Source: Journal of Nanjing Agricultural University [Nanjing Nongye Daxue Xuebao ISSN: 1000-2030] (1996) v.19(3)p.55-58
Translated by Judong Shen, Edited by Mohan Ramaswamy, Kansas State University, 2003

SPATIAL DISTRIBUTION AND SAMPLING TECHNIQUE OF APHIS GLYCINES MATSUMURA

Jianya Su, Kangshan Hao and Xiaoling Shi
(Institute of Agricultural Entomology, Nanjing Agric Univ., Nanjing 210095)

ABSTRACT The spatial distribution of *Aphis glycines* Matsumura was studied. All sets of samples exhibited aggregated patterns of spatial distribution, but did not fit Poisson, Neymann (n=0~4 and ∞), Poisson-binomial and compound Poisson distributions. Of 11 sets of samples tested, 10 sets fitted the negative binomial distribution; only 1 set did not fit. The fundamental components of the spatial distributions of *Aphis glycines* are aggregated distribution of individual populations; the degrees of aggregation increase with the population densities. The spatial distribution parameters ($\dot{m}$, C_Λ, I_δ, $\frac{\dot{m}}{\bar{\bar{x}}}$, α, β) of the soybean aphids and species aggregation average degree (λ) were analyzed, the reason of aggregation patterns of the aphids was discussed, and the relation between the average sizes of the individual population and its average densities was predicted. The theoretical sizes of sampling and sequential sampling plans of fixed levels with precision were determined by utilizing estimated variance/mean relationship obtained from Taylor's power law regression. The theoretical size of sampling is $n = \frac{5.364\bar{x}^{-0.64}}{D^2}$ and the stop line of fixed-precision-level sequential sampling is $T_n = \frac{13.8}{D^{3.125} * n^{0.563}}$.

Key words *Aphis glycines* Matsumura; spatial distribution; sampling

Aphis glycines Matsumura is one of the serious pests on soybean in China. This paper is the first study about the analysis of the characterization of field distribution patterns and the spatial distribution parameters. The application of spatial distribution parameters on the sampling technique has also been explored.

1. Data sources and methods

The population of *A. glycines* in the experimental fields of Nanjing Agriculture University was studied by sampling survey in 1995. The sampling unit was a compound leaf. Four hundred individual plants were investigated continuously. Three pieces of compound leaves were taken from the upper, middle and bottom parts of each individual plant. Totally, eleven fields were surveyed, thus the data of eleven groups of samples were obtained. Those data were applied for the analysis of the distribution pattern characteristics using frequency mapping, degree of aggregation indices and regression model methods respectively. Furthermore, the characteristics of the parameters were investigated.

Received on Oct. 23, 1995

2. Results and Analysis

2.1 The determination of the distribution patterns

The distribution patterns were analyzed using the frequency mapping, aggregation degree indices and regression model methods respectively.

2.1.1 Frequency mapping method

Eleven groups of sample data were listed in the frequency distribution table, and the theoretical frequencies of five kinds of distributions (Poisson distribution, negative binominal distribution, Neymann distribution (n=0~4 and n=∞), Poisson-binomial and compound Poisson distribution) were calculated using computers. Then the chi square value was calculated. The results showed that of 11 sets of samples tested, 10 sets fitted the negative binomial distribution, only 1 set did not fit (probably due to the discrete sample data), and all the samples did not fit other distributions.

2.1.2 Degree of aggregation indices method

For each group of sample, the mean ($\bar{x}$), variance (S^2), average degree of aggregation ($\dot{m}$), *k* value of negative binomial distributions, dispersion index (*C*), Kuno's C_Λ index, Moristita's I_δ, cluster index (*y*), average size index of individual population (I_J) were calculated respectively.

The measurement standards are given in Table 1. It has been shown from Table 2 that all aggregation indices of *A. glycines* conform with the measurement standards [1~3], which accounts for the result that all of the eleven groups of samples belong to clustered distribution.

Table 1. Several aggregation parameters for measuring spatial pattern of insects

Distribution Pattern	Dispersion index *C*	Morisita's I_δ	Kuno's C_Λ	Cluster index (*y*)	Taylor's *b*	Twao's β
Poisson	1	1	0	1	1	1
Aggregation	>1	>1	>0	>1	>1	>1
Regular	<1	<1	<0	<1	<1	<1
Measurements	$\frac{S^2}{\bar{x}}$	$\frac{\sum_{i=1}^{n} x_i(x_i-1)}{N(N-1)}n$	$\frac{S^2-\bar{x}}{x^{-2}}$	$\frac{\dot{m}}{\bar{x}}$	$S^2=ax^{-b}$	$\dot{m}=\alpha+\beta\bar{x}$

Table 2. The aggregation parameters of *A. glycines* population

Date	$\bar{x}$	S^2	C_Λ	C	y	I_δ	$\chi^2_{0.05}$	Degrees of freedom	Pattern
1995-07-24	1.310 0	8.185 7	3.491 4	6.248 6	5.006 6	5.005 8	21.05	18	N.B.D.
1995-07-26	0.987 5	5.205 0	3.661 8	5.270 9	5.325 0	5.325 0	32.19	15	C.D.
1995-07-28	0.776 7	3.563 1	4.211 0	4.587 7	5.619 0	5.620 4	13.28	11	N.B.D.

1995-07-30	0.510 0	2.145 0	4.882 4	4.205 9	7.286 1	7.291 2	3.95	11	N.B.D.
1995-08-01	0.640 0	3.613 4	5.910 7	5.646 0	8.259 4	8.262 7	2.73	11	N.B.D.
1995-08-03	0.429 2	1.851 5	6.121 6	4.314 2	8.821 8	8.731 1	10.24	8	N.B.D.
1995-08-05	0.748 3	2.885 7	3.410 8	3.853 2	4.816 9	4.817 8	13.36	10	N.B.D.
1995-08-07	0.459 2	1.908 3	5.284 0	4.155 9	7.872 6	7.879 9	8.01	11	N.B.D.
1995-08-14	0.306 7	0.861 7	4.868 8	2.809 8	6.900 9	6.912 7	8.00	8	N.B.D.
1995-08-16	0.317 5	1.312 8	5.591 9	4.134 8	10.873 4	10.891 0	10.96	8	N.B.D.
1995-08-18	0.526 7	2.229 5	3.977 4	4.233 2	7.138 6	7.143 6	11.23	9	N.B.D.

* N.B.D. = negative binomial distribution; C.D. = clustered distribution.

2.1.3 Regression model method

The eleven groups of sample data were used to check the distribution of *A. glycines* based on the regression equation: $\dot{m} = \alpha + \beta\bar{x}$, which consists of the relation between average degree of aggregation ($\dot{m}$) and the mean ($\bar{x}$). Iwao proposed this method. The results are as the follows:

$$\dot{m} = 1.953\ 1 + 3.421\ 6\bar{x} \quad (r = 0.875\ 7, F=29.6)$$

The value of α = 1.953 1>0 shows that the fundamental components of the spatial distributions of *A. glycines* population are individual populations. The value of β = 3.421 6>1 shows that the fundamental components of the distributions of *A. glycines* population are clustered distributions.

The Iwao model improved by Rumei Xu is:

$$\dot{m} = 1.920\ 8 + 3.522\ 1\bar{x} - 0.064\ 74\bar{x}^2$$

Its *r* value (*r* = - 0.064 7) approaches 0 and there is little difference between its values of α, β and the values of α, β in the original Iwao model.

The results are as the follows tested by Taylor's regression equation: $S^2 = ax^b$, which consists of the relation between variance (S^2) and the mean ($\bar{x}$):

$$S^2 = 5.364\ 1\bar{x}^{1.3601} \quad (r = 0.976\ 6, F=185.5)$$

The values of *a* = 5.364 1>1 and *b* = 1.360 1>1 show that the distributions of *A. glycines* are all clustered distributions in all densities and the aggregation degrees increase with the population densities.

The F-value in analysis of variance showed that Taylor's variance and regression equation of means reflected the aggregation and distribution patterns of *A. glycines* in fields more accurately than Iwao's average degree of aggregation and regression of mean did. The relevant coefficients of Taylor's regression equation and F value were all greater than Iwao's. The Taylor's *b* value was dependent on specific characters of insect species. As the life behaviors of species vary form each other, the *b* values differ between species a lot. While, for the species with the similar life behaviors and distribution patterns, their *b* values are quite similar between each other. Thus, *b* values are more suitable in the application of sampling experiments than Iwao's parameters.

2.2 The size analysis of individual population of *A. glycines*

The spatial distribution of *A. glycines* is the clustered distribution of individual population structure in terms of the parameters α and β. Its aggregation size relates to the *k* value of negative binomial distribution, which can be represented by the average size index of individual population (*L*) [5]. The established relation equation between *L* and average density ($\bar{x}$) is: $L = 2.063 + 3.711\,1\bar{x}$ ($r = 0.935\,7$). The size of individual population of *A. glycines* is unstable since it increases with the population density.

2.3 Analysis of causes of aggregation

Average degree of population aggregation (λ) proposed by Blacksmith was used to examine the aggregation phenomenon of *A. glycines* in fields. The formula to calculate the average degree of population aggregation is:

$$\lambda = \frac{\bar{x}}{2k} r$$

in which *k* is the parameter of negative binomial distribution, and *r* is the function of $\chi^2_{0.05}$ when the degrees of freedom are 2*k*. The aggregation results from some environmental factors when λ is less than 2. However, when λ is greater than 2, the aggregation results from the combined effects of both insects' behaviors and the environmental factors. The λ values in eleven groups of samples are all less than 2, which shows that the aggregation distribution of *A. glycines* results from the different characteristics of the environment, and it is also related to the very low population density of *A. glycines.*

2.4 Determination of the theoretical sampling size

The theoretical sampling size and the stop lines of fixed-precision-level sequential sampling are determined using the parameters *a* and *b* in Taylor's variance and mean equation. They are as follows respectively:

$$n = \frac{a\bar{x}^{b-2}}{D^2} \qquad T_n = \left(\frac{D^2}{a}\right)^{\frac{1}{b-2}} * n^{\left(\frac{b-1}{b-2}\right)}$$

in which *n* is the size of sampling, T_n is the cumulative number of aphids, *D* is the precision index (n = 0.1, 0.2, 0.3). If the values of *a* and *b* are substituted in the above equation, the theoretical size of sampling and the stop lines of fixed-precision-level sequential sampling under different aphid densities ($\bar{x}$) and different precision requirements could be obtained as follows:

$$n = \frac{5.364\bar{x}^{-0.64}}{D^2} \qquad T_n = \frac{13.8}{D^{3.125} * n^{0.563}}$$

It is shown in Figure 1 that the theoretical size of sampling (n) will increase exponentially with the decrease of the aphid densities ($\bar{x}$). In the process of fixed-precision-level sequential sampling, the investigation could be terminated when the accumulative aphid number reaches the stop lines in Figure 2. In practice, the precision level could be determined by the specific requirements. Usually, D is set to 0.2 in large fields.

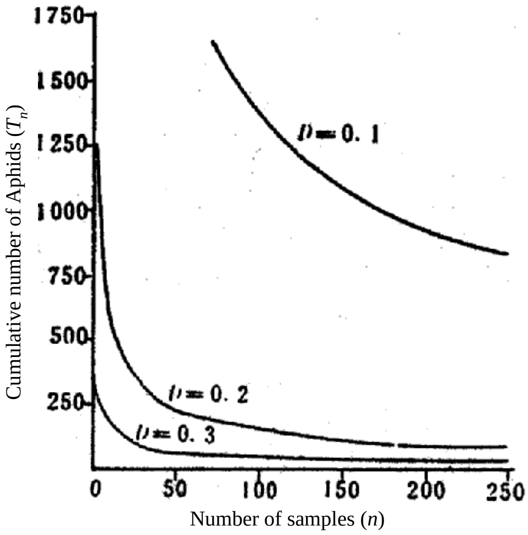

Fig. 1 Sample size curves for leaf samples of *A. glycines*

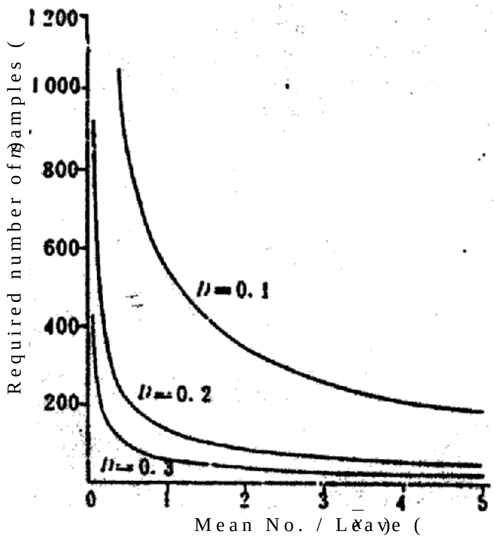

Fig. 2 Stop lines for fixed-precision-level sequential sampling for *A. glycines*

(This paper was reviewed by Prof. Xianian Cheng. The authors acknowledge him)

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(Editor: Hongyan Zhao)