female, and that the males somewhat outnumber the females. The latter fact suggests that parthenogenetic reproduction is not a rare occurrence in this saw-fly.

Parthenogenesis will be considered in a later chapter.

iii) *Results of Rearing in the Insectary.*

The larvae were reared in a Petri-dish or with the rush-plant grown in a pot. The record of each individual was taken separately. The records of rearing are shown in Table IV.

Table IV.

**Records of Rearing, (1).**

| Rearing No. | Oviposition | Hatching | Cocooning | Emergence | Remark |
|---|---|---|---|---|---|
| | | | First Generation | | |
| 1 | — | — | June 17 | Sept. 25 | Rearing begun with collected larvae in 1923. |
| 2 | — | — | „ 18 | „ 24 | Ditto. |
| 3 | — | — | „ 20 | „ 26 | Ditto. |
| 4 | — | — | „ 20 | „ 24 | Ditto. |
| 5 | — | — | „ 15 | „ 24 | Ditto. |
| 6 | May 10 | May 25 | — | — | 1924. Larva died. |
| 7 | „ 10 | „ 27 | — | — | Ditto. |
| 8 | „ 10 | „ 24 | — | — | Ditto. |
| 9 | „ 10 | „ 26 | July 9 | — | 1924. Died in pupal stage. |
| 10 | June 6 | June 16 | „ 19 | — | Ditto. |
| 11 | „ 6 | „ 16 | „ 20 | — | Ditto. |
| 12 | „ 6 | „ 16 | „ 20 | — | Ditto. |
| | | | Second Generation | | |
| 1 | Sept. 27 | Oct. 8 | Nov. 20 | — | 1923. Hibernation. |
| 2 | „ 27 | „ 9 | „ 20 | — | Ditto. |
| 3 | „ 27 | „ 9 | „ 17 | — | Ditto. |
| 4 | „ 27 | „ 8 | „ 20 | — | Ditto. |
| 5 | „ 27 | „ 9 | „ 12 | — | Ditto. |
| 6 | „ 27 | „ 10 | „ 18 | — | Ditto. |
| 7 | „ 27 | „ 8 | „ 12 | — | Ditto. |
| 8 | „ 27 | „ 8 | „ 27 | — | Ditto. |
| 9 | „ 27 | „ 10 | „ 16 | — | Ditto. |
| 10 | „ 24 | „ 6 | Dec. 6 | — | 1924. Hibernation. |
| 11 | „ 24 | „ 6 | Nov. 22 | — | Ditto. |
| 12 | „ 24 | „ 6 | „ 16 | — | Ditto. |
| 13 | „ 24 | „ 6 | „ 25 | — | Ditto. |
| 14 | „ 26 | „ 7 | „ 18 | — | Ditto. |
| 15 | „ 26 | „ 7 | „ 15 | — | Ditto. |

The author reared several times many larvae together in a breeding cage in additions to the rearing experiments which are mentioned above. One of the records of such rearing experiments are shown in Table V.

Table V.

**Records of Rearing, (2).**

| | First Generation | Second Generation | Remark |
|---|---|---|---|
| Oviposition began | — | Sept. 30 | Rearing in 1923. |
| Hatching began | — | Oct. 18 | Ditto. |
| Cocooning began | June 13 | Nov. 9 | Ditto. |
| „ ended | „ 26 | „ 29 | Ditto. |
| Emergence began | Sept. 23 | — | Hibernation. |
| „ ended | Oct. 2 | — | Ditto. |

### iv) *Number of Broods in a Year.*

The results of the rearing experiments in the preceding chapter are substantially the same as those of the field observations which have been stated previously. The full-grown larvae of the first generation make cocoon about the middle of June, pass the warmest part of summer in the cocoon, and emerge as adults about September twenty-fifth. Consequently there are only two generations in a year in spite of the fact that there is sufficient time to complete one generation between the spring and the autumn brood. In none of the rearing experiments with the rush saw-fly, the author succeeded to make the adult emerge in the period between the end of June and the beginning of September.

The author has pointed out in a previous chapter that he saw a few adults about the tenth of July. The author believes, however, from the results of rearing experiments that the emergence of adults at this time is an exceptional phenomenon at least in the vicinity of Kurashiki.

It is interesting to note, in connection with above statement, that there seems to be three generations a year in Hyogo Prefecture where seemingly the same species of the rush saw-fly is found. In other words the appearance of the summer generation is not rare in Hyōgo Prefecture, although it is highly doubtful if all the larvae of the first generation appear as adults in the summer.

### v) *Longevity of Adults.*

The records of observations made on the longevity of the adult are shown in Table VI.

Table VI.

**Longevity of Adults.**

| Individual No. | Date of Emergence | Date of Death | Longevity in Days | Remark |
|---|---|---|---|---|
| | | Spring Brood. | | |
| 1 | May 5 | May 14 | 9 | ♂ |
| 2 | „ 6 | „ 13 | 7 | ♀ |
| 3 | „ 6 | „ 11 | 5 | ♂ |
| 4 | „ 6 | „ 10 | 4 | ♀ |
| 5 | „ 10 | „ 14 | 4 | ♀ |
| 6 | „ 10 | „ 14 | 4 | ♀ |
| 7 | „ 10 | „ 14 | 4 | ♀ |
| 8 | „ 11 | „ 13 | 2 | ♂ |
| 9 | „ 11 | „ 14 | 3 | ♂ |
| 10 | „ 11 | „ 14 | 3 | ♀ |
| 11 | „ 13 | „ 18 | 5 | ♀ |
| 12 | „ 13 | „ 21 | 8 | ♂ |
| 13 | „ 13 | „ 18 | 5 | ♂ |
| 14 | „ 13 | „ 22 | 9 | ♀ |
| 15 | „ 13 | „ 21 | 8 | ♀ |
| 16 | „ 13 | „ 22 | 9 | ♂ |
| | | Autumn Brood. | | |
| 1 | Sept. 25 | Sept. 28 | 3 | ♀ |
| 2 | „ 25 | „ 28 | 3 | ♀ |
| 3 | „ 25 | „ 28 | 3 | ♀ |
| 4 | „ 25 | „ 28 | 3 | ♀ |
| 5 | „ 25 | „ 27 | 2 | ♀ |
| 6 | „ 25 | „ 30 | 5 | ♀ |
| 7 | „ 25 | „ 29 | 4 | ♀ |
| 8 | „ 26 | „ 28 | 2 | ♀ |
| 9 | „ 26 | „ 30 | 4 | ♀ |
| 10 | „ 26 | „ 29 | 3 | ♀ |

The maximum longevity of the spring brood is 9 days, and the minimum 2 days. The average longevity of the male is 5.9 days, and that of the female 5.3 days. In the autumn brood, the maximum longevity of the female is 5 days, and the minimum 2 days. The average is 3.2 days. Thus, the longevity of the autumn brood is shorter than that of the spring brood.

The adult seems to require much water during its life time, and when the adult is fed with a diluted solution of sugar or even with distilled water the longevity is considerably prolonged. The author fed the adults of the spring brood in 1919 with sugar solution, and the result was that the maximum longevity of both the male and female was 16 days, and that the average was 8.6 days for the male, and 6.4 days for the female respectively.

Another point of interest in this connection is that the longevity of the male is a little longer than that of the female.

### vi) *Habits of Adults.*

The rush saw-fly is a sluggish insect. It feigns death and falls down from the leaf on which it is resting, if it is disturbed suddenly. The saw-fly rests on the rush-plant or upon the leaves of grass in the morning and evening, and also when it is windy and rainy. On a calm and warm day it flies about lively. Usually it does not fly more than thirty or forty feet at a time. While the male sometimes keeps flying for a fairy long period, the female usually alights on the rush leaf after flying for a short time.

While the rush saw-fly feeds greedily on the sugar solution when it is in a breeding cage, the author has never seen in the field the saw-fly seeking flowers for honey.

### vii) *Oviposition.*

The female alights on the leaf of the rush, rests on it with its head downwards, thrusts its saw into the tissue and introduces one egg just below the green tissues. It lays only one egg at a time, but it may lay several eggs at different spots of a leaf.

Usually neither very young and soft leaves nor very old and hard ones are chosen for oviposition. In regard to the position on the leaf, the female does not seem to have any choice. However, the basal part is not employed.

Time of oviposition is usually warmer part of the day. The female does not oviposit either very early in the morning or late in the evening. A calm and warm day is especially suitable for oviposition.

As the larva usually makes cocoon on the "boundary"[1] of a rush field, the ermerging saw-flies are especially numerous near the margin of the field and the female usually does not fly far to distribute its eggs over a great area. Consequently it is often seen that the injury upon rush plants is es-

1) A "boundary" (= *aze*, in Japanese) is a small ridge of soil enclosing an irrigated field, for example, a rice-field.

It serves to keep water in the field, and at the same time to separate one plot from another.

pecially severe in a rather limited area near the margin of the field.

The rush saw-fly begins oviposition shortly after the emergence. Therefore, it must be sexually mature when it appears. In other words, there is no pre-oviposition period in this insect. This is apparent from the records of observations shown in Table VII.

Table VII.

**Records of Observations on the Time when Oviposition begins.**

| Female No. | Date of Emergence | Date when Oviposition began | Female No. | Date of Emergence | Date when Oviposition began |
|---|---|---|---|---|---|
| 1 | May 5 | May 5 | 6 | May 11 | May 11 |
| 2 | " 6 | " 6 | 7 | " 15 | " 15 |
| 3 | " 10 | " 10 | 8 | " 15 | " 15 |
| 4 | " 11 | " 11 | 9 | " 10 | " 10 |
| 5 | " 11 | " 11 | | | |

viii) *Fecundity.*

a) *Number of Mature Eggs in the Ovary.*

Since the rush saw-fly is sexually mature when it appears from the cocoon, there must be some mature eggs in the ovary when the adult emerges. It was found that the mature and immature eggs in the ovary can be easily distinguished under a dissecting microscope.

While the mature eggs are almost spindle-shaped being slightly thicker towards one end, whitish and translucent, the immature ones are ellipsoid, white and opaque. Moreover, the latter are sometimes accompanied by a mass of nutritive cells.

The number of mature eggs in the body of dissected females were counted, and the results of observations are shown in Table VIII.

Table VIII.

**Number of Mature Eggs in the Body of the Female.**

| Individual No. | Number of Mature Eggs | Individual No. | Number of Mature Eggs | Individual No. | Number of Mature Eggs |
|---|---|---|---|---|---|
| 1 | 106 | 5 | 134 | 9 | 149 |
| 2 | 104 | 6 | 103 | 10 | 108 |
| 3 | 101 | 7 | 102 | 11 | 124 |
| 4 | 112 | 8 | 127 | 12 | 113 |

Average Number of Mature Eggs per Female .......................................... 115.2

The average number of mature eggs in the body of the female is 115.2.

b) *Number of Eggs laid by a Female.*

The rush saw-fly does not lay eggs freely under confinement. Usually it does not lay all the mature eggs that are found in the ovary even when it is in a large outdoor breeding cage. The author, therefore, let the female oviposit in a cage, and dissected it after death to count the number of mature eggs still left in the ovary. The records of these experiments are shown in Table IX.

Table IX.

**Number of Eggs laid by a Female and that of Eggs left in the Ovary after Death.**

| Female No. | Number of Eggs laid | Number of Eggs still left in Ovary | Total Number of Mature Eggs | Female No. | Number of Eggs laid | Number of Eggs still left in Ovary | Total Number of Mature Eggs |
|---|---|---|---|---|---|---|---|
| 1 | 56 | — | — | 7 | 47 | 79 | 126 |
| 2 | 57 | — | — | 8 | 77 | 24 | 101 |
| 3 | 68 | — | — | 9 | 18 | 80 | 98 |
| 4 | 92 | 0 | 92 | 10 | 53 | 64 | 117 |
| 5 | 112 | 0 | 112 | 11 | 89 | 18 | 107 |
| 6 | 75 | 39 | 114 | 12 | 107 | 0 | 107 |

Average Number of Mature Eggs per Female.............................................108·2

While some of the females used for the experiments laid all the mature eggs, the others laid only a portion of the eggs that they had in their ovaries. By comparing the results in Table VIII and IX, it will be found that the average number of the mature eggs in the ovary agrees fairly well with the average of the sum of the eggs actually laid and the mature eggs still left in the body when the adult dies. This fact proves that the number of the mature eggs in the ovary shows the fecundity of this saw-fly when the adult emerges from the cocoon. Therefore, the author thinks it is certain that the rush saw-fly lays about one hundred eggs under the conditions in the field.

ix) *Parthenogenesis and Sex.*

The unfertilized egg of the rush saw-fly is able to develop as in some other saw-flies. The adults which originate from the unfertilized eggs seem to be always male.

In 1919 and 1920 the author bred larvae which originated from the unfertilized eggs, to see the sex of the adults ermerging from the pupae. Thirty-one adults emerged in 1920, and all of them were male.

Although the number of adults obtained in this experiment was limited' it seems fairly certain that only male saw-flies develop from the unfertilized eggs.

Parthenogenetic reproduction seems sometimes to occur even under outdoor conditions, for the author has observed that the males were slightly more numerous than the females when adults were reared from the larvae collected in the field.[1]

### x) *Egg Period.*

Table X.

**Egg Period.**

| First Generation | | Second Generation | |
|---|---|---|---|
| Period in Days | Number of Eggs | Period in Days | Number of Eggs |
| 10 | 1 | — | — |
| 14 | 4 | 11 | 6 |
| 15 | 4 | 12 | 7 |
| 16 | 1 | 13 | 2 |
| 17 | 3 | — | — |
| Average Egg Period | 14.8 days. | Average Egg Period | 11.7 days. |

The eggs of the first generation in 1924 began to hatch on May tenth, and the hatching was over on May twenty-seventh. The maximum length of the egg period was 17 days, the minimum 10 days, and the average 14.8 days.

The egg period of the second generation extended from September twenty-fourth to October tenth. The maximum incubation period was 13 days, the minimum 11 days, and the average 11.7 days.

Thus, the egg period is about ten to fifteen days according to the time when it is laid.

### xi) *Larval Period.*

The growing period of the larva of the first generation was from 25 to 44 days, and the average was about 36 days. The growing period of the second generation varies considerably. The maximum period observed was 61 days, and the minimum 35 days. According to the results of observations recorded in Table XI the average growing period of the second brood is about 43 days.

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1) See the records in Table III!

Table XI.

**Growing Period of Larva.**

| Growing Period in Days | Number of Larvae | Growing Period in Days | Number of Larvae | Remark |
|---|---|---|---|---|
| 35 | 3 | 44 | 2 | Observations on the second generation. |
| 39 | 7 | 45 | 3 | |
| 40 | 4 | 46 | 2 | |
| 41 | 12 | 47 | 2 | |
| 42 | 8 | 48 | 4 | |
| 43 | 18 | 50 | 1 | |

Average growing period..............43.8 days.

The length of larval period recorded here does not include the time from cocooning to the pupation of the larva. The true larval period including this time is markedly longer than the period which are recorded above, since the larva of the first generation has estivation and that of the second brood has hibernation.

xii) *Number of Moults.*

The larva of the rush saw-fly moults four times, i. e., it has five instars. The growing period consists of the first four stadia. The larva is full-grown after the fourth moulting, and goes into the soil shortly after that.

xiii) *Habits of the Larva*

The larva feeds on the green tissues from the inside of the leaf without injuring the epidermis and makes a mine in the leaf for a short period after it hatches from the egg. This mine is seen from the outside as an irregular white patch.

The length of the time of mining is from five to sixteen days according to the observations on the second generation in 1919. Majority of the larvae stay in the mine for about twelve days.

The larva usually stays in the mine till the end of the third stage, according to the determination of the stadium made by measuring the size of the head. However, some of the larvae of the fourth instar may be found in the mine, while some of the second instar larvae may leave the mine and begin feeding on the green tissues from the outside.

The larva which has left the mine feeds on the green tissues from the outside, and the white pith is not injured. Therefore, the rush-field where a great many rush saw-fly larvae are feeding can be easily recognized even from a distance.

The larva falls down coiling its body when it is disturbed. Since the larva is very slow in movement, it can be easily caught with the hand.

During the day most of the larvae rest near the base of the plant in June and July, migrate in the evening towards the upper part of the leaf, and stay there feeding until the next morning. The migration is reversed in October and November, i. e., most larvae rest near the base of the plant at night and crawl up the leaf in the day-time.

### xiv) *Food Plant.*

The only plant that has been observed as the food plant of the rush saw-fly is the cultivated common rush, *Juncus effusus* L. *var. decipiens* BUCH.

### xv) *Pupation.*

The larva crawls out of the rush-field shortly after the last moulting, to make cocoon in the soil under the weeds on the boundary of the field or on the bank which adjoins to the field.

It seems to be extremely rare that the larva makes cocoon in the wet soil of the rush-field. The reason seems to be that the larva prefers for pupation a rather dry and light soil to a wet and heavy one.

In 1923 the author conducted the following experiment to see the effect of water content of soils upon the selection by larvae of soils for pupation: a large circular earthen basin was divided into three sections, and three kinds of soils, viz., fairly dry, medium-wet and very wet soil, were put into different sections and the same number of full-grown larvae were introduced in each section. Twenty-six larvae in all made cocoons successfully, and the distribution was as follows:—

| | |
|---|---|
| Wet soil section | 2 |
| Medium-wet soil | 2 |
| Dry soil | 21 |

This result shows clearly that the larva prefers a rather dry soil for pupation.

Sometimes the upper half of the cocoon may protrude over the soil surface, if the soil is very hard. Usually the cocoon is made under the soil surface.

Also in 1923 the author conducted another experiment to see the position of cocoon in the soil. Of fourteen cocoons that were made by the larvae employed in the experiment, seven were found between the soil surface and 1.5 cm. depth, six in the second layer 1.5 to 3.3 cm. below the surface, and only one in the third layer 5 to 7 cm. below the surface.

It is apparent from these results that this insect does not go very deep into the soil for pupating.

Judging from the habit in cocooning the overwintering larvae would not be very resistant to adverse climatic conditions. This is probably one of the reasons that the larva prefers for pupation the grass-covered boundary or bank enclosing the rush-field.

### xvi) *Estivation and Hibernation.*

The rush saw-fly larvae pass the warmest part of summer in a dormant state, viz., there is a period of estivation in the life-history of this insect in Okayama Prefecture. The estivation lasts for about ninty days, from about June twentieth to September twentieth. The results of observations on the first generation in the insectary are shown in Table XII.

Table XII.

**Duration of Estivation.**

| Duration in Days | Number of Individuals | Duration in Days | Number of Individuals |
|---|---|---|---|
| 96 | 1 | 100 | 1 |
| 98 | 2 | 101 | 1 |

Average duration..............................................98.6 days.

The cocooning period of the first generation larvae is very long as a result of intervention of estivation. Pupation occurs near the beginning of September, and the adult begins to emerge about the middle of the same month.

The larvae of the autumn brood hibernate in the larval state in the cocoon, and the transformation into pupae occurs in the next spring.

## IV. Spread of the Rush Saw-Fly.

It is probably rare that this insect spreads to a new rush-field by means of the larva, because rush-fields are small in area compared with the rice-field, and situated here and there among rice-fields.

The adults of the first generation appear very rarely in July in Okayama Prefecture, as this has been stated in a previous chapter. Even if they would appear in July, it would be difficult for them to produce the summer brood successfully, since the rush plants in the field are harvested usually about the twentieth of July. A part of the adults would be obliged to seek rush plants in the nursery or the volunteer shoots of rush growing in the field. However, only a small portion of the larvae that hatch from the eggs laid by these adults would be able to reach maturity on account of the scarcity of the volunteer shoots in the field.

Consequently the chief sources of the appearance of the pest in the next year must be the insects appearing in the rush nursery in the autumn.

There are two possibilities for the infestation of a new field; i. e., first, infestation by means of the adult, and second, by means of the cocoon.

Therefore, the author conducted an experiment with the adult in the spring of 1920 to learn how far the adult flies. The method of experiment was to release saw-flies after cutting off the distal portion of a limb in the rice-field, where the rush is grown in its neighbourhood, and then to collect saw-flies a few days afterwards to see if the mutilated saw-flies can be recaptured in the rush-fields situated near by.

On May nineteenth 250 mutilated saw-flies were released. It was a fine day with a breeze blowing from south-west by west. Collection of saw-flies were made on May twenty-second. No mutilated adults were captured at the place where they were released. There was a rush-nursery about 240 feet to the north, where two mutilated adults were captured. All of them were males. Fourteen mutilated adults were captured in a nursery about 240 feet apart to north-east by north; again, these were all males. These two fields were situated leeward to the point where the mutilated adults were released. No mutilated adult was restored in any other rush-fields.

It is apparent from this result that the males are more active than the females and apt to be carried away by the wind; and that the females do not fly more than about 240 feet unless they are carried by a strong wind. This result corroborates the statement already made that the female saw-flies do not fly to a great distance to oviposit. However, the infestation of a rush-field which is fairly far and situated leeward to the place of appearance, may occur by means of adults when a strong wind is blowing.

The larvae of the rush saw-fly may pupate in the soil near the root of the rush-plants when the rush nursery is dry, i. e., not irrigated. In this case the cocoon may happen to be carried to a new field when transplanting occurs; and the new field may be infested.

## V. Resistance of Larva to Adverse Soil Conditions.

In connection with the habit of pupation the author wished to know how resistant the overwintering larvae are to the adverse soil conditions.

For this purpose an experiment was carried out in the winter of 1919 to see the effect of freezing and thawing, and also of extreme dampness of soil on the overwintering larvae in cocoon.

Four earthen unglazed pots were filled with soil, and one hundred full-grown larvae were introduced in each pot. Two of these pots were placed on the south side of the insectary, and the other two were placed on the north side where very little sun's rays reached the pots during the winter. All of the four pots were placed in the holes made in the ground with their brims about two inches above the ground. One of the two pots on the south side was covered with a straw mat and kept fairly dry during the winter and the other was sprinkled with water every two or three days to keep the soil in pot moderately wet. One of the two on the north side was also kept fairly dry, and the other was kept so damp that the soil surface was always barely covered with water.

These pots were placed in the breeding cages near the end of April in the next spring and the appearing adults were recorded. The results were as follows:

Table XIII.
**Resistance of Overwintering Larvae.**

| Position | South Side | | North Side | |
|---|---|---|---|---|
| Soil Condition | Dry | Medium-wet | Dry | Water-covered |
| Number of Larvae introduced | 100 | 100 | 100 | 100 |
| Number of Adults emerged | 81 | 24 | 94 | 0 |

No adults appeared from the water-covered pot, i. e., all the larvae introduced were dead. It is evident from this experiment that dampness of soil accompanied by freezing and thawing is detrimental to the overwintering larva. Few larvae are able to overwinter successfully, judging from the results of this experiment, if they make cocoons in a damp rush-field and are subjected to freezing and thawing during the winter.

## VI. Environment Favourable for the Occurrence of the Rush Saw-Fly.

The injury by the larvae of rush saw-fly is severe usually in a rush-field which is adjacent to a hill, a grass-covered dike or to a farm-house.

The saw-fly is especially common in a dry (i. e., not irrigated) rush nursery. Even in this case the appearance is generally more abundant in a nursery which is situated near a hill or a grass-covered dike than in the other locality.

The occurrence of this insect is rather rare in a rush-field which is situated amid rice-fields and very far apart from the hill or the dike according to the observations made in the vicinity of Kurashiki. Since in such a field the soil is usually damp and the boundary of the field is not rich in weeds, the larvae would not be able to find a safe place for overwintering. Consequently they would not be able to appear many years in such a field.

## VII. Control Measures.

### i) *Experiments to kill the Larva.*

Various substances were already tested by certain entomologists[1] to kill the larva of the rush saw-fly. Among the substances tested the following were reported to be fairly effective: mixture of pyrethrum and ash, mixture of pyrethrum and slaked lime, emulsion of kerosene extract of pyrethrum.

The author tested the following substances to determine the strength required to kill the rush saw-fly larva:—pyrethrum powder, wood ash, quicklime, tobacco dust, soap, kerosene, kerosene emulsion, emulsion of kerosene extract of pyrethrum, arsenate of lead, "tuba-" fluid and "Black Leaf 40" (nicotine sulphate).

The results of the experiment will be stated below:

(1) *Pyrethrum Powder.*

This substance was tested both in the pure state and in combination with wood ash. Pure pyrethrum powder is a very effective substance and kills the larva in a short time.

The mixture of pyrethrum and wood ash is also very effective against the larva of the saw-fly. The mixture was made in the following way: weighed amounts of the two substances were put into a mortar and mixed thoroughly by grinding. This mixture was dusted on the larva. The results of the experiments are shown in the following table:

Table XIV.

**Mixture of Pyrethrum and Wood Ash.**

| Proportion, Pyrethrum: Ash | Number of Larvae used | Number of Larvae killed | Percentage of Larvae killed | Proportion, Pyrethrum: Ash | Number of Larvae used | Number of Larvae killed | Percentage of Larvae killed |
|---|---|---|---|---|---|---|---|
| 1 : 20 | 30 | 30 | 100 | 1 : 90 | 15 | 15 | 100 |
| 1 : 50 | 30 | 30 | 100 | 1 : 100 | 30 | 30 | 100 |
| 1 : 60 | 30 | 30 | 100 | 1 : 100 | 30 | 30 | 100 |
| 1 : 70 | 15 | 15 | 100 | 1 : 150 | 30 | 30 | 100 |
| 1 : 80 | 15 | 15 | 100 | 1 : 200 | 30 | 29 | 96.6 |

This result shows that the mixture is a very effective larvicide, if the two materials are fine and mixed thoroughly.

1) 渡邊淸, 藺葉蜂驅除法.
小貫信太郎, 農商務省農事試驗場報告, 第三十號.
岡山縣立農事試驗場, 明治四十一年度業務功程.

(2) *Wood Ash.*

Wood ash, when used alone, is not effective against the larvae of this saw-fly.

(3) *Quick Lime.*

Although quick lime and slaked lime have been recommended as remedies for the larva of this insect, the results of the tests made by the author does not warrant this recommendation.

(4) *Tobacco Dust.*

Tobacco dust is fairly effective when used alone and in combination with wood ash as well. The strength to be used when the tobacco dust is used in combination with ash has been studied. The results of experiments are shown in Table XV.

Table XV.

**Tobacco Dust.**

| Proportion, Tobacco: Wood Ash | Number of Larvae employed | Number of Larvae killed | Percentage of Larvae killed | Proportion, Tobacco: Wood Ash | Number of Larvae employed | Number of Larvae killed | Percentage of Larvae killed |
|---|---|---|---|---|---|---|---|
| Tobacco alone | 20 | 20 | 100 | 1 : 14 | 20 | 20 | 100 |
| Tobacco alone | 20 | 15 | 75 | 1 : 19 | 20 | 20 | 100 |
| 1 : 4 | 20 | 17 | 85 | 1 : 25 | 15 | 12 | 80 |
| 1 : 9 | 20 | 15 | 75 | 1 : 25 | 15 | 12 | 80 |

It is seen from the results in the table above that tobacco is a good larvicide for this insect although it is less effective than pyrethrum. One part of tobacco mixed with twenty parts (in weight) of wood ash may kill over ninty per cent, if dusting is thoroughly done.

Tobacco extract in hot water was used in some experiments the results of which are not shown in the above table. It was found that tobacco is more effective when used in pure state as dust than when it is used as water extract.

(5) *Soap Water.*

Marseilles soap was tested at various strengths. The efficiency of the soap solution seemed to depend largely upon the thoroughness of spraying. When twenty to thirty grams of soap were dissolved in one litre of water, and a thorough drenching spraying was done, about eighty per cent were killed.

(6) *Kerosene.*

A small quantity of kerosene was dropped on the water surface, and when it spread over the surface, larvae were gently suspended on the water surface. The oil will wet the larvae in this way. This experiment was conducted to see whether it is possible to kill the saw-fly larva by oiling the water in the rush-field or not. The results of experiments are shown in Table XVI.

Table XVI.

**Kerosene.**

| Larvae were placed on the Water Surface, | Amount of Oil per *tan*[1] | Length of Time on the Water Surface | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5 Minutes | | | 10 Minutes | | |
| | | Number of Larvae used | Number of Larvae killed | Per cent killed | Number of Larvae used | Number of Larvae killed | Per cent killed |
| Directly after Oiling | 3 *shō*[2] | 14 | 9 | 64.2 | 15 | 8 | 53.3 |
| | 3 " | 20 | 11 | 55 | 20 | 10 | 50 |
| | 3 " | 18 | 14 | 77.7 | 15 | 11 | 73.3 |
| 30 Minutes after Oiling | 3 " | 18 | 0 | 0 | 20 | 6 | 30 |
| | 3 " | 10 | 0 | 0 | — | — | — |
| 1 Hour after Oiling | 3 " | 19 | 0 | 0 | 20 | 0 | 0 |
| | 3 " | 10 | 0 | 0 | — | — | — |

In would be difficult to kill the larva by oiling the water and making the larva fall on the water surface, because the larva would not be swimming on the water surface more than several minutes under the conditions in the rush-field.

An interesting point which the results in Table XVI suggest is that the toxicity of kerosene seems to decrease after standing more than thirty minutes on the water surface as a thin film. However, the number of tests was limited so that this point needs further study.

(7) *Kerosene Emulsion.*

Varied results were obtained with kerosene emulsion. However it seems certain that this is not a very effective insecticide for the larva of this saw-fly. This emulsion must not be used at a weaker strength than one part of the stock solution[3] to nine parts of water.

(8) *Emulsion of Kerosene Extract of Pyrethrum.*

This emulsion has been recommend by a certain entomologist as an effective larvicide for the rush saw-fly. The results of the experiments made by the present author are shown in Table XVII. The stock solution em-

1) One *tan* = ca. 9.9 ares.

2) One *shō* = ca. 1.8 litres.

3) Formula for the stock solution: Kerosene 1.8 litres, soap 45. grams, water 0.9 litre.

ployed for the experiments was made according to the following formula:

Kerosene......... 1.8 litres, Pyrethrum ......... 45.0 grams,
Soap............... 56.0 grams, Water ............... 0.9 litre.

Table XVII.

**Emulsion of Kerosene Extract of Pyrethrum and Soap.**

| Strength, Stock Solution : Water | Number of Larvae employed | Number of Larvae died | Percentage of Larvae killed | Strength, Stock Solution : Water | Number of Larvae employed | Number of Larvae died | Percentage of Larvae killed |
|---|---|---|---|---|---|---|---|
| 1 : 19 | 30 | 29 | 96.6 | 1 : 29 | 20 | 18 | 90 |
| 1 : 19 | 30 | 27 | 90 | 1 : 29 | 30 | 29 | 96.6 |
| 1 : 19 | 30 | 30 | 100 | 1 : 29 | 30 | 30 | 100 |
| 1 : 19 | 30 | 28 | 93.3 | 1 : 29 | 30 | 29 | 96.6 |
| 1 : 19 | 30 | 30 | 100 | 1 : 29 | 30 | 30 | 100 |
| 1 : 19 | 30 | 30 | 100 | 1 : 29 | 30 | 30 | 100 |
| 1 : 19 | 30 | 27 | 90 | 1 : 34 | 25 | 1 | 4 |
| 1 : 29 | 50 | 40 | 80 | 1 : 34 | 25 | 3 | 12 |

According to the results shown above, one part of the stock solution diluted with twenty-nine parts of water kills over ninty per cent if the emulsion is sprayed thoroughly.

(9) *Arsenate of Lead.*

A commercial arsenate of lead in paste form was used at a rate of three pounds per one *koku*[1].

Hundred per cent killing was obtained, although the effect of the poison appeared rather slowly.

(10) *Tuba-Fluid.*

This whitish solution was supplied by an insecticide dealer.[2] It is made from *Derris* roots. The method of preparation is unknown to the author.

The author tried this solution against various insects. It seems to be particularly effective against the larvae of the rush saw-fly.

The results of experiments are shown in Table XVIII.

The tuba-fluid diluted with water 1000 times of its volume killed 100 per cent of the larvae, as is seen in the table. This solution is therefore a very effective larvicide against the rush saw-fly.

Parallel experiments were made with the tuba-fluid diluted with soap water, and it was found that there seems to be practically no difference in effectiveness between the solution diluted with water alone and that diluted with soap water.

1) One *koku* (石) = ca. 180 litres.
2) Supplied by NARASAKI GOMEI KAISHA (楢崎合名會社), Mihara-machi, Bingo, Japan.

Table XVIII.

**Tuba-Fluid.**

| Ratio, Stock Solution : Water | Number of Larvae employed | Number of Larvae killed | Per cent killed | Ratio, Stock Solution : Water | Number of Larvae employed | Number of Larvae killed | Per cent killed |
|---|---|---|---|---|---|---|---|
| 1 : 100 | 20 | 20 | 100 | 1 : 2000 | 20 | 18 | 90 |
| 1 : 200 | 20 | 20 | 100 | 1 : 2000 | 20 | 17 | 85 |
| 1 : 400 | 20 | 20 | 100 | 1 : 2000 | 20 | 18 | 90 |
| 1 : 800 | 20 | 20 | 100 | 1 : 3000 | 20 | 16 | 80 |
| 1 : 1000 | 20 | 20 | 100 | 1 : 3000 | 20 | 16 | 80 |
| 1 : 1000 | 20 | 20 | 100 | 1 : 3000 | 20 | 10 | 50 |
| 1 : 1000 | 20 | 20 | 100 | | | | |

(11) *Black Leaf 40 (Nicotine Sulphate.)*

"Black Leaf 40" is not very effective against this insect. When used at a dilution of one part to 800 parts of water, it killed only five per cent. It killed about 72 per cent at a dilution of one part to 200 parts of water. Therefore, a fairly strong solution must be used, if it is desired to kill 100 per cent. It is too expensive to be a practical insecticide at such a strength.

ii) *Other Methods of Control.*

(1) *Capturing the Adult Insect.*

The adult saw-fly is a sluggish insect so that it is easy to capture with a collecting net. This method can be effectively practised in the rush nursery in the spring as well as in the autumn.

(2) *Treatments of the Cocoon.*

The weeds of the boundary should be mowed, and the surface soil of the boundary should be scraped off to a depth of about one inch.

The soil thus collected should be piled in a manure-pile or buried deep in the water of the field.

When there is an abundant appearance of larvae in a rush-field, an inner boundary should be made about one foot apart from the boundary, and water should be flooded between these two boundaries.

Full-grown larvae will come to this inner boundary to pupate. Then, the inner boundary should be destroyed and the soil making it should be buried deep in the water when all the larvae of the first brood have made cocoon. This method can be practised also in the irrigated rush nursery.

(3) *Alternation of Crops.*

It is advisable not to culture the rush in the same field more than two or three years successively. The occurrence of the rush saw-fly is probably avoided by planting the rice-plant during several years in the field where, previously, the rush-plant has been cultivated for a few years successively.

The dry (i. e., not irrigated) rush nursery is especially suitable for the occurrence of the rush saw-fly. This is generally a source of infestation as it has been pointed out before. Therefore, a nursery should be made in a new place far apart from the former nursery when there is an outbreak of the saw-fly. Some other kinds of crop should be planted in the former nursery plot.

## VIII. Summary.


The results of studies on an injurious insect, known as "*i-no-hojo*," of the cultivated common rush, *Juncus effusus* L. *var. decipiens*, has been reported in the present paper.

This insect is a new species and has been named *Tomostethus juncivorus* by S. A. ROHWER. The spesies found in Okayama Prefecture appears two times in a year, having a period of estivation between the spring and the autumn brood.

The spring brood larvae appear from about the middle of May to the middle of June, and the period of autumn brood extends from about the twenty-fifth of September to December tenth.

The spread of this insect is generally not rapid, since the female insect does not fly about over a large area to oviposit.

The number of eggs that a female lays is about one hundred. The eggs are able to develop without being fertilized, and the adults derived from these unfertilized eggs are always males.

The average egg period of the first generation is about fifteen days and that of the second generation is about twelve days.

The average larval period is about thirty-six days in the first generation and that for the second generation about forty days.

The only food plant, thus far observed, is the cultivated common rush which is an important plant in Japan for the mat industry.

On maturity the larva leaves the rush-field and makes the cocoon in the soil of the boundary of the field.

The overwintering larva is rather weak in resistance to freezing in winter, and to extreme dampness of the soil. The outbreak of this insect occurs usually in such a place as to give a good protection to the overwintering larvae.

The rush-plant nursery is the chief source of infestation by this insect. Therefore, efforts should be made to exterminate this insect when it appears in the nursery.

Capture of the adults in the nursery, treatment of cocoon and alternation of crops are important measures for preventing the outbreak of this insect pest. Tuba-fluid, arsenate of lead, mixture of pyrethrum and wood ash, and the emulsion made from the kerosene extract of pyrethrum are very effective as larvicides.

**Acknowledgments.**

The author wishes to express sincerest thanks to Mr. S. A. ROHWER of the United States National Museum for determining the specimens of the rush saw-fly.

Thanks are also due to the staff of the Hyogo Agricultural Experiment Station and that of the Fukushima Agricultural Experiment Station, both of whom kindly assisted the author for obtaining the specimens of the rush saw-fly found in those prefectures.

## Explanation of Plates XXXII—XXXIII.

Plate XXXII.

Figure 1. Rush saw-flies.

" 2. Larvae and rush leaves showing the work of the larva.

Plate XXXIII.

Figure 1. Female saw-fly, (× 5.2).

" 2. Abdomen of male.

" 3. Larvae, (× 8).

" 4. A piece of the rush leaf with the mine made by a young larva.

" 5. Pupa, (× 4.5).

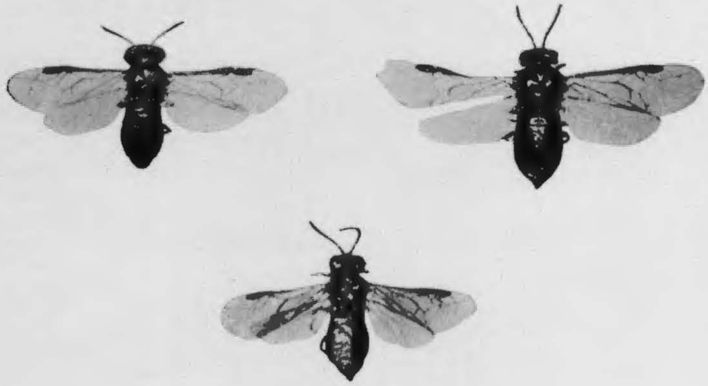
" 6. A part of an ovarian tube containing eggs (× 5.5);

*im*.........immature eggs,

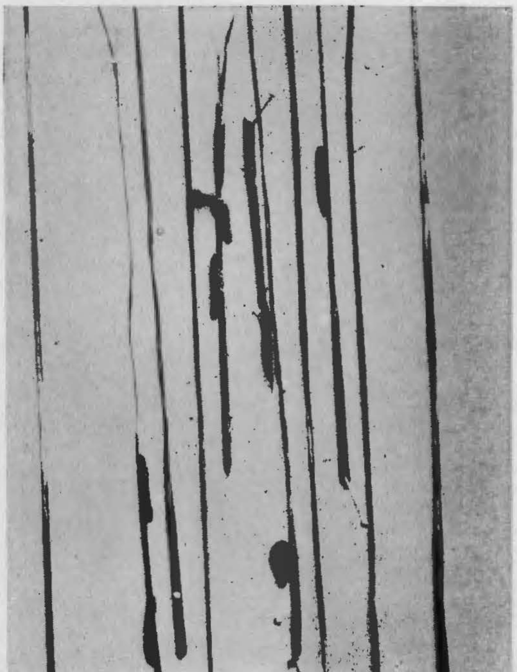
*me*.........mature eggs.

PLATE XXXII.

1.

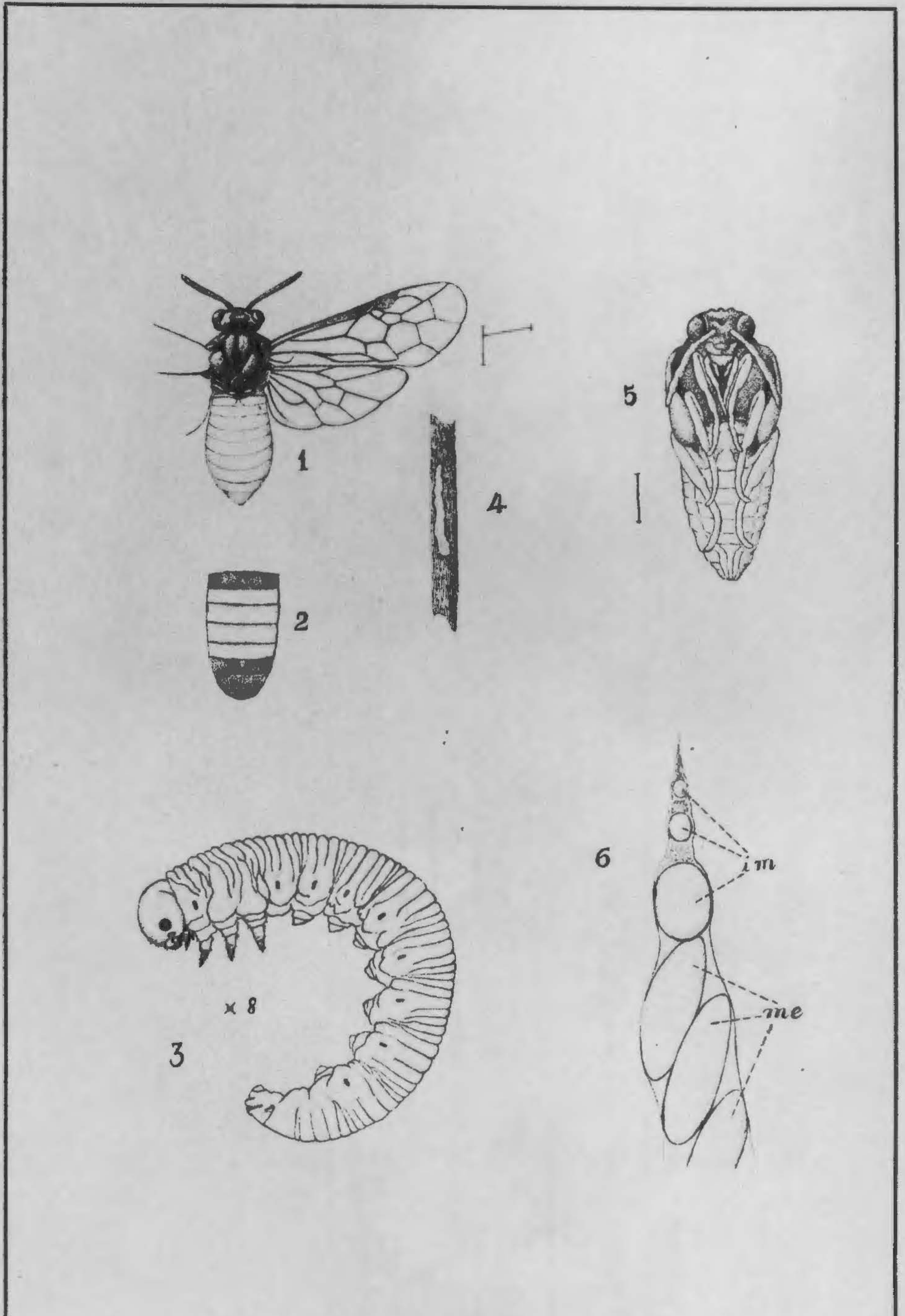


2.



C. HARUKAWA del.

PLATE XXXIII.

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