Characteristics of the Aggregation Pattern of the Striped Rice Borer (*Chilo suppressalis* (Walker)) during the Larval Stage

MUN IL RYOO[1] AND MOON HONG LEE[2]

柳文一・李文弘(1985) 이화명나방幼虫의 空間分布特性

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ABSTRACT The data on the striped rice borer populations, collected in the four years from 1973 to 1976, was reanalyzed to study the characteristics in the aggregation pattern of the insect larvae in the paddy fields. The distribution pattern of the larvae was well fitted to the negative binomial model in both the first and the second generation. With reference to the Green's coefficient of dispersion estimated, the aggregation of the larvae was categorized into three phases: initial high aggregation, changing, and dispersed stable phase. Except the changing phase, each phase in each generation could be defined by a common k. The phase-change was initiated by the larval dispersal between hills of the rice plants: the larvae of the third stage and those of the fifth stage, for the first and second generation, respectively. The characteristics of the aggregation pattern were stable in the second generation. In the first genaration, the pattern was more or less variable, indicating that the life system of the insect in the first generation was more susceptible to the variations of the external physical factors than that in the second generation.

Striped rice borer, *Chilo suppressalis* (Walker), had been an important pest for growing rice in Korea. But in recent years the population trends seem to be stable at low density levels, which may be due to the changes in the cultural practices, for instance, introduction of new rice varieties and the earlier planting time [4,16]. Nevertheless it does not mean that the pest problem will not be serious also in the future: the coevolutionary processes between plants and insects are well known features in many cases.

A thorough analysis of the life system of the striped rice borer at the present status will, therefore, be valuable for solving the possible pest problems in the future. It also could contribute to elucidate the stable mechanism in the other insect populations.

An understanding of spatial distribution pattern and its changes of an animal population concerned is vital in the analysis of the insect population dynamics for the following reasons[5]: 1) The spatial distribution itself is an important structure of the population concerned: the distribution at a given time is determined by complex biological processes that are going in the population at that time, and it may determine or affect the subsequent changes of the population. 2) The pattern of a spatial distribution affects not only the precision of the estimation of the population parameters in field survey, but also the method of data analysis. 3) The information on the changes in the pattern is a prerequisite for a precise time-sequential sampling[12].

From this point of view, we reanalyzed the data on the striped rice borer populations, collected in the four years from 1973 to 1976, to study on the spatial distribution pattern of the insect larvae in the paddy fields.

Kono(1958) and Kanno(1962) reported the pattern of the insect population in paddy fields[6,7]. We concentrated here in the typical aggregation pattern of the larval population of the insect in the quantitative point of view.

MATERIALS AND METHODS

Study area In 1973～1975, four adjacent rice paddy fields, a total size of 0.6ha, at Kotme, Suweon were hired from farmers and divided into six subplots This area was the experimental fields where population dynamic studies on the major rice insects pests were carried out during the same period by the Strengthening Plant Protection Research and Training Organization. In 1976, a well land-reformed paddy fields of 1 ha at Kuwun-dong, Suweon was again rent from a farmer but divided into 10 subplots.

Cultivation Akibare *var.* of japonica type was

1 Dept. of Plant Protection, College of Agriculture, Korea University, Seoul 132, Korea(고려대학교 농과대학 식물보호학과)
2 Institute of Agricultural Sciences, Suweon 170, Korea(농업기술연구소)

transplanted in 2-5 June each year, slightly different year to year, spacing 30cm×15cm. No insectcide and fungicides was sprayed throughout the seasons. Fertilization and weeding were practiced following the standard cultivation.

Sampling procedure Sampling method was slightly modified year to year but it was strictly based on random sampling. In 1973, sampling unit was an adjacent 5-hill in a row and a hill in 1974~75. Number of samples for each date was proportionally allocated to each of five or six subplots, depending on the size of each subplot. Samples were taken from whole study area for each generation. In 1976, sampling unit was same as the previous year but differed in that five different subplots were subjected to each generation of RSB. The efficiency of the different sampling plans seemed not to be significantly different because of the heterogeneity of the sampling unit (rice hill)[18]. Sampled hills were carried into the laboratory and dissected to count the larvae in them. Head width of the larvae found were also measured using micrometer to determine instars of each larvae.

RESULTS

Spatial distribution pattern of the larvae Largely spatial distribution patterns of animals are classified into three categories; uniform, random and contagious pattern[15]. Insects are, however, seldom if ever[8], uniformly disposed in space.

To investigate spatial distribution pattern of the larvae in the field, therefore, goodness of fit of the pattern was tested by the two models; random(poisson distribution) and contagious model(negative binomial distribution). The results were illustrated in Table 1 and Table 2.

In the first generation, the larval distribution was well fitted to the negative binomial model. The k values estimated ranged from 0.09 to 2.05 and did not correlated to the mean densities. Except in the year of 1976, the pattern at the later sampling times was also well fitted to the poisson model, suggesting that changes in the pattern occured during the larval stages (Table 1).

In the second generation, the larval distribution was highly contagious without exception. The k values estimated ranged from 0.004 to 0.530.

In general, the pattern of the larval distribution

Table 1. Spatial distribution pattern of the striped rice borer larvae in the first generation: goodness of fit to Poisson and negative binomial distribution

Sample Date		Mean/Hill	Variance	Goodness of fit to: Poisson	NB	$k^{a)}$
1973.	Jun. 18	0.18	0.20	>0.25[b)]	>0.5	1.10
	25	0.27	0.35	<0.05*	>0.1	1.00
	Jul. 2	0.17	0.21	>0.25	>0.9	0.70
	9	0.34	0.59	<0.01**	>0.9	0.39
	16	0.30	0.42	>0.10	>0.5	1.10
	23	0.11	0.11	>0.10	>0.5	1.50
1974.	Jun. 21	0.06	0.09	<0.01**	>0.75	0.08
	Jul. 1	0.18	0.33	<0.01**	>0.5	0.16
	11	0.16	0.15	>0.25	—	—
	22	0.34	0.42	>0.05	>0.25	1.11
	Aug. 1	0.13	0.15	>0.10	—	—
1975.	Jun. 23	0.26	0.45	<0.01**	>0.75	0.30
	30	0.70	2.20	<0.01**	>0.5	0.36
	Jul. 6	0.57	0.90	<0.01**	>0.25	0.77
	14	0.36	0.70	<0.01**	>0.25	0.28
	21	0.22	0.20	>0.50	—	—
1976.	Jun. 24	0.20	0.59	<0.01**	>0.75	0.09
	Jul. 1	0.54	2.05	<0.01**	>0.1	0.14
	8	0.47	1.12	<0.01**	>0.25	0.22
	15	1.13	2.80	<0.01**	>0.50	0.56
	22	1.08	1.99	<0.01**	>0.25	2.05
	30	0.34	0.53	<0.01**	>0.10	0.53

a) k was estimated by the formula, $log(N/n_0)=klog(1+\bar{x}/k)$ (see Southwood, 1978).
b) The probability of the Chi-square being caculated.

Table 2. Spatial distribution pattern of the striped rice borer larvae in the second generation: goodness of fit to Poisson and negative binomial distribution

Sample Date		Mean/Hill	Variance	Goodness of fit to: Poisson	NB	$k^{a)}$
1973.	Aug. 13	0.28	6.73	<0.01**	0.25	0.006
	20	0.24	5.20	<0.01**	0.10	0.004
	27	0.23	2.34	<0.01**	0.95	0.014
	Sep. 6	0.59	5.17	<0.01**	0.75	0.037
	17	0.51	1.22	<0.10**	0.75	0.160
	Oct. 1	0.32	0.51	<0.05**	0.75	0.530
974.	Aug. 21	0.69	34.25	<0.01**	0.05	0.006
	Sep. 3	0.71	46.18	<0.01**	0.10	0.013
	11	1.58	32.10	<0.01**	0.95	0.045
	20	1.18	16.21	<0.01**	0.25	0.099
	Oct. 2	0.83	3.42	<0.01**	2.50	0.266
1975.	Aug. 19	0.33	10.67	<0.01**	0.25	0.008
	28	0.48	17.60	<0.01**	0.50	0.011
	Sep. 4	0.15	0.94	<0.01**	0.25	0.025
	11	0.43	2.88	<0.01**	0.50	0.050
	18	0.16	0.33	<0.01**	0.95	0.145
	26	0.24	0.65	<0.01**	0.10	0.122

a) k was estimated by the formula, $\log(N/x_0)=k\log(1+\bar{x}/k)$ (see Southwood, 1978).
a) The probability of the Chi-square being calculated.

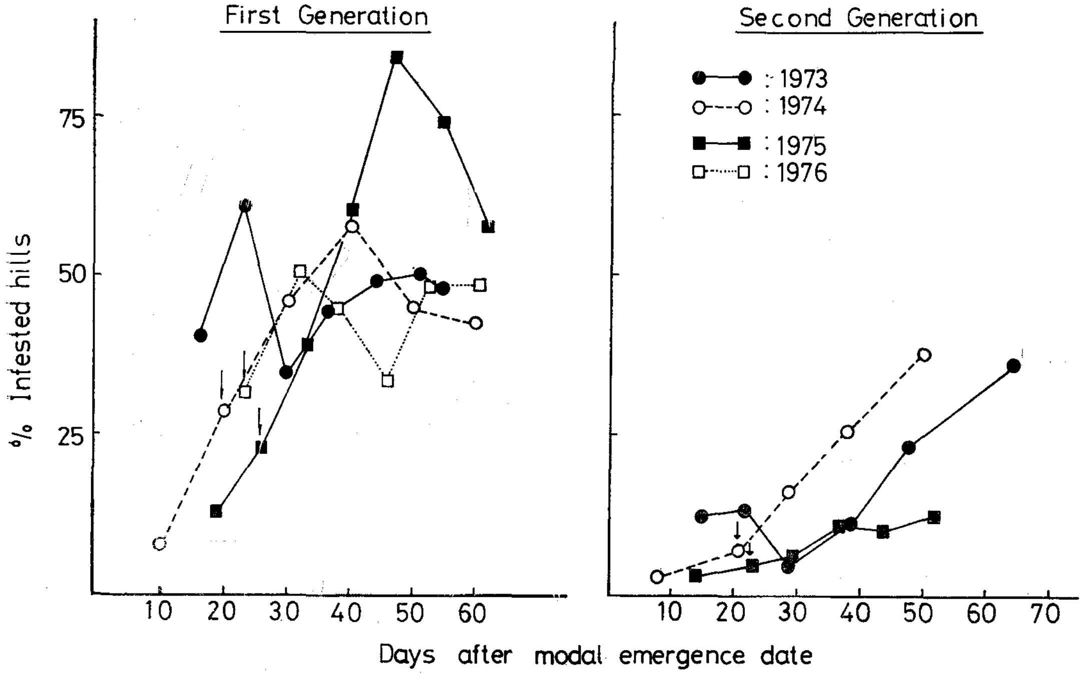

Fig. 1. Changes in the rate of the infested hills on the total hills sampled. The arrows indicate the first time when the larvae of the third (↓) and fifth stage (⬇) were found in the sample.

was well fitted to the contagious model. Similar results were reported by Kono(1958)[7].

Changes in the aggregation pattern of striped rice borer during the larval stage

There are several methods for measuring aggregation,[13,15] but it was reported that Green's coefficient of dispersion[2] and the standardized Morisita's index [14] are not correlated to mean density and, therefore, are the best candidate for use when analyzing actual changes in distribution of organisms with changes in density[9].

Green's coefficient of dispersion is estimated as

$$C_x = \frac{s^2/m - 1}{\sum x_i - 1},$$

where s^2 is the variance, m is the mean density and x_i is the number of individuals in i^{th} sample unit. From the formula, we can see that the coefficient is 0, if the population dispersed in random manner and that it becomes higher as aggregation tendency of population increases.

In order to characterizing the aggregation pattern of the striped rice borer and its changes during the larval stages, the pattern was analyzed by using Green's coefficient of dispersion. The results were shown in Fig. 2.

In the first generation, trends of the changes in the aggregation pattern were different from year to year and no characteristic one was identified. In the years of 1974 and 1976, however, the trends were similar: from high aggregation to low one. The changes which seemed to be caused by the larval dispersion (see Fig. 1), initiated when the third larval stage appeared in the sample (Fig. 1 and Fig. 2). Kanno (1962) reported that the emerged larvae of the rice striped borer began to disperse from the stem on which they hatched to other stems or hills at about third larval stage[6]. There was no information on the age distribution of the larval populations in 1973. But in 1975, the larvae found at the first sampling date (June, 23) had partly developed to the third instar (6.1%). It can thus be said that the larvae at that time had already dispersed, even partly, from the initial high aggregation.

In the second generation, trends of the changes in the aggregation pattern were typical: from the initial high aggregation to low and stable pattern. The changes which also seemed to be caused by the larval dispersion (see Fig. 1), initiated when the

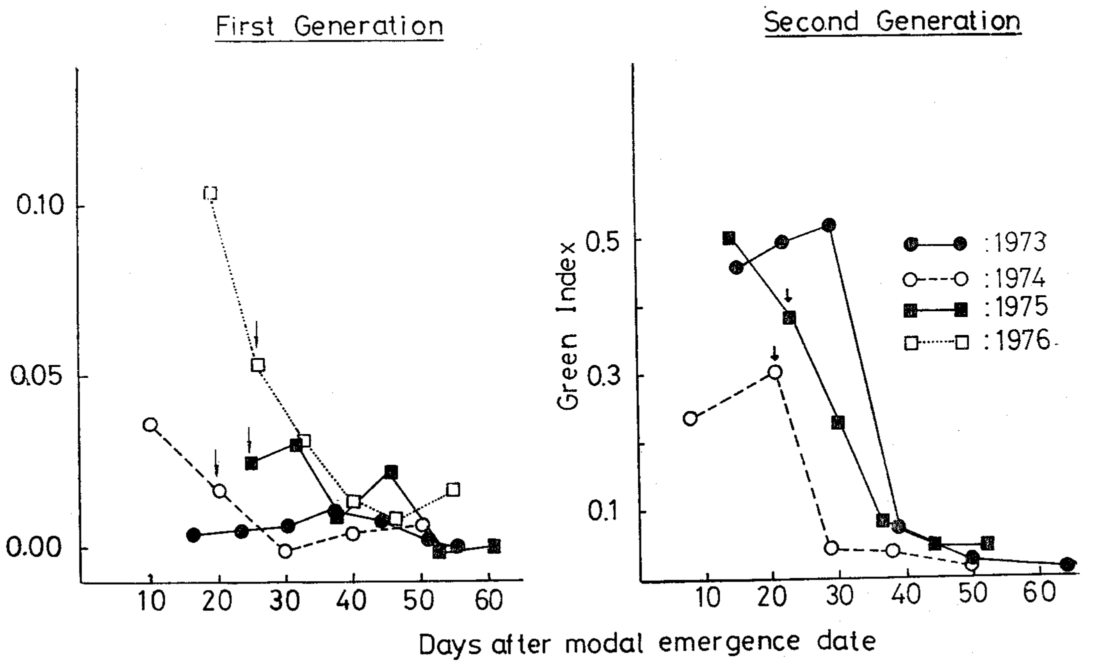

Fig. 2. Changes in the Green's coefficient of dispersion. The regression of the coefficient on the mean density was not ginifiscant. The arrows indicate the first time when the larvae of the third(↓) and fifth stage (⬇) in the sample.

fifth larval stage appeared in the sample (Fig. 1 and Fig. 2).

In general, the aggregation pattern of the rice striped borer larvae was characterized by the three phases: 1) initial high aggregation phase, 2) changing phase and 3) more or less dispersed phase. The feature was not clear in the first generation, suggesting that the life system of the insect in the generation is unstable in comparison with the second generation.

Homogeneity of the larval aggregation pattern in each phase

As mentioned above, the aggregation pattern of the insect larvae could be characterized by the three

Table 3. 'Common k' of negative binomial of the aggregation phases of the striped rice borer larvae estimated by the derivation of a regression method and the Analysis of Variance

Generation	Phase	'Common k'	ANOVA			
			S.V.	d.f.	MS	F
First	Third	0.75	Slope $1/k_c$	1	39.4	31.2**
		(0.57~1.09)[a]	Intercept	1	0.92	0.73
			Error	8	1.26	
			$\chi^{2b)}=11.007$		P>0.25	
Second	First	0.01	Slope $1/k_c$	1	5.39	12.7*
		(0.006~0.07)	Intercept	1	0.63	1.5
			Error	4	0.42	
			$\chi^2=2.328$		P>0.75	
Second	Third	0.11	Slope $1/k_c$	1	60.8	31.6**
		(0.09~0.14)	Intercept	1	0.36	0.19
			Error	6	11.6	1.93
			$\chi^2=2.011$		P>0.95	

a) The numbers in the parenthesis are the 95% confidence interval of the 'common k'

b) Homogeneity test for the 'common k' estimated phases in the both generations. The question then is whether each phase can be described by a common index. In order to illucidate this, the common k of the negative binomial in each phase was estimated and the homogeneity of it was tested by the methods provided by Bliss and Owen[1].

The initial phase of the first generation was excluded in this analysis because of its small sampling group. The second phase (changing phase) in both generations could also not to be described because of their unstable features.

As presented in Table 3, all the three phases analyzed could be described by the characteristic common k. Homogeneity of the k in each phase was also accepted. The common "k"s and their 95% confidence interval estimated were 0.75(0.57−1.09), 0.01(0.006−0.073) and 0.11(0.09−0.14) for the third phase of the first generation, the first and the third phase of the second generation, respectively. The results indicated that the larval aggregation pattern could be described by the three homogenous phases without regarding variations from year to year.

DISCUSSION

Females of the striped rice borer moth lay their eggs in clusters of scores on leaves of rice plants. The newly hatched larvae disperse by using silk they produce. The settled larvae feed on inner part of leaf sheaths and then bore into the rice stems. The stems injured by the larvae discolor to brown and then wither[11]. Until this stage the larvae seem to be gregarious(Fig. 2). As the stems wither, the larvae disperse into the other stems or hills. This phenomenon was clearly shown by the abrupt decrease of the C_x-Index. Once the dispersion had occured, the aggregation pattern seemed to be stable, suggesting no more dispersal of the larvae to the other hills. The larval aggregation pattern could be thus characterized by the three phases; 1) initial high aggregation phase, 2) changing phase, and 3) more or less dispersed stable phase.

Except in the changing phase, the larval aggregation in each phase could be defined by a homogeneous common k of negative binomial (Table 3), indicating that the aggregation pattern is a characteristic of the larval population. The first phase(initial high aggregation) in the first generatien was unidentified in the two years out of four (Fig. 2). It seemed, however, not due to the real variations of the phase, but due to the influence of physical environment which could affect larval development: in the year of 1975, for instance, the larvae in the third stage (dispersal initiating stage) were found even in the first sampling date. The first generation of the insect coincides with the seed bed stage or early main paddy stage of rice plant. In the stages, the size of hills is small and the spacing between hills is more or less wide, which could provide the life system of the insect highly susceptible to the external physical factors. Thus it can be said that the first phase in those years would be identified, if we could arrange the the sampling plan under the day-degree concept.

Kanno(1962) reported that the larval dispersion began at about the third larval stage. The present study revealed that the dispersal stage of the larvae was flexible in relation to the condition of rice plant. In the first generation, the rice plant which are in growing stage could be more susceptible to the injury caused by the insect larvae than those of the full grown stage in the second generation. Thus the larvae in the former should be forced to disperse to other hills at the third larval stage, whereas they began to disperse at the fifth larval stage in the latter. The quantity of the food for supporting gregarious larvae could also play a role as some other insects[10,17] : the size of rice plant per hill is greater in the second generation of the striped rice borer.

摘 要

1973년부터 1976년까지 농촌진흥청 농업기술연구소 포장에서 수집된 成績을 分析, 이화명나방幼虫의 空間分布特性을 調査하였다.

幼虫의 空間分布는 世代에 差異없이 負의 二項分布를 따르고 있었다.

集中係數(Green's coefficient of dirpersion)를 지표로 하였을때 幼虫의 集中度는 初期高集中期, 過渡期, 低集中安定期의 3단계로 진전됨이 판명되었으며 이중 過渡期를 除外한 各단계는 各世代에서 共通"k"에 의해 集中度를 정의할 수 있었다.

集中度의 단계적 변화의 原因으로 幼虫의 株間移動이 判明되었으며 제 1 세대에서 3齡幼虫, 제 2 세대에서 5齡幼虫이 分散하는 것으로 나타났다.

幼虫集中度에 있어서의 이러한 特徵은 제 2 세대에서 뚜렷하였으며 제 1 세대의 경우 해(年)에 따른 변이폭이 컸다. 이는 제 1 세대幼虫의 生命系(Life system)가 제 2 세대의 그것에 비해 外的 環境要因의 변이에 따라 크게 영향받고 있음을 시사하는 것으로 생각되며 Day-Degree 개념에 따른 환경변이의 수렴이 검토될 수 있을 것으로 思料된다.

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