Studies on the Rice-Borer, *Chilo simplex* Butler. I.†

On the Prolonged Emergence Period of the Moth in Spring. i.

By

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Introduction.

It was nearly fifty years ago when Yoshitami Naruto began observations on the rice-borer, *Chilo simplex* Butler, and meantime our knowledge on this rice pest has been much advanced. Indeed, it may probably be said that no injurious insect either of the staple crop or of the fruits and vegetables has been so eagerly studied as the rice-borer. The writers however must state that very little as yet has been known about the physiology and ecology of this important rice pest in spite of a long period of observations and experiments devoted to the study of the rice-borer. As a matter of fact, the physiological and ecological studies on the injurious insects have been taken up in Japan only several years ago, so that the information along these lines of studies are much needed. Therefore, the writers have undertaken the ecological studies on the rice-borer. Our investigations have been planned on various phases in the life-history of the rice-borer. Some of the experiments conducted up to the present time are still of a rather preliminary nature. However, the writers wish to publish, in a series of papers, the results which have been obtained so far and which the writers consider to be interesting and important for some reasons.

Part I. Development of Hibernating Larvae and their Places of Hibernation.

As it is well-known, the majority of hibernating rice-borers pass winter in straws, i. e., in the harvested culms of the rice-plants, but some of the larvae hibernate in the stubbles of the rice-plants which are standing in the rice-field

† This and the following papers are the slightly modified English editions of the writers' papers which were published in "*Nōgaku-Kenkyū*," No. 17, 1931.

after the harvest. These straws and stubbles may be found under different conditions. For instance, some straws may be piled up in the field either in a sunny place or in shade while the others may be kept in the barn and protected from the sun's rays and rain. Similarly the stubbles may be found under various conditions. Some stubbles may be quite long and reach a few inches above the soil in the rice-field while the others may be very short in some cases being almost at the level of the rice-field. Again, some may be in sunny places during the day while the others may be in the shade for the most part of a day.

These differences in the conditions under which the straws and stubbles are found, would probably have some influence upon the larvae which are hibernating in them. For, the radiant energy which is given off by the sun to the straws or stubbles must vary greatly according to whether the straws or stubbles are in the sunshine or in the shade for the most part of a day. Therefore, the temperature of the hibernacula where the rice-borers are hibernating may not be the same in different hibernacula even in the case where the air temperature is the same both in the sunshine and in the shade. In fact, this difference has recently been shown in certain forest hibernacula by Holmquist[1].

Appearance of the adults of the rice-borer in spring continues for quite a long period. Usually, it lasts from 70 to 80 days. The causes of such a prolonged period of emergence may be numerous, but it would seem to be reasonable to expect that the differences in the conditions under which the larvae are hibernating may be at least one of the important factors which affect the emergence of the moth in spring.

In view of these circumstances, the writers have undertaken to carry on observations and experiments to see if there is any relation between the time of pupation and emergence of hibernating rice-borers and the temperature of the hibernacula.

i. Temperature of Hibernacula.

Method of Measurement of Temperature. It was considered that the most convenient method of measuring the temperature inside of a culm is to use a thermocouple. Accordingly, a thermojunction made of copper and constantan was attached to a portable galvanometer made by the Leeds and Northrup Company. A thermos-bottle with water of a known temperature was used as the standard. One end of the thermojunction was placed in the thermos-bottle and the other end was inserted into the culm, the temperature of which is to be determined. The writers did not consider that this was the most accurate method to be used, since the deflection of the galvanometer may to some extent vary due to varying conditions existing in the circuit even when the electromotive force at the end of the junction remains constant. However, the determination of temperature by the ordinary mercury thermometer is not feasible in the present case and the thermojunction method was considered to be better.

Number of Temperature Determinations made during a Day. Measurements of the temperature of straws and stubbles were made during the daytime only. In most cases the determinations were made three to four times a day. However, on a few occasions, it was not possible to make so many determinations owing to the bad weather. The temperature of air changes rather quickly even during a short period in which several measurements of the temperature of straws and stubbles are made. Therefore, every time when the temperature of straws or stubbles was measured, the temperature of air was determined with a mercury thermometer to compare it with the temperature of straws and stubbles.

Hibernacula selected for the Determination of Temperature. The places for hibernation which were selected for measurements of the temperature, were the stubbles of the rice-plants standing in the field and the rice straws which were harvested and piled by the side of the laboratory. There were two kinds of stubbles, tall and short. The tall stubbles were about 15 centimeters high while the tip of the short ones was almost at the level of the rice-field.

Small bundles of straws the diameter of which was about 6 centimeters were used for the determination of the temperature of straws. Two straw bundles were made and the one was placed on the ground in a sunny place on the south side of the laboratory while the other was placed in the shade on the north side. It must be mentioned here, in connection with this, that the straw bundle on the south side of the laboratory was not always in sunshine during the daytime. It was in shade for short time before the sunset. Similarly, the bundle in the north side was not always in shade during the whole daytime. It was in sunshine for a few hours in the morning.

The rice straws which were examined for rice-borers to see the progress of pupation and emergence were kept piled in two different places, namely, the one pile was in a sunny place on the south side and the other, in the shade on the north side of the laboratory. A considerable amount of rice straws were made into a pile, so that the temperature in the inner part of this straw pile could not be measured by the method mentioned already. The temperature in this straw pile must have been different from that of the small straw bundle which was used for the determination of temperature of straw. However, the temperature of a culm which was near the surface of this straw pile must have been fairly similar to that of a culm in the small straw bundle which was used for temperature determination.

Results of Temperature Determinations. The results of temperature measurement are shown in Table I.

Table I.

Temperature of Stubbles and Straws.

Dates of Determinations	Temperature of Stubbles or Straws	Air Temperature at the Time of Determination of Stubble (straw) Temperature	Mean Daily Air Temperature	Remarks
i) 1927.				
	A. Tall Stubbles. (Variety of rice-plant unknown.)			
4 : 22	16.1	16.3	8.0	
〃 25	21.3	20.9	14.4	
〃 27	26.4	24.8	19.3	
5 : 3	21.3	20.0	17.7	
〃 5	20.1	19.6	14.4	
〃 9	23.3	20.3	16.7	
〃 11	20.4	19.8	17.4	
〃 13	19.1	18.1	15.2	
〃 19	23.7	22.4	16.7	Rain on May 18. Stubbles wet.
〃 26	27.2	26.6	20.0	Rain on May 24.
6 : 6	28.8	26.6	20.9	Rain on June 6.
〃 18	22.4	22.2	18.0	
〃 20	28.8	27.3	21.8	
	B. Straws. (In sunshine in the forenoon only.)			
4 : 22	16.5	16.8	Same as given above.	
〃 25	21.2	21.3		
〃 27	25.0	24.0		
5 : 3	21.1	19.8		
〃 13	18.9	18.0		
〃 19	23.1	22.5		
〃 26	26.8	26.5		
6 : 6	27.7	26.7		
〃 18	23.8	22.2		
〃 20	29.1	27.3		
ii) 1928. (Variety.....*Omachi.*)				
	A. Tall Stubbles.			
3 : 29	15.3	13.4	7.2	
4 : 4	17.2	13.8	8.5	
〃 10	18.9	17.0	12.1	
〃 16	21.7	18.4	12.2	
〃 20	20.4	18.3	13.9	
〃 23	16.1	11.8	7.7	
〃 26	17.9	16.9	11.5	
〃 30	24.6	23.8	18.1	

Dates of Determinations	Temperature of Stubbles or Straws	Air Temperature at the Time of Determination of Stubble (straw) Temperature	Mean Daily Air Temperature	Remarks
5: 2	21.7	14.4	15.5	
〃 10	21.8	20.3	14.3	
〃 14	25.2	24.1	20.7	
〃 17	22.0	21.6	15.4	
〃 21	26.6	25.6	19.9	
〃 23	23.6	23.0	18.3	
〃 26	26.7	25.6	19.9	
〃 30	29.6	29.2	21.8	
6: 5	27.7	26.6	18.0	
〃 7	28.7	28.2	20.3	
〃 9	30.3	29.2	20.9	
〃 12	27.8	27.6	22.3	
〃 15	26.9	26.2	21.3	
	B. Short Stubbles.			
3: 29	19.0	13.4	Same as given above.	
4: 4	18.0	13.8		
〃 10	18.8	17.0		Rain on April 9.
〃 16	23.2	18.4		
〃 20	21.1	18.3		
〃 23	16.5	11.8		
〃 26	17.0	16.9		
〃 30	25.0	23.9		
5: 2	23.7	14.3		
〃 10	21.5	20.3		
〃 14	24.1	24.1		
〃 17	24.3	21.6		
〃 21	28.1	25.6		
〃 23	23.1	23.1		
〃 26	27.5	25.6		
〃 30	29.8	29.2		
6: 5	28.8	26.6		
〃 7	29.3	28.2		
〃 9	31.5	29.2		
〃 12	28.4	27.6		
〃 15	26.6	26.2		
	C. Straws in Sunshine.			
3: 29	20.8	16.1	Same as given in "A."	
4: 4	19.0	14.7		
〃 10	16.7	17.1		

Dates of Determinations	Temperature of Stubbles or Straws	Air Temperature at the Time of Determination of Stubble (straw) Temperature	Mean Daily Air Temperature	Remarks
4: 16	23.8	20.9	Same as given in "A."	
〃 20	22.0	18.7		
〃 23	17.5	12.9		
〃 26	18.5	16.9		
〃 30	30.2	25.7		
5: 2	23.4	22.4		
〃 10	23.7	20.4		
〃 14	27.0	24.9		
〃 17	26.1	21.3		
〃 21	29.3	25.7		
〃 23	24.9	23.0		
〃 26	26.0	24.4		
〃 30	28.7	28.8		
6: 5	25.4	24.5		
〃 7	26.4	26.2		
〃 9	28.3	27.9		
〃 12	26.6	26.0		
〃 15	26.2	26.1		
	D. Straws in Shade.			
3: 29	14.4	13.3	Same as given in "A."	
4: 4	14.9	12.5		
〃 10	16.7	16.3		
〃 16	21.8	18.7		
〃 20	18.8	18.2		
〃 23	11.7	11.0		
〃 26	17.2	16.7		
〃 30	24.0	23.2		
5: 2	20.0	20.6		
〃 10	21.8	20.6		
〃 14	24.5	23.7		
〃 17	21.1	21.0		
〃 21	25.7	25.5		
〃 23	23.2	22.6		
〃 26	24.0	24.6		
〃 30	27.9	28.5		
6: 5	26.0	24.8		
〃 7	28.3	26.9		
〃 9	28.1	28.0		
〃 12	28.0	26.7		
〃 15	28.5	26.1		

Dates of Determinations	Temperature of Stubbles or Straws	Air Temperature at the Time of Determination of Stubble (straw) Temperature	Mean Daily Air Temperature	Remarks
iii) 1929.	(Variety.....*Omachi*.)			
	A. Tall Stubbles.			
4: 1	21.9	16.4	10.9	
〃 8	21.2	14.7	10.8	
〃 15	21.6	16.0	10.4	
〃 23	22.8	17.2	9.5	
〃 30	25.9	22.9	17.2	
5: 6	23.4	17.9	11.3	
〃 11	29.7	22.7	16.3	
〃 16	28.9	22.9	16.7	
〃 20	31.6	25.8	18.4	
〃 24	29.3	24.8	18.8	
〃 27	27.5	23.2	17.1	
〃 31	29.7	24.2	17.9	
6: 4	29.6	30.9	22.1	
	B. Short Stubbles.			
4: 1	21.7	16.5	Same as given above.	
〃 8	21.4	14.7		
〃 15	21.6	16.0		
〃 23	23.2	17.2		
〃 30	25.6	22.9		Rain on April 29.
5: 6	23.7	17.9		
〃 11	28.2	22.7		Rain on May 10.
〃 16	29.1	22.9		
〃 20	31.4	25.8		
〃 24	29.6	24.8		
〃 27	28.3	23.2		
〃 31	28.8	24.2		
6: 4	29.4	30.9		
	C. Straws in Sunshine.			
4: 1	24.0	18.5	Same as given in "A."	
〃 8	19.8	17.2		
〃 15	22.7	17.7		
〃 23	25.4	19.1		
〃 30	28.1	23.9		
5: 6	25.1	19.2		
〃 11	31.8	23.7		
〃 16	25.3	24.4		
〃 20	30.3	25.8		
〃 24	28.6	24.8		
〃 27	28.1	23.7		
〃 31	28.9	23.7		
6: 4	28.1	29.8		

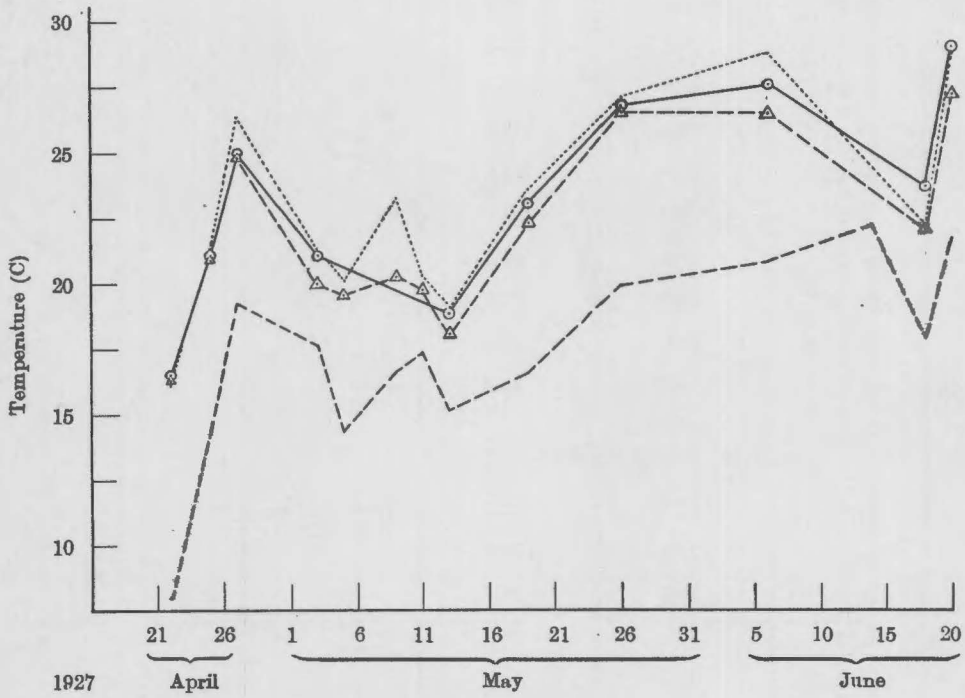
Dates of Determinations	Temperature of Stubbles or Straws	Air Temperature at the Time of Determination of Stubble (straw) Temperature	Mean Daily Air Temperature	Remarks
	D. Straws in Shade.			
4: 1	20.2	14.5	Same as given in "A."	
〃 8	20.8	15.1		
〃 15	20.3	16.7		
〃 23	21.6	17.5		
〃 30	25.8	21.4		
5: 6	23.1	17.5		
〃 11	26.9	23.0		
〃 16	26.5	21.5		
〃 20	30.9	25.7		
〃 24	30.0	25.0		
〃 27	28.1	23.3		
〃 31	30.3	20.6		
6: 4	27.7	30.2		
iv) 1930. (Variety.....*Omachi.*)				
	A. Tall Stubbles.			
4: 4	18.4	14.2	8.5	
〃 8	21.8	16.7	12.3	Rain on April 8.
〃 16	23.1	17.7	8.1	
〃 22	22.3	19.0	12.2	
〃 28	23.2	18.3	14.3	Heavy rain on April 27. Cloudy and strong wind on April 28.
5: 6	23.4	18.9	15.5	
〃 13	29.6	24.2	18.4	Rain on May 12.
〃 21	27.6	23.3	18.9	Cloudy and strong wind on May 21.
〃 29	31.3	26.6	19.4	
6: 4	28.6	24.2	18.5	
〃 10	27.9	28.2	20.6	
	B. Short Stubbles.			
4: 4	19.9	14.2	Same as given above.	
〃 8	21.0	16.7		
〃 16	23.5	17.6		
〃 22	24.1	18.8		
〃 28	21.7	18.3		Rain on April 28.
5: 6	23.6	18.7		
〃 13	28.6	24.2		
〃 21	27.5	23.3		
〃 29	30.8	26.6		
6: 4	28.7	24.2		
〃 10	27.8	28.2		

Dates of Determinations	Temperature of Stubbles or Straws	Air Temperature at the Time of Determination of Stubble (straw) Temperature	Mean Daily Air Temperature	Remarks
	C. Straws in Sunshine.			
4: 4	18.7	15.6	Same as given in "A."	
〃 8	21.5	16.6		
〃 16	22.0	16.7		
〃 22	21.5	19.8		
〃 28	22.9	18.5		
5: 6	24.8	19.6		
〃 13	29.9	24.6		
〃 21	26.7	24.0		
〃 29	29.8	26.6		
6: 4	28.6	23.6		
〃 10	29.6	28.8		
〃 18	24.7	27.2		
	D. Straws in Shade.			
4: 4	17.7	13.7	Same as given in "A."	
〃 8	21.4	16.8		
〃 16	20.6	16.3		
〃 22	19.1	19.2		
〃 28	23.8	18.9		
5: 6	23.5	19.2		
〃 13	27.1	24.4		
〃 21	25.6	22.4		
〃 29	30.9	27.1		
6: 4	28.8	24.1		
〃 10	29.2	29.3		
〃 18	22.9	25.7		

The results in Table I are shown graphically in Figures 1 to 4.*

* To avoid the complicacy of resulting figures, air temperature is not plotted in certain cases. The results shown in the figures are the results of determination of air temperature immediately following the determination of stubble temperature.

Fig. 1.



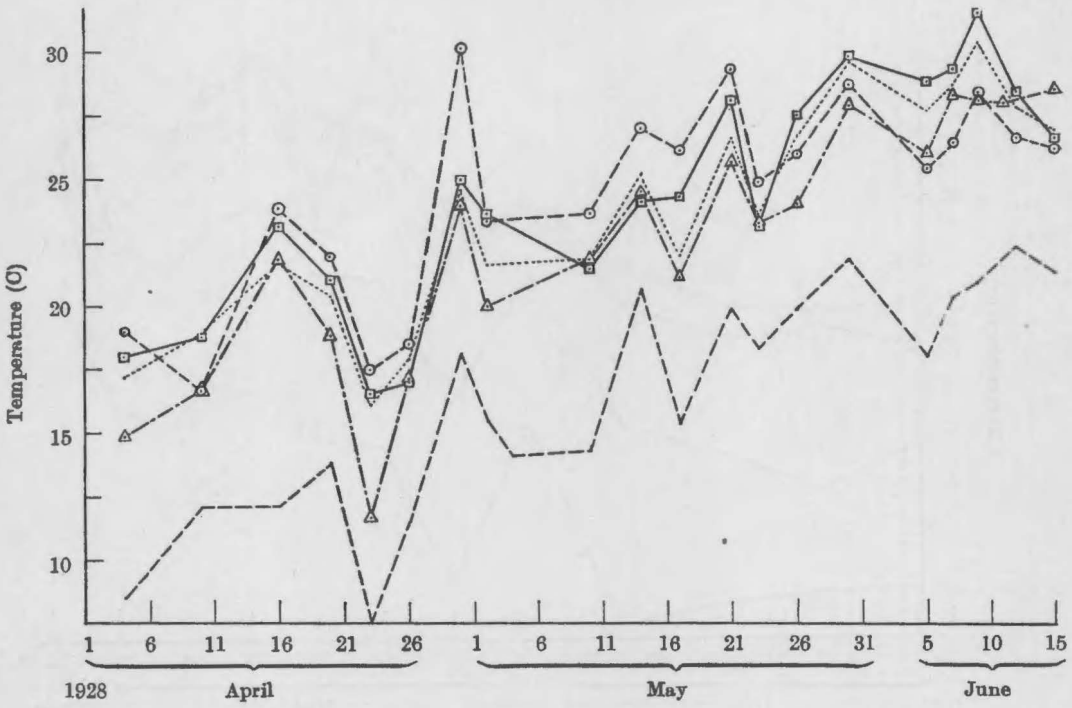
..... Temperature of tall stubbles.

o—o—o " straws.

Δ--Δ--Δ Air temperature at the time of temperature determination.

– – – – – Mean air temperature of the day on which temperature determinations were made.

Fig. 2.



..... Temperature of tall stubbles.

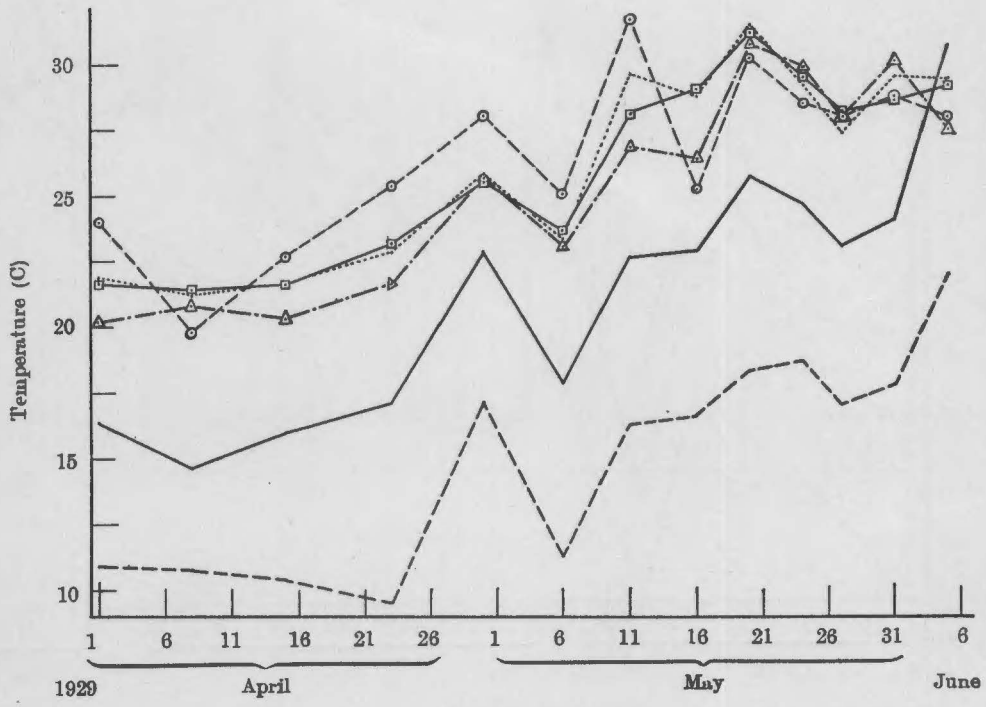
□—□—□ " short stubbles.

○--○--○ " straws in sunshine.

△-·-△-·-△ " straws in shade.

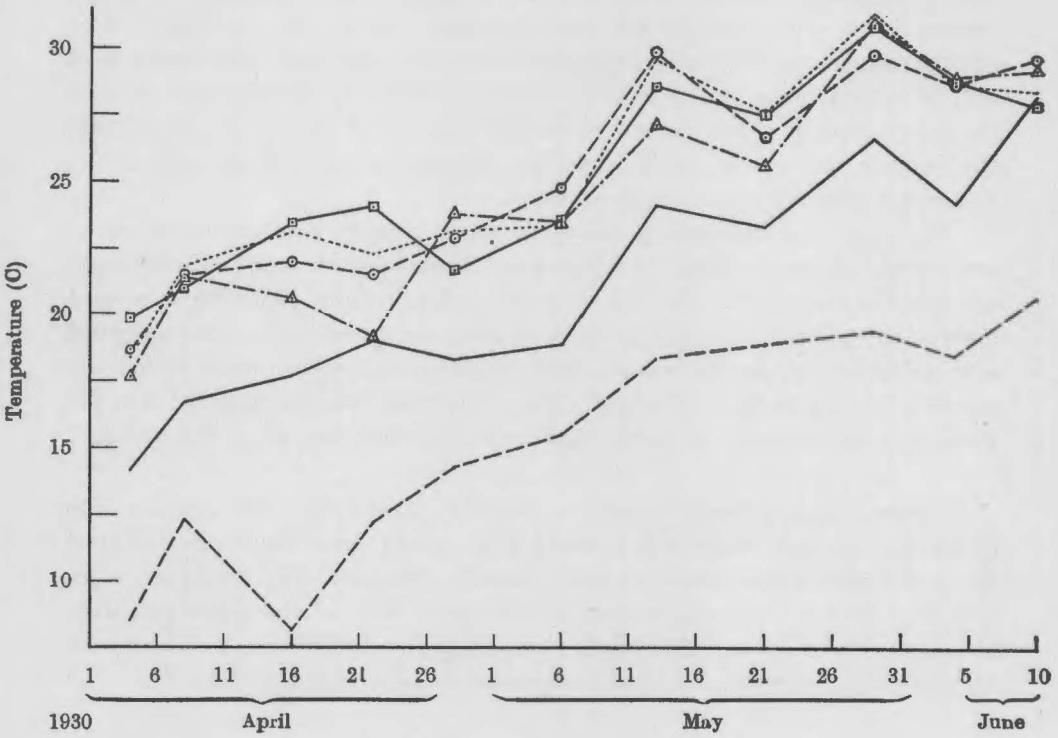
– – – – – Mean air temperature of the day on which temperature determinations were made.

Fig. 3.



Temperature of tall stubbles.
" short stubbles.
" straws in sunshine.
" straws in shade.
Air temperature at the time of temperature determination.
Mean air temperature of the day on which temperature determinations were made.

Fig. 4.



Air Temperature at the Time of Determination of Temperature of Straws and Stubbles. When determination of temperature of straws and stubbles was made, the air temperature was also measured immediately after that, and these two determinations were compared each other. As it is evident from the records in Table I, the temperature of straws and stubbles was considerably higher than the air temperature at the time of the determination. In some cases the differences between the air and the straws or stubbles amounted to more than 7 to 9 degrees. Only in a few exceptional cases, the temperature of straws in the shade was slightly lower than the air temperature. This seems to have occurred when the straws or stubbles were wet owing to the rain previous to temperature determination or when it was cloudy and warm.

Mean Daily Temperature of Air and Temperature of Stubbles and Straws. Determinations of temperature of straws and stubbles were made three to four times a day in most cases as it has been previously stated. The average of these determinations was markedly higher than the mean daily air temperature as it will be evident from the records in Table I. This is to be expected because the determinations of temperature of stubbles and straws were made only during the daytime and not at night when the temperature of stubbles and straws descended much lower than in the daytime.

Therefore, it is desirable to know the actual average temperature of straws and stubbles in cases where the temperature measurements were made throughout the day and night. For this purpose, a temperature recording apparatus must be used. Since it was not possible to use a temperature recorder equipped with a thermojunction, the writers used a thermograph with a small cylindrical sensitive part made by J. Richard. This cylindrical bulb was inserted into the center of a small bundle of straws, the diameter of which was about 6 centimeters.

Temperature of Straws at the Outer Layer of a Straw Pile. The sensitive bulb of the thermograph, which was inserted into a small straw bundle as described above, was placed on a straw pile and exposed to the sun. The maximum, minimum and average daily temperature of the outer layer of the straw pile were obtained in this manner. The results thus obtained in 1931 were compared with the maximum, minimum and mean temperature of air as shown in Table II.

(Consult Table II on page 191.)

According to the results shown in Table II, the following conclusions may be made: In almost all the cases, the minimum temperature of air was slightly higher than the minimum temperature of straws while the maximum temperature of straws was without any exception markedly higher than the maximum air temperature.

When the average of temperature is compared, it is evident that, out of 33 days, there were only 3 on which the average of air temperature exceeded that of straws. In one instance, the average of temperature of straws exceeded as much as 4.5 degrees over that of air.

The straw pile gives off its heat at night so that its temperature descends lower than that of air. But, during the daytime, the straws are much warmed by direct sun's rays and they attain to a very high temperature which more than offsets the fall of temperature of the straws at night. Consequently, the average of temperature of straws at the outer layer of a straw pile is almost always higher than the average of air temperature.

Table II.

Comparison of Temperature of Air and That of Straw Pile at the Outer Layer.

(1931)

Dates	Temperature of Straw			Temperature of Air			Difference in Average Temp. (Excess of Straw Temp. above Air Temp.)	Weather
	Maximum	Minimum	Average	Maximum	Minimum	Average		
4: 5	17.0	3.2	11.4	15.9	4.2	11.1	0.3	
〃 6	23.9	2.6	10.1	15.3	3.3	9.0	1.1	
〃 7	22.9	−0.2	8.1	10.0	0.8	5.5	2.6	
〃 8	15.7	−2.3	5.4	9.4	−2.2	4.3	1.1	
〃 9	25.8	−2.0	8.3	13.8	−2.1	6.7	1.6	
〃 10	27.8	0	12.0	17.9	−0.1	10.0	2.0	
〃 11	15.6	5.2	10.8	13.1	5.8	10.2	0.6	
〃 12	20.4	1.7	9.6	14.0	1.8	8.4	1.2	
〃 13	29.0	4.2	14.1	18.6	5.1	11.9	2.2	
〃 14	19.6	7.3	13.4	19.2	8.2	13.0	0.4	
〃 15	22.0	4.4	12.9	16.5	4.8	11.4	1.5	
〃 16	40.0	6.2	19.5	23.9	5.4	15.1	4.5	
〃 17	28.9	7.7	17.6	20.8	10.0	15.6	2.0	
〃 18	28.6	3.0	14.2	16.8	8.7	11.7	2.5	
〃 19	37.0	6.7	16.2	18.0	6.1	12.5	3.5	
〃 20	24.0	8.4	15.2	17.0	9.0	13.2	2.0	
〃 21	24.2	14.1	17.3	19.0	14.1	15.8	1.5	Rain.
〃 22	19.8	3.6	13.6	17.0	8.0	13.8	−0.2	Rain.
〃 23	25.6	1.8	12.0	17.0	2.7	11.0	1.0	
〃 24	14.9	10.4	12.3	12.4	10.7	11.7	0.5	Rain.
〃 25	24.0	7.0	13.7	17.8	8.0	13.6	0.1	
〃 26	29.6	4.0	15.1	21.0	5.6	13.7	1.4	
〃 27	25.8	13.9	18.1	21.1	14.6	17.4	0.7	
〃 28	30.7	16.0	20.1	24.0	16.0	19.0	1.1	
〃 29	23.6	15.9	19.0	20.2	15.7	17.6	1.4	Rain.
〃 30	30.3	11.0	17.6	21.2	11.4	16.1	1.5	
5: 1	23.5	4.0	14.1	20.3	6.8	14.3	−0.2	
〃 2	29.7	0.3	13.1	21.3	3.9	13.9	−0.8	
〃 3	33.7	1.9	14.5	23.0	4.8	14.1	0.4	
〃 4	33.0	3.7	16.3	25.0	5.3	15.9	0.4	
〃 5	37.5	4.1	17.7	26.0	7.0	16.6	1.1	
〃 6	35.5	6.1	19.0	25.0	8.8	17.2	1.8	
〃 7	40.0	8.0	19.8	26.0	10.2	18.1	1.7	Rain.

Temperature of Straws in a Straw Pile. It may be expected that the temperature in a straw pile at a certain depth from the surface of the straw pile would differ slightly from the surface temperature of the pile since straw is a bad conductor of heat. Therefore, in 1931, the writers measured the inside temperature at a distance of about one foot below the surface of a straw pile using the same thermograph as described in the preceding paragraph. The results of measurements are shown in Table III.

Table III.

Temperature in a Straw Pile at a Distance of About One Foot from its Surface.

(1931)

Dates	Temperature in Straw Pile			Temperature of Air			Excess of Average Temp. of Straw over That of Air, (Straw Temp. minus Air Temp.)	Remarks
	Maximum Temp.	Minimum Temp.	Average Temp.	Maximum Temp.	Minimum Temp.	Average Temp.		
5: 13	25.0	16.9	19.9	24.2	11.2	17.6	2.3	Fine.
〃 14	24.0	16.9	19.5	26.0	10.3	18.1	1.4	〃
〃 15	19.1	17.0	18.1	21.6	16.0	18.0	0.1	Storm in the afternoon.
〃 16	18.3	15.0	16.7	22.0	13.0	17.8	−1.1	Fine.
〃 17	17.2	15.0	16.2	19.8	9.4	15.4	0.8	〃
〃 18	18.9	16.1	17.2	21.0	9.2	15.4	1.8	Cloudy in the afternoon.
〃 19	18.0	13.2	15.2	21.9	5.1	14.5	0.7	Fine.
〃 20	23.7	15.1	17.5	24.2	9.2	17.4	0.1	〃
〃 21	20.0	15.4	18.0	22.0	14.6	17.4	0.6	Fine / Rain.
〃 22	20.0	15.3	17.4	20.0	12.4	16.5	0.9	Rain / Fine.
〃 23	20.0	15.3	17.5	22.6	8.6	16.7	0.8	Fine.
〃 24	16.8	14.4	16.4	24.0	8.1	17.2	−0.8	〃
〃 25	17.8	14.3	15.8	22.9	9.2	16.3	−0.5	〃
〃 26	17.7	14.2	16.1	23.4	9.0	16.9	−0.8	〃
〃 27	20.0	14.8	17.4	25.2	10.6	18.4	−1.0	〃
〃 28	19.6	16.4	18.1	25.9	14.1	19.6	−1.5	Rain at night.
〃 29	19.7	16.6	17.9	23.7	12.9	18.8	−0.9	Fine.
〃 30	19.8	15.4	17.4	23.8	11.1	17.7	−0.3	〃
〃 31	21.2	16.0	18.5	26.9	11.2	19.3	−0.8	〃
6: 1	21.7	16.6	18.7	26.6	12.4	20.0	−1.3	〃
〃 2	19.7	16.6	17.6	24.2	13.2	19.2	−1.6	〃
〃 3-9	—	—	—	—	—	—	—	—
〃 10	20.1	17.8	19.1	26.0	14.7	20.7	−1.6	Fine.
〃 11	21.6	18.1	19.7	24.0	18.1	20.0	−0.3	Fine / Rain.
〃 12	22.0	18.2	19.1	25.1	13.9	19.2	−0.1	Rain / Fine.
〃 13	19.9	17.3	18.7	27.1	11.5	19.8	−1.1	Fine.
〃 14-18	—	—	—	—	—	—	—	—
〃 19	21.0	19.9	20.3	27.0	18.9	22.6	−2.3	Fine.
〃 20	20.1	19.7	20.0	25.0	20.0	21.5	−1.5	〃
〃 21	20.1	19.9	20.0	25.0	19.5	22.0	−2.0	Fine / Rain.
〃 22	21.0	19.7	20.3	27.2	19.1	22.7	−2.2	Rain / Cloudy.
〃 23	20.9	20.1	20.5	23.0	20.2	21.6	−1.1	Rain.
〃 24	21.5	20.3	20.9	24.7	20.0	22.1	−1.2	〃
〃 25	24.7	21.1	22.5	27.2	20.4	23.4	−0.9	Fine.
〃 26	25.8	22.0	23.5	28.6	21.0	24.8	−1.3	〃
〃 27	25.2	22.7	23.7	29.2	20.2	25.0	−1.3	〃
〃 28	24.9	23.0	23.7	29.0	22.0	25.0	−1.3	Fine / Rain.

It may be expected at the outset that the temperature in a straw pile varies with the prevailing outside air temperature at the time of temperature determination, and also that it must be different according to the position in the straw pile, where the determination of temperature is made.

A study of the results in Table III shows that the average temperature at a depth of about one foot in the straw pile was slightly higher or almost equal to the outside air temperature until about May 23rd. After May 24th, however, the condition was reversed and the temperature inside of the straw pile was always lower than the outside air temperature. This difference became gradually more pronounced as the season advanced. This indicates that the rise of temperature in the straw pile was always slightly slower than that of the outside air temperature owing to the fact that straw is a bad conductor of heat. It will be mentioned in a later chapter that this lag in the rise of temperature in a straw pile exerts its influence on the development of the larvae hibernating in the straw.

Temperature of Stubbles in the Rice-Field. The rice-plants were cut so as to leave two kinds of stubbles in the field. The tall stubbles were about 15 centimeters in height and the short ones hardly protruded above the soil surface of the rice-field. These two kinds of stubbles were used for temperature determinations. In order to determine the temperature inside of a culm, one end of thermojunction was inserted into the cut end of one of the culms which formed a stubble and the deflection of the galvanometer was read.

These two kinds of stubbles did not show a large difference in their temperature. On a fine day, the temperature of the short stubbles was slightly higher than that of the tall ones in most cases, but the short stubbles were often wet at the time of temperature determination when it was rainy on a previous day or on a day before the preceding day and, on such an occasion, the short stubbles usually showed a lower temperature than the tall ones. This was considered to be due to the circumstance that short stubbles were difficult to dry up and that they were cooled by evaporation of water.

Temperature of Straws. A small straw bundle, the diameter of which was about 5 centimeters, was used for temperature determination as has been previously stated. Therefore, its temperature must have been different from the temperature inside of a large straw pile. It would be nearly the same as the temperature at a depth of about 5 centimeters in the outer layer of a large straw pile, though these two temperatures might not be quite the same. The one of the straw bundles used for temperature determination was laid on a sunny place on the south side of the laboratory and the other, in the shade on the north side.

When the results of temperature determinations were compared, it was found that, in almost all cases, the temperature of the bundle in the sunshine was higher than that of the bundle in the shade. Occasionally, however, the temperature of the latter was higher than the former. For instance, this occurred in the first half of June in 1928, in the last half of May in 1929, and near the end of May and

the beginning of June in 1930. It is difficult to give a satisfactory explanation for this phenomenon. However, it has been thought that various weather conditions, such as cloudiness, precipitation, the direction and intensity of wind, etc. would have been responsible for the phenomenon.

Comparison of Temperature of Straws and that of Stubbles. When the temperature of stubbles and that of the straw bundle in the sunshine were compared, it was found that, in most cases, the temperature of the latter was higher than the former. In some cases, however, the situation was reversed. In 1930, the temperature of the two did not show any consistent relationship; i. e., sometimes the temperature of the straw bundle in the sunshine was higher than that of stubbles while, in other cases, the reverse relation was observed. The reason for such a contradictory result was not known.

After the end of May, a consistent relation could not be found between the temperature of straws and that of stubbles. The temperature of the straw bundle in the shade was, in nearly all cases, lower than that of stubbles. However, after about the 20th of May, the temperature of straw bundle in the shade often exceeded that of stubbles.

Temperature of Stubbles and that of the inner Part of a Straw Pile. The temperature of the inner part of a straw pile was not measured until the spring of 1931, so that, in three preceding years (1928—1930), it was not possible to compare the temperature of stubbles with that of the inner part of a straw pile. However, from the results of observations made in 1931 which have been described in a previous paragraph, the following inference may be made: The temperature of straw at a certain depth below the surface of a straw pile must be lower than the temperature of its outer layer of the straw pile; it must also be lower than the temperature of stubbles. The reason is that, according to the results of observations in 1931, the air temperature was higher than the inside temperature of a straw pile and also that both the temperature of stubbles and that of straws at the outer layer of a straw pile were higher than that of the air.

From what has been stated above, it may be concluded that, in April and May, the temperatures of the hibernacula of the rice-borer are in the order of (1) *the outer layer of a straw pile in the sunshine*, (2) *short stubbles*, (3) *tall stubbles* and (4) *straw bundle in the shade.* The temperature of the inner part of a straw pile is lower than the first three hibernacula just mentioned.

In short, it is evident that the actual temperature of the hibernaculum of the rice-borer is different according to the place where the hibernaculum is found, and also that the temperature of the hibernaculum may be considerably different from the temperature of the air.

ii. Development of Hibernating Rice-Borers in Spring.

It has been shown in the preceding chapter that the temperatures of different hibernacula may show considerable differences and also that the tem-

perature of hibernaculum may be sometimes considerably different from that of the surrounding air. It seemed quite natural to suppose that such differences in temperature of different hibernacula should affect in spring the development of the larvae which have been overwintering in those hibernacula. Accordingly, the stubbles and straws were examined at different intervals beginning in the early spring, and the number of larvae, pupae and adults* were recorded.

The results obtained are shown in Table IV.

Table IV.

Results of Observations on Pupation and Emergence of Rice-Borers in Various Hibernacula.

Dates of Examination	Number of			Per cent. of		Remarks
	Pupae	Adults	Larvae	Pupation	Emergence	
i) 1927.						
A. Tall Stubbles.						
4: 27	0	0	20	0	0	Number of stubbles examined 20.
〃 30	2	0	32	5.7	0	〃
5: 3	0	0	20	0	0	〃
〃 6	0	0	25	0	0	〃
〃 9	1	0	18	5.0	0	〃
〃 13	0	0	26	0	0	〃
〃 20	0	0	16	0	0	〃
〃 26	1	0	11	8.3	0	〃
6: 3	2	0	5	28.5	0	〃
〃 11	8	1	1	80.0	10	〃
〃 14	11	5	1	64.7	29.4	Number of stubbles examined 30.
〃 23	0	9	1	0	90.0	〃
B. Straws. (In sunshine in the forenoon only.)						
4: 30	0	0	16	0	0	
5: 3	0	0	22	0	0	
〃 9	0	0	26	0	0	
〃 13	0	0	22	0	0	
〃 20	0	0	32	0	0	
〃 30	0	0	13	0	0	
6: 9	0	0	14	0	0	
〃 11	1	0	15	6.3	0	
〃 17	2	0	19	9.4	0	
〃 20	9	1	13	39.1	4.3	
〃 23	7	1	9	41.1	5.8	
〃 30	11	3	3	64.7	17.6	

* The number of adults which already emerged was determined from the number of the pupal skins from which the adults had already escaped.

Dates of Examination	Number of			Per cent. of		Remarks
	Pupae	Adults	Larvae	Pupation	Emergence	
ii) 1928. (Variety.....*Omachi*.)						
A. Tall Stubbles.						
5: 4	0	0	31	0	0	Number of stubbles examined 30.
〃 10	2	0	58	3.3	0	〃
〃 19	0	0	93	0	0	〃
〃 22	1	0	120	0.8	0	〃
〃 25	3	1	84	3.4	1.1	〃
〃 31	11	1	70	13.4	1.2	〃
6: 4	10	1	31	23.8	2.3	〃
〃 7	33	1	26	55.0	1.6	〃
〃 10	21	2	17	52.5	5.0	〃
〃 16	45	12	4	73.7	19.6	〃
〃 19	24	18	2	54.5	40.9	〃
B. Straws in Sunshine.						
4: 26	0	0	52	0	0	
5: 2	2	0	42	4.5	0	
〃 16	0	0	55	0	0	
〃 28	0	0	39	0	0	
6: 1	1	0	41	2.3	0	
〃 5	3	0	37	7.5	0	
〃 7	5	1	36	11.9	2.3	
〃 10	7	0	26	21.2	0	
〃 13	4	0	33	10.8	0	
C. Straws in Shade.						
5: 16	0	0	50	0	0	
〃 25	0	0	42	0	0	
6: 1	0	0	53	0	0	
〃 5	0	0	39	0	0	
〃 7	5	0	42	10.6	0	
〃 10	9	1	30	22.5	2.5	
〃 13	3	1	26	10.0	3.3	
〃 19	10	2	35	21.2	4.2	

Dates of Examination	Number of			Per cent. of		Remarks
	Pupae	Adults	Larvae	Pupation	Emergence	
iii) 1929. (Variety.....*Omachi.*)						
A. Tall Stubbles.						
5: 2	0	0	52	0	0	Number of stubbles examined 30.
〃 13	0	0	20	0	0	〃
〃 21	0	0	69	0	0	〃
〃 27	1	0	55	1.7	0	〃
6: 1	5	0	42	10.6	0	〃
〃 4	1	0	70	1.4	0	〃
〃 8	12	0	34	26.0	0	〃
〃 10	11	0	25	30.5	0	〃
B. Straws in Sunshine.						
4: 22	0	0	51	0	0	
5: 13	0	0	51	0	0	
〃 23	0	0	66	0	0	
〃 27	0	0	41	0	0	
6: 3	1	0	32	3.0	0	
〃 6	3	0	38	7.0	0	
〃 10	10	0	35	22.2	0	
C. Straws in Shade.						
4: 22	0	0	52	0	0	
5: 13	0	0	53	0	0	
〃 23	0	0	52	0	0	
〃 27	1	0	50	1.9	0	
6: 3	0	0	62	0	0	
〃 6	1	0	44	2.2	0	
〃 10	10	0	40	20.0	0	

Dates of Examination	Number of			Per cent. of		Remarks
	Pupae	Adults	Larvae	Pupation	Emergence	
iv) 1930. (Variety.....*Omachi.*)						
A. Tall Stubbles.						
3 : 17	0	0	264	0	0	Number of stubbles examined 50.
4 : 1	1 ?	0	243	0.4 ?	0	〃
〃 16	0	0	209	0	0	〃
5 : 1	0	0	200	0	0	〃
〃 12	2	0	224	0.8	0	〃
〃 21	11	1	194	5.3	0.4	〃
〃 26	37	0	163	19.0	0	〃
〃 31	41	0	91	31.0	0	〃
6 : 5	41	2	46	46.0	2.2	〃
〃	48	13	23	57.1	15.4	〃
B. Straws in Sunshine.						
3 : 10	0	0	51	0	0	
〃 31	0	0	66	0	0	
4 : 15	0	0	59	0	0	
5 : 1	0	0	56	0	0	
〃 12	0	0	71	0	0	
〃 22	1	0	58	1.8	0	
〃 31	7	0	50	12.2	0	
6 : 7	18	2	21	43.9	4.8	
〃 14	9	7	16	28.1	21.8	
〃 22	17	4	9	56.6	13.3	
C. Straws in Shade.						
3 : 10	0	0	64	0	0	
〃 31	0	0	91	0	0	
4 : 15	0	0	73	0	0	
5 : 1	0	0	110	0	0	
〃 12	0	0	64	0	0	
〃 22	0	0	62	0	0	
〃 31	0	0	70	0	0	
6 : 7	5	0	57	8.0	0	
〃 14	7	0	54	11.4	0	
〃 22	32	7	24	50.7	11.1	

In 1927, the total number of rice-borers that were found was rather small, so that the percentage of pupation and emergence based upon this number could not have been very accurate.

The short stubbles were also examined. But, the result was not recorded in Taple IV since it was considered that the result could not be very reliable owing to the circumstance that the total number of rice-borers found was rather small.

Figures 5 to 8 have been drawn, using the results in Table IV to show how the pupation and emergence went on.

Fig. 5.

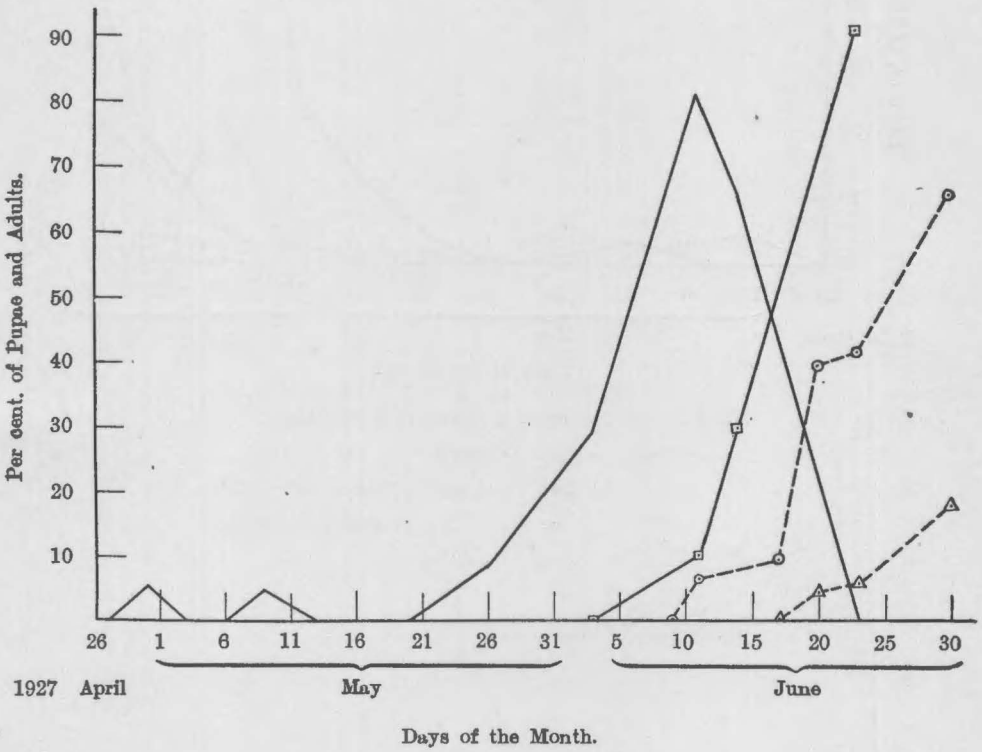
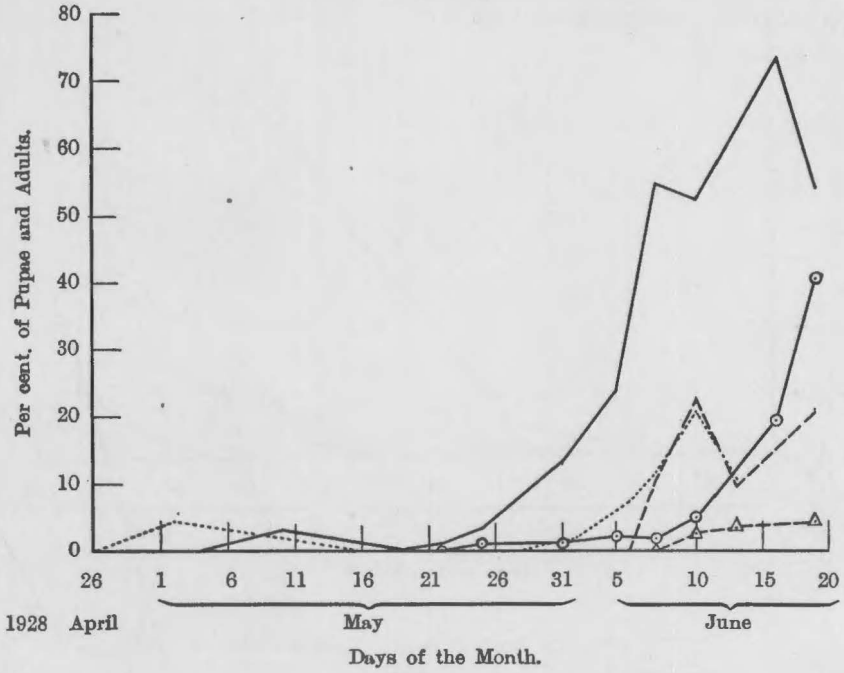
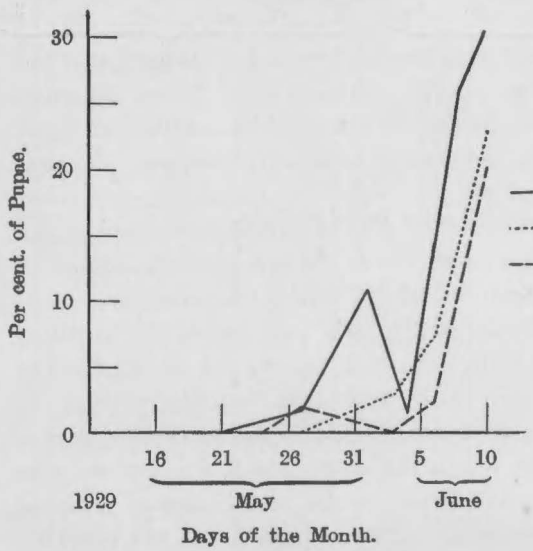


Fig. 6.



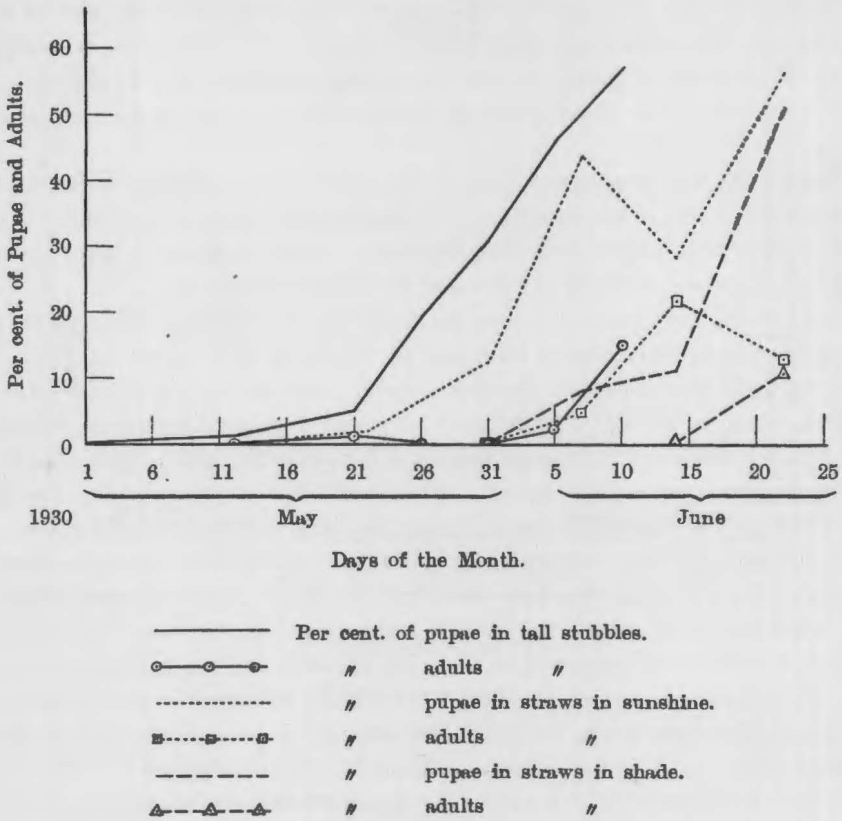
Per cent. of pupae in tall stubbles.
" adults "
" pupae in straws in sunshine.
" " in straws in shade.
" adults "

Fig. 7.



Per cent. of pupae in tall stubbles.
" " in straws in sunshine.
" " in straws in shade.

Fig. 8.



According to the records in Table IV, the first pupa was found on April 30th, and the first moth appeared on June 11th, in 1927, in tall stubbles while, in the straw pile which was in the sunshine during the forenoon only, the first pupa was found on June 11th, and the first adult on June 20th, in 1927. Thus, the emergence began 9 days later in the straw pile than in the stubbles. After that time, also, the pupation and emergence proceeded much slower in the straw pile than in the stubbles as it is evident in Figure 5.

In 1928, the first pupa was observed on May 10th in the stubbles while, in the straw pile in the sunshine, it was found on May 2nd. In this case, appearance of the first pupa was about a week earlier in the straws than in the stubbles. However, this pupa seemed to be an exceptionally early pupa since the pupation ceased for some 30 days after that, namely, until June 1st. In the stubbles, pupae were found for the second time on May 22nd. After that time, the pupation in the stubbles went on from one to two weeks earlier than in the straw pile as it is apparent from Figure 6. In the straw pile in the shade, the first pupa was seen on June 7th. Therefore, pupation in the straws in the shade showed a lag of some 16 to 17 days when it was compared with the pupation in the stubbles.

When two kinds of straw piles, i. e., the straw pile in the sunshine and that in the shade, are compared, it is seen that the pupation began earlier in the former than in the latter. But, after about June 10th, there could be found almost no difference in the progress of pupation. The emergence began earliest in the stubbles and its progress was in the order of *the stubbles*, *the straw pile in the sunshine* and *the straw pile in the shade*.

In 1929, the first pupa was found on May 27th in the stubbles and on June 3rd in the straw pile in the sunshine while, in the straw pile in the shade, it was found on May 27th. After June 3rd, the order of the progress of pupation was *the stubbles*, *the straw pile in the sunshine* and *the straw pile in the shade*.

In 1930, the first pupa was seen on April 1st in stubbles. This pupa was extremely earlier in comparison with any of the three first pupae in the other three years. It was suspected, therefore, that it might have been a dead pupa of the first generation in 1929. After April 1st pupae were not found for a considerable period of time, and the second pupa was found on May 12th. After that time, the pupation took place continuously. In the straw pile in the sunshine, the first pupa was found on May 22nd, and in the straw pile in the shade, on June 7th.

In the stubbles, the first pupal skin was found on May 21st, but no emergence was observed for the following two weeks and the second moth was seen on June 5th. After that time, adults appeared continuously. In the straw pile in the sunshine, the first moth appeared on June 7th while, in the shade, the emergence began strikingly later, namely, on June 22nd. Thus, the order of the progress of pupation and emergence was *the stubbles*, *the straw pile in the sunshine* and *the straw pile in the shade*.

Of the two straw piles, the one in the sunshine and the other in the shade, pupation began much earlier in the former than in the latter. However, there was a tendency that the difference in the rate of progress in pupation became almost imperceptible by about June 25th, as has been pointed out previously.

The results of observations on the time of pupation and emergence were briefly described above. These results, however, can not be interpreted as the actual time when the pupation and emergence occurred for the first time under the natural field conditions. The results of the trap-light experiments which are not incorporated in the present paper showed that, under the field conditions, the pupation and emergence occurred much earlier than the time which the results described above indicate.

In the experiments such as described here where a limited amount of stubbles and straws have to be examined at a time, it can not be expected that the time of the appearance of the first pupa and adult as determined by this method exactly agrees with the actual date of the appearance of the first pupa and adult in a rice-field of an extended area. The results of the present experiments indicate when the pupation and emergence began in the various hibernacula which were selected for the experiments, and also in what order the pupation and emergence progressed. In this connection, we have already stated that the pupation and emergence began earliest in the stubbles and that the order of the progress of

pupation and emergence was the stubbles, the straw pile in the sunshine and the straw pile in the shade.

Summary and Conclusions. From what has been stated above, the following conclusions may be drawn in regard to the relation between the temperatures of hibernacula and the time of the pupation and emergence.

The comparison of the straw bundle in the sunshine with that in the shade revealed that the temperature of the former was higher than that of the latter. Corresponding with this result, the pupation and emergence began and proceeded earlier in the straw pile in the sunshine than in the straw pile in the shade in spring and early summer. The statement just given above is correct so far as the outer layer of a certain thickness of a straw pile is concerned. In the inner part of a large straw pile, the difference in temperature would probably not exist in the straw pile in the sunshine and that in the shade. Accordingly, there would probably be no difference in the time of pupation and emergence of the hibernating rice-borers in the straw piles treated in two different manner. This is probably the explanation for the result of observation that, after about June 10th, there was almost no difference in the progress of pupation between the straw pile in the sunshine and that in the shade.

When the stubbles and straw bundle in the shade were compared, it was found that the temperature was always higher in the former than in the latter. Corresponding with this, the pupation and emergence began and proceeded earlier in the former than in the latter.

In these two cases cited above, the beginning and progress of the pupation and emergence are in positive relation with the temperature of the hibernacula. Such a relation does apparently not exist in the case of the straws in the sunshine and the stubbles. Thus, the temperature of the straw bundle in the sunshine was higher than that of stubble in most cases. In spite of this finding, the pupation progressed earlier in the stubble than in the straw pile in the sunshine*. This apparent discrepancy in the two cases cited above seems to be explained in the following way. The straw which was used for the temperature determination was a small straw bundle which was laid on the ground whereas, for the examination of the progress of the development of hibernating larvae, the data were obtained from a rather large straw pile. As it has been stated in a previous paragraph, the temperature of the small straw bundle must have been higher than the temperature inside of the large straw pile. Although the precaution was taken to interchange, at times, the upper and lower straws in the straw pile, the temperature inside of the straw pile must have been lower than that of the stubbles. Therefore, the pupation in the straw pile proceeded slower than in the stubbles though a few pupae appeared earlier in the outer layer of the straw pile than in the stubbles.

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* In 1928, the first pupa in the straw appeared earlier than in the stubbles, but the pupation ceased for the following two weeks in the latter and for three weeks in the former. After that, the pupation progressed much earlier in the stubbles than in the straw.

The circumstance pointed out above was probably a factor which made the hibernating larvae in a straw pile pupate and emerge later than those in stubbles. However, there might have been some other important factors besides the difference in the temperature. As Babcock[2], Townsend[3], and others[4] maintain, the amount of water which was actually in contact with hibernating larvae might have exerted some influence on the development. Obviously, the stubbles in the rice-field are often moistened by the precipitation, whereas the straw in the inner part of a straw pile is rarely moistened by rain or dew. This difference may influence the time of breaking-up of hibernation.

In short, we may conclude as follows: The time of the appearance, in spring, of the pupa and adult of the rice-borer differs considerably according to the places where hibernation takes place. An important factor which causes this variation in the time of appearance is the temperature of hibernaculum. The temperature of the air alone is not the sole factor which affects the development of hibernating rice-borers. There is a considerable difference, in different hibernacula, in the amount of radiant energy which a hibernaculum receives from the sun according to whether it is in the sunshine or in the shade. This brings forth a considerable difference in the temperature of different hibernacula as has been shown by Holmquist[1]. Consequently, the temperatures of hibernacula differ from the air temperature in different degree. The temperature of hibernaculum is an important factor which determines the time of pupation and emergence.

Part II. Effect of the Moisture of Hibernacula on the Time of Pupation and Emergence.

On discussing the effect of temperature on the pupation and emergence of the rice-borer in the previous chapter, it has been suggested that the contact water might exert some influence on the prolonged period of the emergence of the rice-borer. The recent investigations on the insect physiology indicate that not only the temperature above a certain degree is necessary for breaking up the hibernation and the development of insects but also that the moisture plays an important rôle. According to Babcock[2], Townsend[3] and others[4], besides the moisture contained in air, the contact water, i. e., amount of water which actually moistens the bodies of hibernating insects has an important influence on them.

In view of these opinions, the following experiments were conducted in order to ascertain if the contact water actually affects the time of the pupation and emergence of the hibernating rice-borer.

Method. Hibernating rice-borers were collected and they were made to bore into the dried culms of the rice-plant or the wheat, or sometimes in strips of corrugated card-board paper. These were divided into three groups: A, B and C. These were placed separately in three glass jars. Group A was moistened

with water once in a week ; group B, once in two weeks while group C was not moistened at all and served as the control. The glass jars were kept in a thermostat except in *Experiment 1930, (iii)* which was carried out at variable temperatures in the insectary.

Result. While these glass jars with the rice-borers in them were kept in the thermostat, a considerable part of the larvae were attacked by a fungus and killed. Owing to this fungus attack, very satisfactory results were not obtained. The results are shown in the following table.

Table V.

Effect of Moisture on Pupation and Emergence.

Description of Experiments		Experiments Started on	Pupation		Average Number of Days from the Beginning of Experiments to Pupation	Emergence		Average Number of Days from the Beginning of Experiments to Emergence	Per cent. Emerged	Remarks
			Began on	Ended on		Began on	Ended on			
1929	Group A	March 4	—	—	—	April 21	May 18	59.8	62.0	At 20°C. Moulds on dead larvae.
	〃 B	〃	—	—	—	〃 22	〃 17	59.1	33.0	〃
	〃 C	〃	—	—	—	〃 29	June 17	78.3	46.0	〃
1930 (i)	〃 A	Jan. 16	—	—	—	March 11	April 19	70.0	54.3	At 25°C.
	〃 B	〃	—	—	—	〃 26	May 18	86.8	34.3	〃
	〃 C	〃	—	—	—	April 5	〃 11	101.9	17.1	〃
1930 (ii)	〃 A	March 15	—	—	—	April 2	May 3	38.7	69.0	At 25°C.
	〃 B	〃	—	—	—	March 29	〃 11	40.3	73.2	〃
	〃 C	〃	—	—	—	April 15	〃 19	50.3	75.2	〃
1930 (iii)	〃 A	Dec. 17, 1930	—	—	—	June 12	July 10	190.1	57.5	Variable temperature in insectary.
	〃 B	〃	—	—	—	〃 16	〃 16	192.3	29.5	〃
	〃 C	〃	—	—	—	〃 20	〃 14	201.1	10.5	〃
1931 (i)	〃 A	March 19	—	—	—	May 4	May 24	58.2	30.0	20°C → 25°C.
	〃 B	〃	—	—	—	〃 12	〃 19	58.3	23.0	〃
	〃 C	〃	—	—	—	April 26	〃 31	64.9	44.0	〃
1931 (ii)	〃 A	March 7	March 26	May 7	33.7	April 4	May 17	43.5	49.0	25°C.
	〃 B	〃	〃 25	〃 10	36.3	〃 2	〃 20	46.1	63.5	〃
	〃 C	〃	〃 27	〃 23	43.7	〃 8	June 2	53.9	55.0	〃

According to the records in Table IV, the emergence of moths in group C began, in most cases, considerably later than in groups A and B. *Experiment 1931*, (*i*) was an exception, in which the emergence began slightly earlier in group C than in the other groups.

The average duration from the commencement of the experiment to the end of emergence in group C was, in most cases, considerably longer than in the other two groups. *Experiment 1930*, (*iii*) was exceptional in that the differences of the average durations in the three groups were very small.

When group A and group B are compared, it is hardly possible to find out a significant difference, either in the beginning of emergence or in the average duration from the commencement of experiment to the end of emergence.

In *Experiment 1931*, (*ii*), observations were made on the time of pupation also. According to the results of the observations, the pupation in group C ended considerably later than in the other two groups, so that the average duration from the start of the experiment to the end of pupation was the longest in group C. The average pupal period was 9.8 days in groups A and B, and 10.2 days in group C. Thus, there was almost no difference in the pupal period in three groups. The result seems to indicate that presence of contact water affects chiefly the duration from the start of experiment to the end of pupation, and that the pupal period itself is not much affected by the presence of contact water.

In either of the experiments reported here, the emergence of moth occurred in a considerably long period, and it was not possible to induce moths to appear at a time or in a very short period of time by moistening with water. From the results described above, it seems that moistening with water has some effect on the pupation and emergence of hibernating rice-borers. However, the different treatments given to the hibernating larvae did not produce conspicuously different results. This fact probably indicates that a certain unknown factor or factors other than temperature and moisture may have something to do with the breaking-up of hibernation.

As to the percentages of moths emerged from the larvae which were given the different treatments, a consistent relation could not be found. In short, this experiment is by no means conclusive yet and further experimentation is desirable.

Literature Cited.

The papers regarding the rice-borer in Japan are very numerous, so that all of them can not be mentioned here. Only those which are cited in the present paper are listed below.

1) Holmquist, A. M., Studies in Arthropod Hibernation. III. Temperature in Forest Hibernacula. Ecology, XII: 387—400, 1931.

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