Centrifugal Progress of Outbreaks of the Rice Stem Borer, *Chilo suppressalis*

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INTRODUCTION

The outbreak of the rice stem borer, *Chilo suppressalis* occurred in 1953 not only in Kyushu Island but almost all over the southwestern Japan. Analysis of the records of annual catch of moths in light traps, however, reveals that the peak years of different points of observatory stations do not show any correspondence in time even among points located in the same Prefecture.

It may be said that in consideration of outbreaks of the rice stem borer, spacial limitation relative to an outbreak year is liable to have been neglected by many authors. Accordingly, we attempted from this viewpoint to analyze the outbreak which was observed in Kyusyu Island during the period of 1953 to 1956 and other characteristics observed in that period.

METHODS

Records of moths caught in light traps were collected from thirty points of observatory stations located all over Kyusyu Island.

The rice stem borer has two generations a year in Kyushu district and generally the total moth population of the summer (the first) generation predominates the fall (the second) one. The relative population size of these two generations at each station is comparatively fixed year by year.

UTIDA (1958) used a formula to eliminate these seasonal differences and by which the long-term trend of the population fluctuation can be treated ignoring the variation caused by seasonal changes as follows: The corrected value of the fall generation = (each value for moths captured in the fall generation) × (the mean population level of the moths in the summer generation during the whole range of observed years) / (that of the fall generation). Using these values the long-term population fluctuation curve is made at each station. Some of the examples of these curves are given in Fig. 3, and a map of the station from which the capture records were obtained is given in Fig. 1.

Sex ratio ($\varpi/\delta+\varpi$) was also calculated from the light trap records. Sex ratio in terms of generation fluctuates partly due to the difference of the mean level of sex ratio between the summer and the fall generation. Thus, to minimize an outward appearance due to inter-generation difference, the deviation of each sex ratio from the mean level of each generation was calculated with its 99 per cent confidential limit.

RESULTS

Special Limitation of the 1953 Outbreak

Thirty examples of the population fluctuation curves are obtained from all over Kyushu Island. These curves are given in graph as shown in Fig. 2, and there exist several groups of points differing in their outbreak years. Moreover, the 1953 outbreak was only observed in the northwestern district of Kyushu Island. Other districts where are geographically isolated from the northwestern...
district can be considered independent in their spatial extension of the 1953 outbreak. It seems that this is a remarkable space limitation of the 1953 outbreak in Kyūsū Island. In the following paragraph, we shall confine our discussion to this northwestern district, and refer to the 1953 outbreak unless to make any remark.

**Delayed Occurrence in Outbreak Year.**

Some examples out of twenty three curves of population fluctuation in the northwestern district except for Iki and Gotō Islands are given in Fig. 3.

It can be found that the first peak of the outbreak in this district appeared in the summer generation of 1953 at Saga and Sirota that are situated at the centre of Saga Plane. Then, the occurrence of peak generation delayed as remote from the centre until the outbreak come to an end at Hirado where the peak came at the summer generation of 1956.

Stations belong to the same outbreak year are encircled as shown in Fig.4. It is to be noted that the centrifugal extension of outbreak takes its way to southward coastal region rather than to northward mountainous region. It leaves, however, some doubt with regard to the centre of the outbreak, because Tosu which is 50 km. distant from Shirota in a northeast direction had a peak in 1952 earlier.
Fig. 2. Schematic representation of population diagrams of the rice stem borer moths. Length of horizontal lines shows duration of years of available capture records. Double circle denotes a peak generation, single circle denotes the generation shows high density next to the peak, triangle the termination of outbreak. The first and the second generations are distinguished respectively by the open and the black mark, e.g. the open double circle means that a peak appeared in the first generation.
Fig. 3. Examples of population fluctuation curves of the rice stem borer moths. The open circle shows the first generation and the solid one the second generation.

These facts infer us that the initiation of the 1953 outbreak had started from Tosu in 1952 and the 1953 outbreak of Shirota and Saga affected on second peak of Tosu in 1954. Shirota and Saga are tentatively adopted as the centre of the 1953 outbreak because evidences are insufficient to support this fact.

Munekata and Yukuhasi show peak at the summer generation of 1954. It is difficult to decide by the available data whether outbreaks of these places were induced under the direct influence of the 1953 outbreak. For this reason these two places are tentatively excluded from the area of 1954 outbreak in Fig. 4.

Sex Ratio
Sex ratio of the rice stem borer fluctuates generation by generation and year by year. Each station has its specific average value of
Fig. 4. Centrifugal extension of the 1953 outbreak of the rice stem borer.

the sex ratio of each generation. To eliminate these variations specific to both station and generation, deviations of sex ratio from the mean value of respective generation at each station are plotted as shown in Fig. 5.

It is noteworthy that high values of sex ratio are observed closely accompanied with the outbreak at Shirota, where is the centre of the 1953 outbreak. This association between high sex ratio and the outbreak can be seen at most of the stations though not so close as at Shirota.

Other feature in this regard is the relation between the termination of the outbreak and the low sex ratio (Table 1). The low sex ratio can be seen one or two generations before or simultaneously with the end of the outbreak in sixteen out of twenty one stations.

**Food Habit and Migration of Larvae**

A mass emigration of larvae that heavily infested the rice plant was observed in the late fall, 1952 at Saga before the 1953 outbreak of the moths, and they invaded the vegetable field adjacent to the paddy field, where they fed a cruciferous plant, *Brassica campestris*, the garden radish, *Raphanus sativus* var. acanthiformis, Taro, *Colocasia Antiquorum* var. *esculenta* etc. In another case, larvae were found migrating across the pavement road with six metre width, and fed in the stem of Medake bamboo, *Pleioblastus Simoni* (see photographic illustrations).

In Japan, the normal range of host plants of the rice stem borer is almost confined to the rice plant, but sometimes the larvae feed on the stem of Makomo, *Zizania latifolia*, a graminaceous weed which grows in marshy places.

**DISCUSSION**

Climatic factor, especially low temperature in the period of July, is currently believed to be responsible for the cause of the initiation of outbreaks of the rice stem borer. Low temperature to the advent of the peak emergence of the first generation moth prolonged the appearance of moths and bring about an enormous increase of laying eggs on rice plant seedlings in paddy field (ISHIKURA, 1950; MIYASHITA & Itô, 1961).

Low temperature during the period of the young larvae of the first generation, namely in the late part of July, lowered the mortality of larvae because of the water temperature in the paddy field being held low (TSUTSUI et al., 1955). Then gradual increase of population continues to reach a peak at the first generation of the next year and the population decreases abruptly in the following second generation (ISHIKURA, 1951).

The 1953 outbreak was preceded by low temperature in July during the period from 1950 to 1952. Even if we allow the theory of climatic release as an initiation of the 1953 outbreak, the delayed occurrence of outbreaks
Fig. 5. Fluctuation of sex ratio from the mean values of the first and the second generations. Solid circle shows the value which is significant with 99 per cent confidence and the open circle non significant. Other explanations refer to Figs. 2 and 3.
in centrifugal manner from the outbreak centre is impossible to explain.

SCHWERDTFEGER (1950) considered that the delayed occurrence of outbreak year which was often observed in the nun moth, *Lymantria monacha*, is rather due to difference of local conditions that determine at what time the infestation will reach a sever stage than often assumed to be moth flight.

Long range dispersal of the spruce budworm, *Choristoneura fumiferana*, was reported by GREENBANK (1956, 1957) in regard to an initiation of outbreak. He believed that the moth dispersal plays an important role in the course of an infestation and favourable conditions of climate and forest stand are the prerequisite for the successful development of an outbreak by invaded moths.

The progress of outbreaks of the spruce budworm have been followed by PILSON & BLAIS (1961) beginning in 1939 and ended in 1958 across Quebec in Canada covering about 700 miles in an easterly direction. They concluded that climatic release and dispersal of adults were responsible for this progress of outbreaks.

The direct observation of mass flight of moths in the 1953 outbreak was not made, but it is unlikely to attribute these delayed occurrences of outbreaks to the difference of development rate of outbreak at each place, because of their centrifugal spread from centre and area continuity of infestation. The fact that the coverage of the 1953 outbreak was within 150 km. in diameter also rejects the possibility of delayed occurrence of climatic factor.

From these circumstantial evidences it can be supposed that moth dispersal must have been a contributing factor for the radial extension of the 1953 outbreak.

Change of sex ratio in favour to female is responsible for the fluctuation of population density. TSAI & WANG (1933) suggested the possibility of forecasting an outbreak in some insect species by the sex ratio of the preceding generation. According to SCHWERDTFEGER (1950), climate, nutrition and biotic factor such as parasites affect sex ratio of forest insects. And he found a possitive correlation between sex ratio and the population density of *Panolis flammea* (SCHWERDTFEGER, 1952). GREENBANK (1957) found the fact that females predominate in the invading population of the spruce budworm moths.

It can not be decided, at the present state, whether the high sex ratio was an immediate cause of inducing outbreak or a resultant phenomenon of outbreak. As shown in the Fig. 5, there exists a relatively close coincidence between the end generation of outbreak and the one which firstly shows the low sex ratio with 99 per cent confidence after the outbreak. This also suggests an underlaying density dependent mechanism which controls the sex ratio other than abiotic factors.

It must be noticed that the termination of the outbreak of each place retards in time as remote from the outbreak centre, and this may be produced by density dependent factors, especially by parasitic wasps as UTIDA (1958) suggested in his analysis of outbreaks of the rice stem borer.

**SUMMARY**

Analysis of records of annual catch of moths in light traps of the rice stem borer, *Chilo suppressalis*, during the 1953 outbreak in Kyūshū Island reveals that the occurrence of outbreak year of different observatory stations delayed in time and shows a spacial limitation in its extention of infestation.

The 1953 outbreak is supposed to be originated initially at the central zone of Saga Plane and spread in centrifugal manner covering the coastal zone of Ariake Sea and ended in 1956.

It was observed in most of the stations that the 1953 outbreak accompanied with significantly high value of sex ratio lasted at least for two consecutive generations, but it can not be decided whether the high sex ratio is an immediate cause of inducing outbreak or a resultant phenomenon of outbreak.

Mass emigration of larvae was observed at Saga in the late fall in 1952, and feeding on unusual host plants was also occurred at the larval mass emigration.
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REFERENCES


要

ニカメイチュウの大発生において見られた大発生年の遺心的ずれと地域的広がり

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これまでニカメイチュウの大発生を問題とする場合、その地域的広がりと発生年の同時性の規定があいまいであった。1953年に西日本全域にわたって見られるニカメイガの大発生を九州各地の30ヵ所から集めた大発生年を中心とする長期の誘ガ成績に基づいて解析を行なった。各地の誘殺曲線の年次変動からうかがえる大発生には同一県内の観測地点間でも一致を示さなかった。これを見地図上に示すと九州北部（有明海沿岸地帯）では佐賀県を中心として隣接諸県に発生年および世代に時間的ずれを見せて遺心的に行波していることが認められた。しかし九州のほかの地域ではかならずしもこの期間に大発生が認められず、地域的にも九州西北部の大発生はそれ自身の地域的限定性を持っていることが認められた。九州西北部の大発生の中心と見られる佐賀県域および佐賀市の大発生の直接的病因は気候・耕種条件（肥料解禁など）があずかったと思われるが、中心点からの遺心的かつ連続的な大発生の広がりは、成虫の集団飛翔による他地域への侵入が最も有力なものと考えられる。またこのときの大発生に伴った特異な現象は性比（♀/♂+♀）が非常に高く、大半の場所で少なくとも2世代以上にわたって1%の危険率で各地点の1、2世代期別平均性比より有意に高い値を示した。また有意な最低性比はほとんど大発生の終息世代もしくはその前後の世代に観察された。

大発生の終息世代は、大発生世代ほどには顕著ではないが、大発生の中心より離れるにしたがい同様に時間的にずれを示している。

1952年には佐賀市でイネに大被害を与えた2化期幼虫が団結して通常の寄主植物ではないメダケ、タカナ、大根、さといもなどを加害するのが観察された。
Explanation of photographs: Damage caused by larvae of the second generation of the rice stem borer at Saga city in the late fall of 1952 (a). Larvae of the rice stem borer feeding on Taro, *Colocasia Antiquorum* var. *esculenta* (b). Medake bamboo, *Pleioblastus Simoni*, infested by the larvae (c).