# What has Happened to the Rice Borers during the Past 40 Years in Japan ?

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## Introduction

*Chilo suppressalis* (Walker) and *Scirpophaga incertulas* (Walker) are the economically important two rice borers in Japan. Although the distribution of *Scirpophaga* is much restricted to southern Japan, the maximum area of paddy fields infested by *Scirpophaga* was one tenth of that of *Chilo*. *Scirpophaga* is monophagous and has 3 generations per year, while *Chilo* is oligophagous having 2 generations. In 1948, a maximum of 130,000 ha of paddy fields was infested by *Scirpophaga*. Since then an ever decreasing trend in occurrence has been observed and it is presently almost extinct from Japan.

On the contrary, *Chilo* had increased in infested areas until the early 1960's when the infestation was at its maximum. Since 1970 the area infested by *Chilo* has continued to decrease. No evidence of local extinction of *Chilo* has been reported. Currently, the population density of *Chilo* seems to fluctuate around at a low level, specific to each locality. In this paper, the causes of the differential population trends between the two species of rice borers will be discussed.

## Population trends and their causal agents

The annual changes over 45 years in the area infested by the 1st generation of *Chilo* and *Scirpophaga* are shown in Fig. 1. The outbreaks of *Scirpophaga* were observed during 1945–50 and again to a lesser extent in the early 1960's. The major factor responsible for the earlier outbreak was the

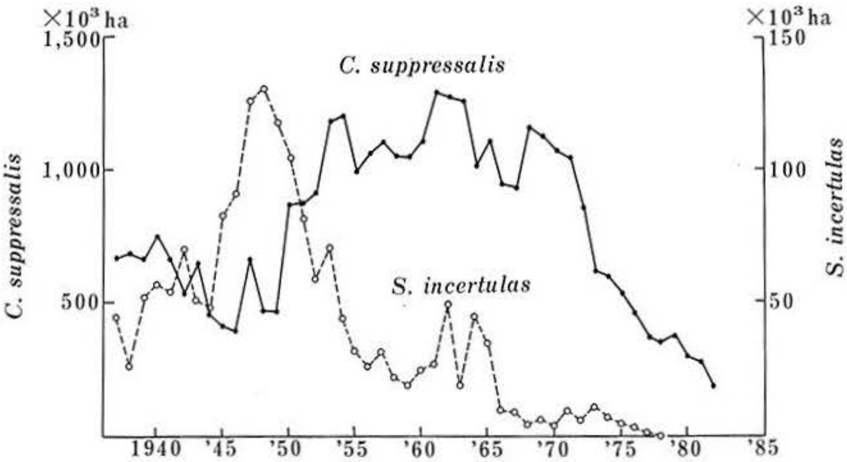


Fig. 1. Annual changes in hectarage of paddy fields infested by two borer species in Japan[6)]

**Table 1. Factors responsible for the population decrease in *Chilo suppressalis***
(Modified Table 2 in Kiritani, 1977)[4]

| Factor | Stage of larvae affected | Since around |
|---|---|---|
| 1. Cultivation of early planted rice | Overwintering larvae | 1955 |
| 2. Replacement of panicle weight type with panicle number type varieties* | Growing larvae of 1st and 2nd gens. | 1955 |
| 3. Use of BHC granules | 1st gen. | 1960 |
| 4. Utilization of stalks as manure for vinyl house culture | Overwintering larvae | 1960 |
| 5. Early harvest of middle season rice by 2–3 weeks | Overwintering larvae | 1960 |
| 6. Increase in amount of slag ($CaSiO_3$) by 2–3 times | Growing larvae of 1st and 2nd gens. | 1965 |
| 7. Introduction of combined harvester in association with burning stalks | Overwintering larvae | 1965 |
| 8. Nursery tray insecticide treatment in association with machine planting | 1st gen. | 1970 |

* Panicle weight type: big (heavy) panicles, but less in number of panicles.
Panicle number type: more panicles, but each panicle is smaller.

staggering of planting of rice. However, *Scirpophaga* had been controlled by the simultaneous practice of late planting of rice. In 1948, *Scirpophaga* infested 130 thousands ha of rice. Since then it has shown an ever decreasing trend in the infested area. The introduction of synthetic insecticides including BHC and parathion following the 1948's outbreak was most likely responsible for this decline. In the 1980's, *Scirpophaga* disappeared from the national agricultural statistics, because it occurs only sporadically over 20–30 ha in the southernmost part of Kyushu. It is likely that *Scirpophaga* will become extinct in Japan sooner or later[6].

The decline of *Chilo* started following the decrease of *Scirpophaga* with a time lag of about 15 years. The sign of decrease of *Chilo* has been observed since the early 1960's. The ever decreasing trend of *Chilo* became clearer in the 1970's. These are shown in Fig. 1, where the two lines for *Chilo* and *Scirpophaga* crossed each other around at 1950. This indicates that the factors responsible for the population dynamics of two species of borers are different from each other. As shown in Table 1, the various factors were responsible for the decline of the *Chilo* population, either singly or jointly. These factors have reduced the survival rate either of the overwintering or the growing larvae of *Chilo*. Except for BHC granules, these new technologies have been introduced for increasing rice production and saving labor[4,5].

**Table 2. Effect of area-wide withdrawal of insecticidal control against the 1st generation of *Chilo suppressalis* for five successive years on the percentage of injured sheaths in Niigata Prefecture**[1]

| Year | No insecticide control area* | Conventional control area** |
|---|---|---|
| 1975 | — *** | — *** |
| 1976 | 2.5**** | 2.5**** |
| 1977 | 2.1 | 3.1 |
| 1978 | 2.0 | 3.5 |
| 1979 | 2.3 | 3.7 |

* 17 ha. ** 1200 ha. *** The first year of experiment. **** Paddy fields were examined for injured sheaths before the chemical treatment.

There have been some disputes about the role of insecticides in suppressing the *Chilo* population. Table 2 shows the comparison of damage due to *Chilo* between the two localities of paddy fields that have been treated with and without insecticides. Obviously, the results showed no significant difference in the percentage of injured sheaths between the

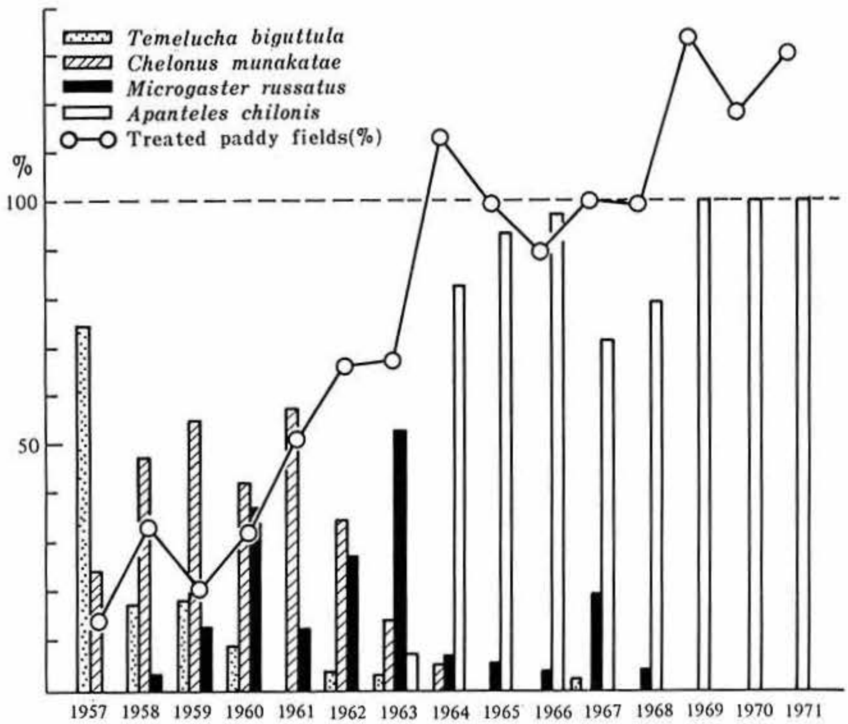


Fig. 2. Faunal changes of larval parasites of *Chilo suppressalis* in Aomori[8]

two areas. This indicated that some environmental factors other than the insecticides may be the contributing factor in the maintenance of a low population density of *Chilo*[1].

## Change in parasitic fauna of *Chilo* larvae

If an ever-decreasing trend of *Chilo* is to be continued, the extinction of *Chilo* population could be expected locally somewhere in Japan. However, there has been no report of such local extinction. Therefore, it is reasonable to look for some density-dependent factors preventing *Chilo* from the local extinction.

In this respect, drastic changes in faunal composition of larval parasites had occurred everywhere in Japan. One of the examples is shown in Fig. 2. The fauna of larval parasites has been changed in relation to the intensity of pesticide treatment of paddy field in Aomori Prefecture. These solitary parasites, i.e. *Microgaster russatus*, *Chelonus munakatae* and *Temelucha biguttula*, having 1–2 generations per year with a rather narrow host range were replaced by *Apanteles chilonis*, a braconid parasite which is multivoltine with 4–5 generations per year, polyphagous and gregarious. The replacement of braconid parasite showed parallelism with the intensification of chemical control. This change-over was completed around 1964 when all of the paddy fields in Aomori Prefecture received pesticide treatments at least once during the cropping season[8].

Similar phenomena can be observed in other parts of Japan[5]. Table 3 shows the replacement by braconid occurred as early as the late 1950's in western Japan or several years earlier than in eastern Japan. This delay in eastern Japan was due to less intensive pesticide control as compared with western Japan. Although the exact causes of these faunal changes remain to be solved, a low larval density could be partly responsible for the

Table 3. Time when *Apanteles chilonis* became dominant among larval parasite faunae of *Chilo suppressalis* in Japan

| Prefecture | Time | References |
|---|---|---|
| Fukuoka | 1955–57 | 2 and 7 |
| Tochigi | around 1964 | 3 |
| Fukui | 1962 | 9 |
| Aomori | 1963 | 8 |

change of parasites from the specialist to the generalist type which is more adaptive to the disturbed environment.

## Density dependency of parasitism

The relationship between the percentage parasitism of *Chilo* larvae and the number of moths caught by a light trap was also examined on the basis of the data obtained at Kuroishi City in Aomori Prefecture (Fig. 3). *Chilo* occurs only once a year in Aomori Prefecture which is located in the northernmost distribution range of *Chilo*. We have data on the percentage parasitism of overwintering larvae during the period of 1957–79 or over 23 years at Kuroishi City. The records of moth catches can be divided into the two periods, i.e. 1957–64 and 1965–79. In the former period, the moth catches exceeded 1000 every year, while in the latter, the annual catches were always less than 1000. It is noteworthy that each of these two periods also corresponds to the periods with two different parasitic faunae. A great difference is observed between the two periods in the response of percentage parasitism against the moth catches. Before 1964, the percentage parasitism decreased with an increase in the moth catches, or changed inverse density-dependently, while it changed density-dependently with a minor variation in the late period after 1965. The parasite which was dominant during this density dependent phase was the generalist, *Apanteles chilonis*.

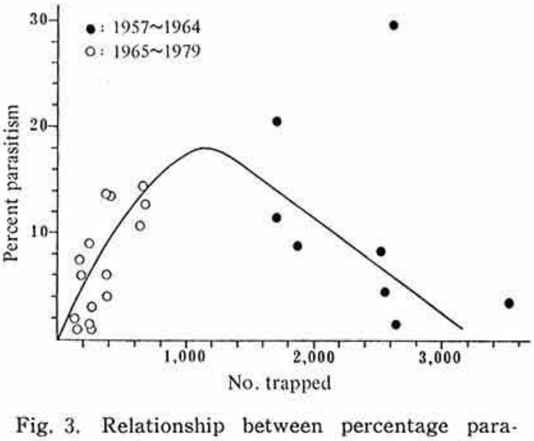


Fig. 3. Relationship between percentage parasitism of larvae and light catches of moths in *Chilo suppressalis* at Kuroishi, Aomori

## Conclusion

A low larval density induced by various cultural practices seems to provide an arena where the interaction system between *Apanteles* and *Chilo* works around a new equilibrium point. The current situation of *Chilo* could be illustrated by a reproduction curve with higher and lower points of equilibrium (Fig. 4). The population density of *Chilo* may continue to increase up to the high equilibrium point once the density passes through the releasing

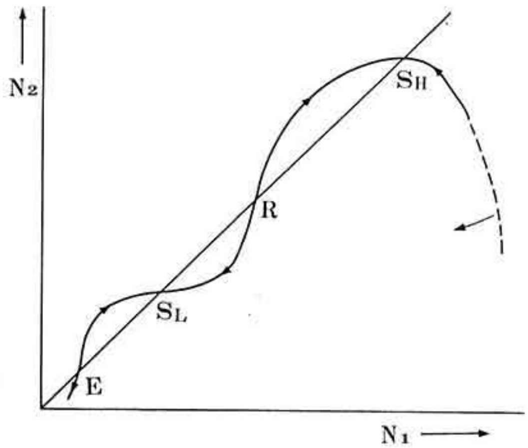


Fig. 4. Hypothetical reproductive curve for *Chilo suppressalis*
$S_L$: Low equilibrium due to parasites.
$S_H$: High equilibrium due to intraspecific competition.

point or unstable equilibrium point. It is considered that the high level of equilibrium during the early period had been maintained by intraspecific competition. So far there have been no cases of successful biological control of rice borers in the world[5]. The present case illustrates the feasibility of biological control of rice borers, through the more sophisticated manipulation of the agroecosystem.

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