Local Differences of Seasonal Life Cycle in Rice Stem Borer, *Chilo Suppressalis* WALKER

By KEN-ICHI KISHINO

1st Agronomy Division, Tohoku National Agricultural Experiment Station

Rice stem borer is one of the most important injurious insects of rice plant in Japan and it is usually bivoltine in practically all regions of Japan.

But in the northern regions of the mainland of Japan and in Hokkaido, it is univoltine while it is trivoltine in the southern regions of Shikoku.

The remarkable regional difference of the seasonal prevalence of this insect has been recognized. But still many problems have been left obcure on the mechanism and cause of this regional difference.

The author has carried out comparative studies on the physiological characteristics of the development and diapause of the populations of different appearing pattern to clarify the forming mechanism of different seasonal life cycle and the geographical variation of such physiological characteristics. The outline of the studies is described hereunder.

Local differences of stem borer appearance and environment

Since Japan is ranged from 31°N Lat. to 41° extending from north to south, the climate of the northern region is very different from that of the south. As this difference seems to be very important in further investigation, its outline and the specific points on the appearance of this insect shall be described in advance.

1) *Local differences of the time of moth appearance*

Fig. 1 shows the local differences of the

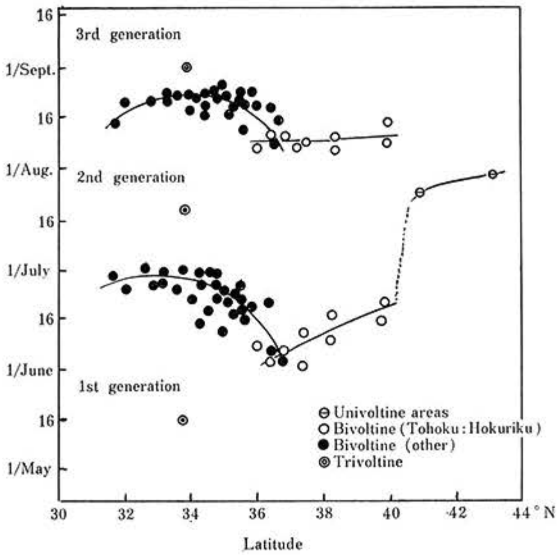

Fig. 1. Geographical variation of the moth appearance peak

time of moth appearance on the basis of latitude. It shows the specific local differences of the first and the second moth appearance. The first moth appearance is very late in the univoltine area and is very early in the trivoltine area. And as to the bivoltine area, though it is early in the northern region and is late in the southern region generally, this area can be divided into two different areas by setting up a boundary around at 36°N. Lat., and the time of moth appearance in the north of this boundary is somewhat different in aspect from that in the south, that is, the higher the latitude, the later the appearance.

The variation range of the second moth appearance is less than that of the first one, and the second moth appearance in the bivoltine and trivoltine areas shows the same trend as the first one.

It is presumable that there are four fundamental types of seasonal life cycles of the rice stem borer in Japan as follows: (1) univoltine type, (2) early appearing bivoltine type, (3) late appearing bivoltine type, and (4) trivoltine type.

2) Local differences of environment

The local differences of the physical and biological factors which seem to be mostly related to the emergence time of this rice stem borer among the environmental conditions are analyzed hereunder. Fig. 2 shows the relation between the yearly total amount of effective temperature and day length at several places. It seems that there exists a high correlation between the amount of effective temperature and latitude. Day length becomes longer from the place of low latitude to that of high latitude, but its trend is variable by season.

Between Kagoshima, a southern city (31.5°N), and Sapporo, a northern city (43.1°N), there are the differences of 1600 day-degrees in temperature and of about one hour in day length on the summer solstice.

The season of cropping of rice as the host plant may be one of the biological factors.

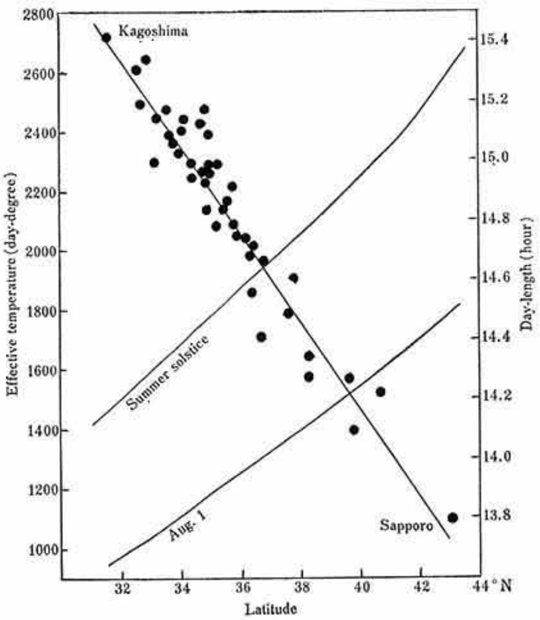

Fig. 2. Geographical variation of the effective temperature and latitudinal fluctuation in day length. Right ordinate, time from sunrise to sunset; left ordidate, accumulated amount of degree-days above 10°C

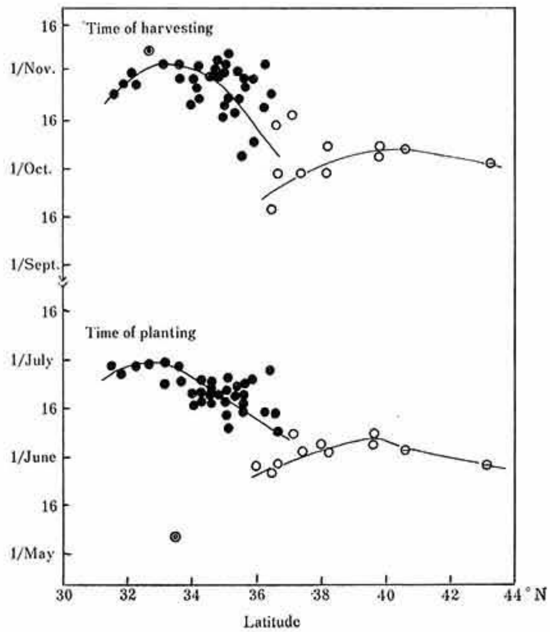

Fig. 3. Geographical variation of the rice cropping season. See Fig. 1.

Fig. 3 shows the local differences of the cropping season. The time of planting is generally earlier in northern areas and is later in southern areas, therefore, this is a reversed trend to the geographical variation of the amount of effective temperature. But there may exist a boundary line around latitude 36°N as to the planting time of rice and the opposite areas of this line show a different trend with each other, that is, in the north of this line, the more the distance from this boundary, the later the planting time. This is a parallel trend with the clinal variation of the amount of effective temperature.

The time of harvesting, though its variation range is large, shows almost the same trend as the time of planting. Thus some specific geographical variation could be recognized on the cropping season of rice plant.

Mechanism forming different life cycles

The physiological characteristics on the development and diapause of the representative population of different life cycles in each area had been analyzed, and on the basis of this analytical results and correlated environmental factors, the mechanism forming the

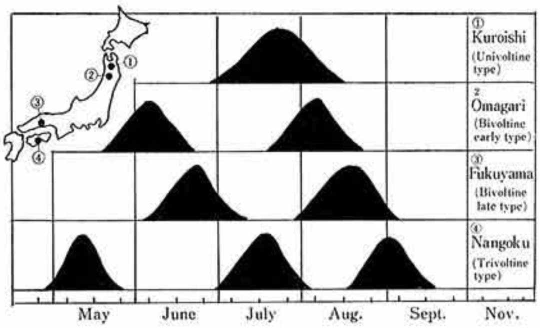

Fig. 4. Diagram of moth appearance in the different seasonal life cycle areas

different life cycles was presumed. The selected representative areas are as follows; univoltine type—Kuroishi (40.6°N), early appearance bivoltine type—Omagari (39.5°N), late appearance bivoltine type—Fukuyama (34.4°N), and trivoltine type—Nangoku (33.6°N). Fig. 4 shows the diagram of moth appearance and positions of these places.

1) *Differences of physiological characteristics*

Table 1 shows the days from incubating day (April 15) with the temperature of 25°C to the pupation of the populations, which were gathered before hibernation at the four representative places described above and hibernated at Omagari to investigate the post-diapause development of hibernating larvae. As to the post-diapause development, the Omagari population was the fastest, and the Nangoku population followed it. There was no great difference between the Kuroishi and the Fukuyama populations, and both of them were late in the development.

Table 2 shows the comparison on the larval duration under the non-diapausing condition (16L:8D)—25°C to find the difference of non-diapausing larval development. Though some

Table 1. Comparison on the post-diapause development among the populations with the different seasonal life cycle

Population	Duration of post-diapause development (days)					
	1967	1968	1969	1970	1971	mean
Kuroishi	47.6	53.8	56.2	49.3	57.4	52.9
Omagari	27.7	20.8	16.2	22.8	24.7	22.4
Fukuyama	54.4	38.8	55.9	59.5	68.9	55.5
Nangoku	31.8	30.6	—	—	—	31.1

Table 2. Comparison on the non-diapausing larval development among the populations with the different seasonal life cycle

Population	Duration of larval development (days)					
	1967	1968	1969	1970	1971	mean
Kuroishi	30.7	29.9	33.9	31.1	28.5	30.6
Omagari	25.3	26.6	23.9	25.5	24.5	25.3
Fukuyama	50.9	34.7	41.4	—	—	42.3
Nangoku	35.4	36.7	—	—	32.4	34.8

yearly variation of larval development can be recognized, the Omagari population was the fastest in the development, and the development of other populations succeeded it in order of Kuroishi, Nangoku and Fukuyama. This order was different from that of post-diapause development.

Fig. 5 shows the appearance of diapausing

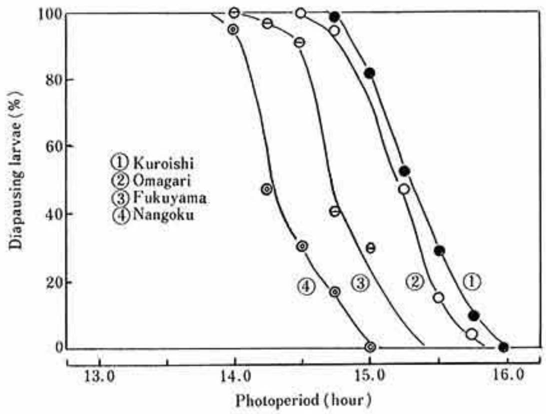

Fig. 5. Photoperiodic reaction of the populations with different seasonal life cycles

larvae by means of rearing under the photoperiod of fifteen minute intervals at the temperature of 25°C to find the difference of photoperiod of diapause induction. The photoperiod of diapause induction of the Nangoku population is shortest, and that of Fukuyama, Omagari and Kuroishi become longer in this order. Therefore, the photoperiod of diapause induction seems to vary according to the latitude of the population's original places.

2) Forming mechanism of different life cycles

The photothermograph, which shows the correlation between photoperiod and temperature, has been utilized as an effective means for the analysis of the occurrence of pest insects.

The analysis of the occurrence of pest insects by means of the photothermograph on the basis of the physiological characteristics described above can clearly reveal the mechanism forming the different life cycles of populations in their respective original places. Namely at Kuroishi, an univoltine area, as the larval development at the post-diapause period of hibernating generation is slow, the time of diapause induction comes at the end of the hibernating generation and about a half of the amount of effective temperature is consumed at the post-diapausing generation. And as the day length is shorter than the critical value of diapause induction at the photosensitive stage of the first generation, the diapause is induced in the first generation and the necessary and sufficient growth for hibernation will be accomplished with the rest of the effective temperature.

Thus the univoltine life cycle is formed. At Omagari, a bivoltine area, the post-diapause larval development is rapid and the time of diapause induction comes just before the completion of the first generation. Consequently the diapause can be induced in the second generation. As the post-diapaus larval development of hibernating generation and non-diapausing larval development are rapid, bivoltine life-cycle of early appearance can be formed.

At Fukuyama, the time of diapause induction comes at the end of the larval development of the first generation, therefore a non-diapausing larval development is carried out as Omagari population, and the diapause can be induced in the second generation. Consenqutly a bivoltine life cycle can be formed. But it is a bivoltine life cycle of late apperance because the post-diapause larval development of the hibernating generation and the non-diapausing larvel development are slow.

At Nangoku, a trivoltine area, as the time of diapause induction comes at the post-larval development stage of the second generation, non-diapausing larval development is carried out twice during this period, and the diapause can be induced at the third generation. Sufficient effective temperature exists in this area to form a trivoltine life cycle.

Therefore, it is presumed that the formation of different life cycles depends on the physiological characteristics of larval development

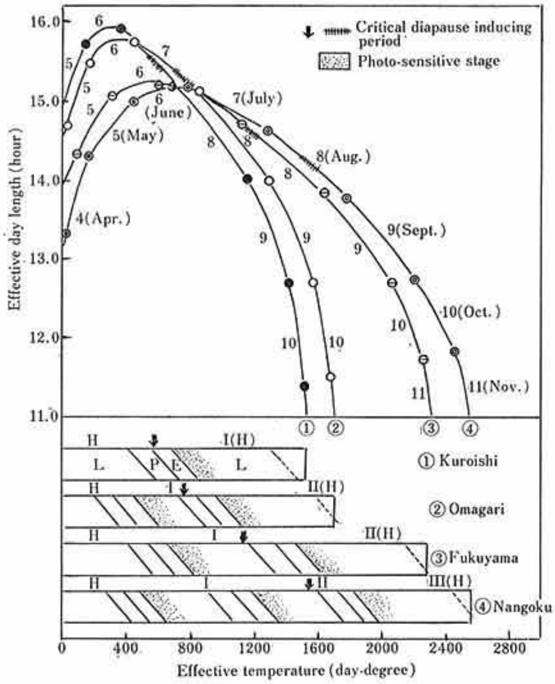

Fig. 6. Photothermographic analysis of the different seasonal life cycles. H; hibernating, I; 1st, II; 2nd, III; 3rd generation, L; larva, P; pupa, E; egg

and diapause, and on photoperiod and temperature.

Geographical variation of physiological characteristics of larval development and diapause

The sample insects gathered from many localities throghout this country were investigated to find the geographical variation of the physiological characteristics of larval development and diapause which had been recognized to be closely related to the appearance of rice stem borer. Fig. 7 shows the results.

1) Post-diapause development of larvae of hibernating generation

Fig. 7-A shows the development duration of the larvae, which were gathered before hibernation and hibernated at Omagari. The larvae were incubated at 25°C from April 15.

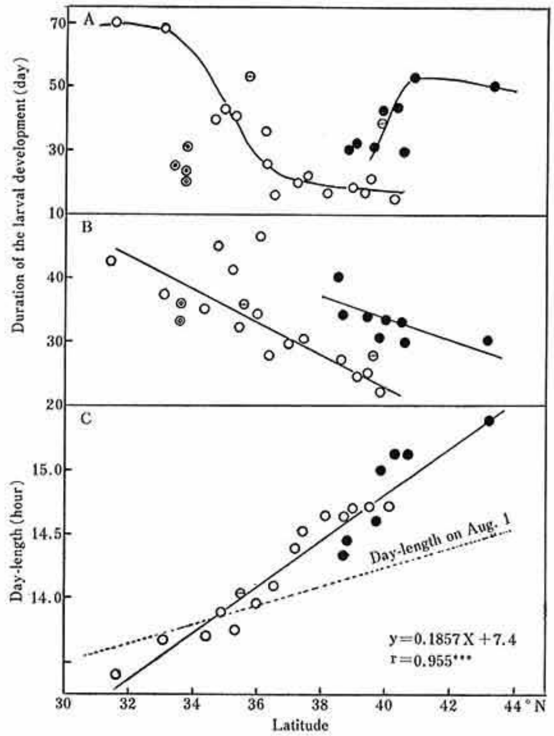

Fig. 7. Geographical variation of the physiological characteristics of the development and diapause. A; post-diapause development in hibernating larvae, B; non-diapausing larval development, C; critical photoperiod for diapause induction, ●—univoltine areas, ○—bivoltine areas, ⊙—trivoltine areas, ⊖—complicated areas

The post-diapause larval development shows very specific types on the basis of the latitude, that is, in the bivoltine area from 36°N to 40°N is a zone where the insects develop very rapidly, and in the north and south of this rapid development zone, there are the zones of slow development—viz. the univoltine area in the north and the same bivoltine area in the south. The trivoltine area is far out of this trend. This geographical variation is similar to the variation of planting time of rice in Fig. 3. Therefore, it is presumed that planting time is seriously related to the formation of these physiological characteristics.

2) Non-diapausing larval development

Fig. 7-B shows the larval duration reared

under the non-diapausing condition (16L:8D, 25°C).

In the univoltine and bivoltine areas, the non-diapausing larval development becomes apparently faster according to the increased latitude. An apparent developmental difference can be recognized between the univoltine area and its neighboring bivoltine area, and a dislocation is formed in the clinal variation at the boundary between univoltine and bivoltine areas. This variation may be closely related to the amount of effective temperature during the hatching of the first generation larvae to the end of development.

3) Diapause inducing photoperiod

Fig. 7-C shows the critical photoperiod of diapause induction estimated from the pupation of the first generation larvae reared under the photoperiod of fifteen minute intervals at 25°C. There is a high correlation between the critical photoperiod and the latitude of population's origin, and the lower the latitude, the shorter the photoperiod. Since this regression line is not parallel with the line of photoperiodic variation determined on the basis of a certain date, the diapause induction does not occur simultaneously on the same date in every area—, it is recognized that the diapause in the northern area is induced earlier than that in the southern area. The geographical variation of this physiological characteristics is a clinal variation which corresponds to the geographical inclination of the climate, and temperature and photoperiod seem to be closely related to its formation.

Conclusion

It was manifested that there are four life cycles of rice stem borer in Japan and the post-diapause development of larvae of the hibernating generation, non-diapausing larval development and photoperiodic reaction have important roles on the formation of these life cycles. With these physiological characteristics under environmental conditions, especially in the relevance of photoperiod and temperature, the life cycles from univoltine to trivoltine might be formed respectively.

In the larval development and diapause of rice stem borer, the specific geographical variation, which corresponds to temperature, photoperiod or to the cultivation time of rice, was recognized, and it was presumed that this variation was established as a result of adaptation to environmental conditions.

The physiological characteristic of the larval development and diapause seems to have a role to make life cycle synchronize with seasonal rhythm of the climate and of rice culture under reciprocal compensating relevance.