Forecasting of Rice Stem Borer Occurrence in Japan

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Introduction

As is well known, in 1940, rice plants in the western part of Japan including Kyushu, Shikoku and a part of Honshu were heavily damaged by rice leaf hoppers, and the damage resulted in a loss of 234,000 t corresponding to 2% of the total rice production at that time.

Consequently, from a economic point of view at that period before World War II, it was quite reasonable that forecasting the outbreak of injurious insects and diseases was taken up as a important phase of agricultural improvement aided by the govornment.

Although the forecast of the rice stem borer, *Chilo suppressalis* Walker was always accompanied with some technical difficulties, we had considerable data, mainly obtained by light traps set up throughout Japan, during past several decades. In fact, at the beginning of this work, the statistical method based upon the light trap data was generally applied. Some investigaters took notice of the relationship between climatic conditions and the occurrence of the borer, and successfully introduced some formulae useful for the forecasting. [5),7),9),10),11)]

Aftere the war, however, following the introductin of large quantities of powerful insecticides which have been applied almost in all paddy fields of Japan, the ecological status of the insect has changed. Besides this, recently the extraordinary early cultivaton of rice plants has been extended to such an extent that the rice plant is liable to be attacked by this borer at all stages. Accordingly, the statistical method of forecast based on the records accumulated up to date seems to be less useful. So that, some trials which will be described later were started from about 1950.

Now, the observatory stations totaling 540 in number are scattered throughout Japan, and detailed data are offered from each prefecture every 15 days from April to October. From this work came a great deal of materials useful for the advancement of studies on this interesting subject.

The forecasting of rice stem borer has been investigated from several aspects as follows:

1) Determination of peak-date of moth appearance.
2) Assessment of insect population at some critical period.
3) Outbreak pattern of the insect.
4) Determination of most optimum time to apply insecticides.
5) To determine whether it is useful to apply insecticides or not prior to emergence of the insect.
6) To survey area where the damage caused by this borer is usually serious.

Regarding these, the author intends to demonstrate the recent advances in the work concerning the forecasting of the rice stem borer from both fundamental and applied phases.

Life history and injury

The rice stem borer emerges twice a year, but in southern parts of Shikoku it is reported to have three generations, while in Hokkaido and in some parts of northern Honshu it appears only once a year. There are at least two distinct ecotypes showing different characteristics. The first ecotype, which is called "Shonai-ecotype", is distributed in such prefectures as Akita, Yamagata, Niigata, Toyama and Ishikawa facing the Japan Sea, and has comparatively a shorter life cycle than the second, which is called "Saigoku-ecotype", and occurs in the western part of Japan. Tsuchiyama point out that the rice stem borer occurring in Kochi Prefecture (the southern part of Shikoku) shows characteristics other than that of "Saigoku-ecotype," which may be called "Tosa-ecotype."[2] Recently, it has been reported that three is the univoltine rice stem borer in a limited area in Niigata Prefecture (1963).

The overwintering larva seems to begin showing signs of awaking from diapause early in the spring by increasing its sensitivity to environmental conditions, especially to temperature. In this regard, it may be worthy of note that the diapause intensity of larvae fluctuates year by year, and this is the major factor which affects the time of the moth appearance.

The time of the moth appearance varies greatly according to local climatic conditions, the cultivation routine of the rice plant and the genetical differentiation of the insect. As a general trend, the time of moth appearance becomes earlier from year to year, corresponding to the introduction of the extraordinarily early cultivation of rice plant.

Larvae hatch out in succession 10 days after eggs are laid, and immediately bore into the stem. When the larvae grow to some extent and the rice plants wither, they begin to disperse gradually to neighbouring stems. The damage caused by the first generation larvae is known as so-called "dead heart" and when it breaks out severely the crop is almost destroyed.

At the beginning of August the larvae commence to pupate, and the peak of moth emergence comes around the 15th to 25th of August.

The moths which appear during each generation vary in number from location to location due to environmental conditions. In paddy fields where early cultivation is introduced, larval survival in the first generation is liable to be greater and this leads to the large population of the moth in the second period. But, on the other hand, in areas where insecticides are applied as a matter of course, the population of the second generation becomes smaller.

Great damage which is recognized as white head is often brought about by the second generation larvae in the autumn. Very poor rice grains are produced when larvae feed on the rice plants after heading or blooming, and the plants are liable to wind break.

It has been proved that the later the moth appears, the less the damage. So, when the number of moths and the time of their appearance are forecasted to be less and later than usual, respectively, chemical control measures become unnecessary.

After harvest of the rice, the larvae remain in the stems or stubbles. With seasonal advancement they begin to enter diapause and overwinter in a state of quiescense.

It may be noticed here that there are some areas where the infestation of the borer is always heavier compared with that of the neighbouring areas. This phenomenon is so remarkable that the farmers must use a lot of insecticides in the former case and still have a lower yield, whereas in the latter they need not to apply insecticides. In general, such a difference as mentioned above seems to be attributable to the silicon supplying power of soils. The soil of more infested paddy fields contain a low level of available (easy soluble) silicon, and vice versa[8]

Method of forecast

Time of moth appearance

It is very important to forecast the peak-date of the moth appearance, because the opportune time to apply insecticides is determined by the time of the peak of the moth appearance. Generally, the most suitable time to use insecticides is considered to come about 2 weeks later than peak-date in the first generation, while it coincides with the peak-date in the second generation.

First moth appearance : At present so called "Incubation method" is widely adopted. In this method about 300 larvae collected from the field early in spring are transferred to the incubator regulated at 25°C, and relative humidity is maintained at 90-95%. The incubation should start on the same date every year. And the period before pupation is measured. Most of larvae under such conditions finish to pupate by the beginning of May. When the period from start to average pupation date is longer or shorter than usual, then the time of moth appearance under natural conditions can be expected to be delayed or accelerated. This method is based on the fact that the intensity of diapause in the hibernating larvae, on which time of moth appearance conclusively depends, varies year by year. An example which may illustrate this phenomenon is shown in Fig. 1. From the relationship between the intensity of larval dispause and the time of moth appearance can be introduced a simple formula expressed as $y=ax+b$ (y : Peak-date of moth appearance in June, x : Diapause intensity expressed by average days before pupation or emergence at 25℃, a and b : Constants).

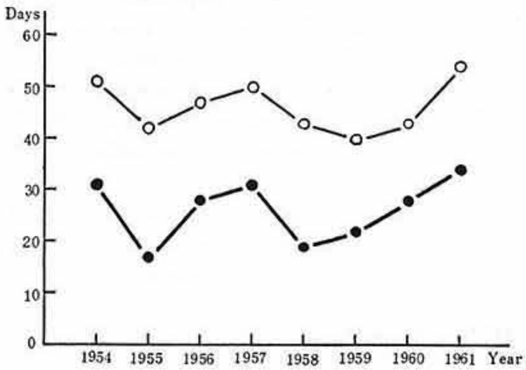

Fig. 1 Goodness of fit in forecasting 50% moth appearance in first period(at Kumagaya).
—o— Days from May 1st to 50% moth appearance date
—•— Days before 50% pupation at 25℃ (Incubation started from March 10th)

In order to confirm the physiological feature of diapause in this borer concerning the matter mentioned above, precise studies on the hormonal mechanism of the larval diapause have been carried out. From the results hitherto obtained, it is concluded that the larvae diapause in the rice stem borer is caused and maintained by the inhibitory action of the corpora allata on the brain-prothoracic system.[3]

Second moth appearance: Judging from light trap records, the time of second moth emergence seems to correlate with the mean temperature in July. On this basis, some formulae for forecasting the time of moth appearace have been introduced. However, the method which seems to be most reliable at present is considered to be the "pupation curve method". This was first demonstrated by Suenaga (1955)[13] and is now practically applied.

When we observe the pupation ratio every day or every other day from the end of larvae period in the paddy field, then we are able to get a pupation curve which shoud be correlated with that of emergence. From this relationship, a 50% emergence date or average date of emergence can be forecast eight or nine days prior to average emergence. It may be added that this period means the pupal period at that time.

Ishii (1955)[4] proposed to take up the so called "probit method" which was successfully applied in Hiroshima Prefecure. On the other hand, Torii (1959)[15] has advanced a logit method to forecast 50% peak-date. According to him this method is convenient when applied in a case where the emergence curve of moths is asymetric.

In forecasting of the second moth appearance another method called "cyst method"[1] was successfully introduced. The principle of this method depends on the fact that the spermatocysts of male larvae grow in diameter with the larval maturation towards the pupation. Goodness of fit in forecasting by means of these methods is quite high especially when attempting to forecast the peak-date of moth appearance in limited area.

Population density

Although insecticides such as Parathion, EPN, Baycid, Sumithion, BHC etc. are generally applied prior to rice stem borer occurrence, it is still desirable to forecast the population of the larvae which largely relates to the degree of damage on the rice plant. However, to date the technique of the forecasting the population seems to be unsatisfactory compared with that of the moth appearance.

Population density in first perid: The light trap records have proved that the number of moths which appear during the first period highly correlate with the number that appeared in the second one of the previous year. From this relationship, a simple formula has been worked out to forecast the former. An example is given bellow.

$y=2.3x+401.7$ (y; Catch of moths in the first appearance, x: Catch of moths in the second appearance of the previous year).

Recently, it has been discovered that there is a high positive correlation between the number of moths in the first appearance (y) and the number of hibernating larvae per acre which are successful in pupation (x). The latter(x) may be introduced by sampling the larvae in the paddy fields and obtaining pupation ratio in the experimental population kept at 25℃. Some examples are given below (Table 1).

At Yoshimi(Saitama Pref.):

$y=0.028x+1071$

At Chichibu(Saitama Pref.):

$y=0.022x-328$

At Kumagaya(Saitama Pref.):

$y=0.017=940$

Table 1. Goodness of fit in forecasting rice stem borer moth population in first appearance.

Locality	Year	Number of moths forecasted	Actual number of moths caught by light trap
Yoshimi	1955	2610	2534
	1956	1134	1511
	1957	3481	3648
	1958	2220	2016
	1959	1504	1241
Chichibu	1954	953	595
	1955	953	501
	1956	0	442
	1957	2324	2788
	1958	1347	1142
	1959	100	147
Kumagaya	1954	2464	2143
	1955	-*	3777
	1956	1239	1333
	1957	2014	2454
	1958	-*	1503
	1959	1126	915

* Omitted because of lack of test animals

According to Tsutsui(1949)[16], larval population density usually falls in western Japan, if the maximum temperature of paddy field water rises above 35℃ during the rice growing period after transplanting. However, this does not mean that the higher water temperature causes the death of rice stem borer larvae, because Kono et al. (1961)[6] obtained the opposite results that exposure to the high temperature (as high as 36° to 37℃ for several hours a day) did not affect the larvae which were reared on an artificial diet under aseptic condition. Therefore, it may be reasonable to consider that the growing larvae decrease in number by some microbial organisms at high temperature under natural conditions.

Population density in second period: It is a difficult problem to forecast the population of moths which appear during the second period by measuring the population density of the first generation, because most of the larvae are sometimes killed by natural enemies in their final stages. However, roughly speaking the population of larvae which approach the full-grown stage seems to indicate the scale of moth appearance.

Upon the forecasting of population, the sampl ing should be made according to a strict program which is designed previously.[15]

Outbreak pattern

Recent advances in agricultural practice have resulted in a change in field population and seasonal prevalence of the rice stem borer. Namely, it is often observed that there appear dimorphic peaks in the moth emergence curve. However, the causes which affect the pattern of the moth appearance in the field have been fairly well analyzed. The data obtained at Dejima of Ibaraki Prefecture revealed that the ratio of moth catch which forms the first peak in the first moth appearance, is highly correlated with the ratio of early harvesting area to the total paddy area concerned. This trend was also observed in materials gathered from the field, which were incubated at 25℃ in order to forecast the time of moth emergence. Such phenomenon may be understood from the fact that the intensity of larval diapause becomes slighter when forced starved by early reaping. At Dejima the date of 50% moth catch seems to come earlier in the area where the ratio of late reaping is rather high compared with other area. And also it has been indicated that the population of moths measured by means of light trap increases with advancement of the early reaping of the rice plant.

Generally, in the area where the ratio of early transplantation of rice was high, the population of the moth was maintained large so far as our experiments were concerned.

As Yoshimeki(1964)[17] pointed out, because of the cooperative work of both the government and prefectural agencies in these activities, there scarcely occurred a severe outbreak of rice stem borer during past 10years. Nevertheless, insect pest problems have been complicated from year to year, and the forecasting practice may have to be modified to meet every-changing conditions. In such a sense, the direct supervisions by local forecasters have proved to be useful to level the accuracy of forecasting of the outbreak of this borer.[14]

Summary

The mass-outbreak of leafhoppers that occurred over almost all of Japan in 1940 led to the institution of a national pest forecasting system in 1941. Since then the method of forecasting insects, especially rice stem borer, has been modified to meet every change in the rice cultivation.

In case of the rice stem borer forecasting should be, at least, composed of two elements; namely forecasting the time of insect appearance and population assessment. In all events, however, it is most desirable to forecast the peak-date of moth appearance, because the opportune time to apply insecticides can be worked out by knowing this. To this end, a so called "experimental method of forecasting" has been established and adopted by the observatory station. This method is based upon the time that moth appearance can be seen by measuring the degree of some physiological development in the larval stage.

On the other hand, although the method to forecast the population is unsatisfactory, many efforts have been made recently and some method which is better seems to be developing. In fact, the goodneess of fit in forecasting has reached as high as 90% or more of late year.

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Resistance of Rice Plant to Bacterial Leaf Blight and Strains of Causal Bacteria

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Bacterial leaf blight of rice [causal bacteria : *Xanthomonas oryzae* (Uyeda et Ishiyama) Dowson] that is known to have occurred frequently since the latter part of the 19th century, increased rapidly in this century, and recently has been affecting some 300,000 or 400,000 ha. This disease, together with rice blast and sheath blight, are the three biggest diseases of rice in Japan. It has recently been recognized that bacterial leaf blight occurs in several countries in southeastern Asia, such as Formosa, the Philippines, Indonesia, Thailand, India and Ceylon. Thus, it is thought to be distributed in most of the leading rice producing countries of the world. Although no data on affected area and damage in these countries are available, injuries from this disease will become more serious with improvement in rice cultural methods and extension of fertilization.

In Japan, however, studies on bacterial leaf blight of rice have developed remarkably in recent years, clarifying to a large extent the overwintering of casual bacteria, the process of infection, the development and the spread of the disease. These results of studies have been combined with the development of new chemicals to achieve a considerable success in the control of the disease. But the Japanese control method thus developed can not necessarily be applied with the same success in other countries where the environments and conditions of rice culture are completely different. Therefore, each foreign country should study control methods with consideration of its own peculiar conditions. Most of the strains of the pathogen with different virulences and rice varieties with different resistance which have been studied so far and described in this report are Japanese ones. It should be taken for granted that many varieties completely heterogenous in resistance and various strains of the pathogen in virulence are distributed in foreign countries. Therefore, each country should study strains of bacterium and resistance of each rice variety independently from that in Japan.

Strains of bacterial leaf blight of rice

The isolates of bacterial leaf blight pathogen are somewhat different from each other in physiological properties such as production of hydrogen sulfide, liquefaction of gelation, decomposition of arabinose,[12] etc. But it is hard to classify these bacteria into strains by such different properties. Since the most conspicuous difference is usually recognized between isolates in their susceptibility to phage and virulence against rice varieties, these two properties have become the criteria for the classification of bacterial leaf blight pathogen into strains.