Source: Chinese Journal of Oil Crop Sciences [Pin-Yin: Zhongguo Youliao Zuowu Xuebao ISSN: 1007-9084] (1982) v.3 p.59-61.
Translated by Zhiyun Jia, Chinese Academy of Agricultural Sciences, Edited by Professor George Liang, Kansas State University, 2003

The relationship between population fluctuations of alates of soybean aphid and the epidemic level of soybean virus disease in the fields

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Soybean virus diseases are transmitted mainly from alates of the soybean aphid (*Aphis glycines* Matsumura). In recent years, because of great increases in soybean aphid populations, the soybean virus occurred in many areas, seriously affecting both the quantity and quantity of soybeans. It is of great importance to determine the relationship between aphid population size and level of the epidemic. To achieve this goal, we studied the relationship between population fluctuations of alates of soybean aphid and the epidemic level of the soybean virus disease, to provide a theoretical basis for both identifying the best time to destroy aphids and for further study of the epidemics of soybean virus diseases.

I. Methods

Increasing rate of soybean virus disease: A previous method was to depict the S-shaped curve. However, since it was difficult to describe the S-curve when studying the epidemics of soybean virus diseases, we considered the whole green plant that could develop disease as 1, the area of the infected area as *x*, and the area of the remaining plant to be (1-*x*). $\frac{x}{1-x}$ represents the ratio of infected parts, to reflect the degree of infection. Natural logarithm, (ln) of every $\frac{x}{1-x}$ was used as the y-axis, with observation date as x-axis. The slope represents the increasing rate of virus disease, from the original formula by Van der Plank, i.e.

$$r = \frac{1}{t2 - t1}(1n)\frac{mx2}{x1}\frac{(1-x1)}{(1-x2)}$$

where r represents the daily increasing rate of virus diseases, $x1$ and $x2$ represent, respectively, the quantified state of the disease at $t1$ and $t2$, and m represents the index of increased leaf area of infected host plants during $t1$ to $t2$.

To facilitate calculation, we simplified the formula as follows:

$$r = \frac{1}{t2 - t1}(1n)\frac{mx2(1 - x1)}{x1(1 - x2)} = \frac{1}{t2 - t1}\left[1nm + 1nx2 + 1n(1 - x1) - 1nx1 - 1n(1 - x2)\right]$$

$$= \frac{1}{t2 - t1}\left(1nm + 1n\frac{x2}{1 - x2} - 1n\frac{x1}{1 - x1}\right)$$

Because the soybean virus is a disease agent, *m* should not be considered, therefore,

$$k = \frac{1}{t2 - t1}\left(1n\frac{x2}{1 - x2} - 1n\frac{x1}{1 - x1}\right)$$

We began to investigate the virus disease on May 27 when seedlings are vigorously growing and, selecting 600 plants of the common soybean variety "Jin-Dau #2", i.e., recording the diseased plants once every five days as 1/600, every diseased plant found was calculated

$\ln\frac{x}{1 - x}$ for the observation, to make the diagram:

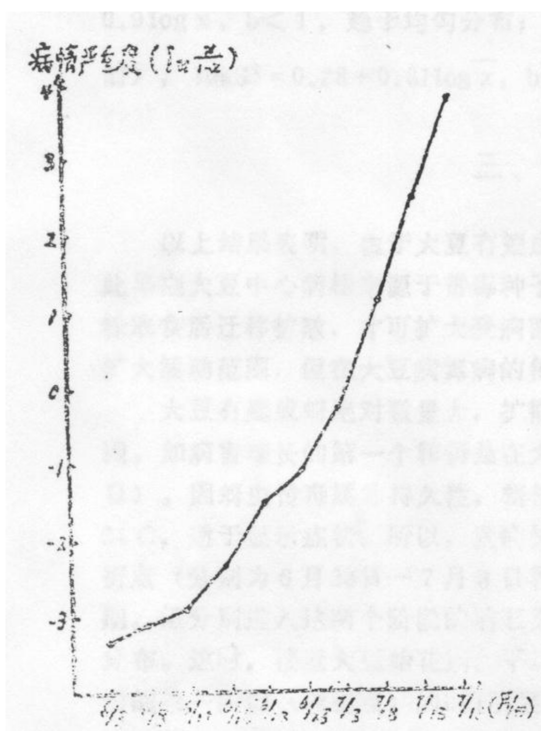

Figure 1. Development of soybean virus disease during 5-day intervals

Also, from Taylor's formula by this experience, $S^2 = a\bar{x}^b$, to obtain mean squares (s^2) and sample mean ($\bar{x}$), we calculated the distribution of insects (aphids). Taking log on both sides, $\log S^2 = \log a + b \log \bar{x}$, then it fits a linear regression equation. $b \rightarrow 0$, indicates uniform distribution, b=1 represents random distribution, and b>1 means aggregate distribution.

Recording and calculating the population fluctuation and distribution pattern of soybean aphids:
According to the time when soybean aphid occurred, along with local weather patterns and soybean development conditions, we investigated the date for soybean aphids to migrate to fields where soybeans were cultivated, beginning from May 15. The Y-axis represents the number of aphids for each 100 infected plants (recording every 5 days), and the X-axis represents the date of the 5-day interval.

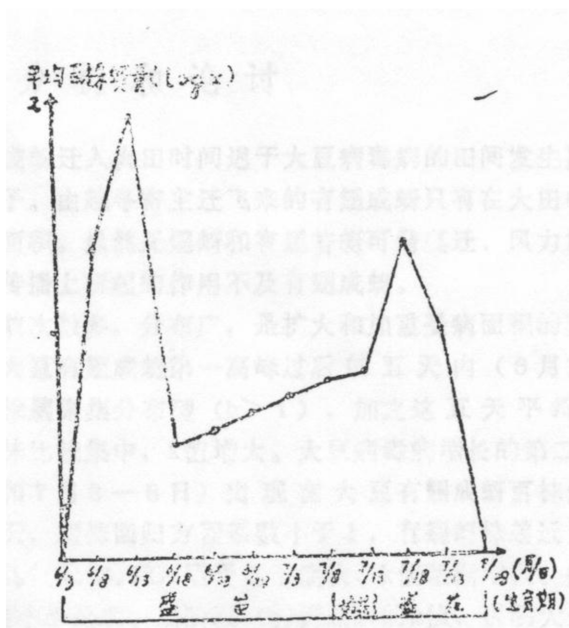

Figure 2. Population fluctuation of alates of soybean aphid in the field

II. Results

Observations from May 27 emergence of soybean until July 18 florescence, demonstrated that the alates of soybean aphid began to migrate into soybean fields on June 8. A few infected plants began to appear beginning June 13, and all observed plants (600 individuals in all) were infected by July 18. There were three turning points during the process of virus disease transmission, i.e., from June 13 to 18 (*k*=0.124), June 28 to July 3 (*k*=0.176), and July 3 to 8 (*k*=0.272) (see Table 1).

Month/ Day	May27 - June3	June3 – June 8	June 8 – June 13	June 13 June 18	June 18- June 23	June 23- June 28	June 28- July 3	July 3- July 8	July 8- July 13	July 13- July 18
K	-0.672	0.038	0.054	0.124	0.152	0.07	0.176	0.272	0.207	0.26

Table1. Increasing rate of soybean virus disease in the field

From Figure 2, there were two peaks in the population fluctuation of field alates of soybean aphid, one appearing on June 13, the emergence of soybean, and the other on July 18, when the flowering reached a peak. The interval of the two peaks was 35 days. From June 8 to June 13, showing the first peak for the number of aphids per 100 plants, $\log S^2 = -11.4 + 1.1 \log \bar{x}$, $b>1$, indicating clustered distribution of aphids. From June 28 to July 5, which was just before the second peak for the increase of virus disease, $\log S^2 = 0.19 + 0.9 \log \bar{x}$, $b<1$, indicating uniform distribution. From June 28 to July 5 (just before the third turning point for the increase of virus disease), $\log S^2 = 0.28 + 0.81 \log \bar{x}$, $b<1$, representing uniform distribution of aphids.

III. Discussion

The above results show that the early infected plants were originated from infected seeds, because the alates of soybean aphids appeared in the fields later than the occurrence of the soybean virus disease. The alates of aphids coming from winter host plants can increase the area of infected plants and spread the disease after they have eaten the infected plants in the field. Although adult wingless soybean aphids and alates could increase their range of activity by crawling and by wind, they caused less damage than winged aphids in transmission of soybean virus disease.

The absolute number of alates of soybean aphid is large. The alates can disperse many times, distribute across vast areas, and that is the main reason for increasingly infected areas of the plants. *e.g.*, the first turning point for the increase of the virus disease occurred within five days after the first peak in number of alates of soybean aphid (June 13- June 18). Because the infestation of aphids could not last long, the infected plants showed an aggregate distribution ($b>1$), and the average temperature for five days was 24^{o}, suitable for aphid activity. The infested plants displayed an aggretaed distribution with an increased *k* value. The second and third turning point (June 28- July 3 July 3- July 8, respectively) for the increase of soybean virus disease occurred during the period of the least number of alates of soybean aphid for every 100 plants. However, in the first five days for these two periods, the gregression coefficient was less than 1 ($b<1$) and the distribution pattern of the alates tended to be uniform. This period was near the beginning of the flowering period of soybean plants, with an average temperature of 23.9°, very suitable to displaying symptoms of infection, and the *k* value increased gradually. The *k* value in the first turning point for the increase of virus disease was evidently smaller than those in the second and third period, which showed that the *k* value mainly depended on the even distribution of field alates. The factors that affected the spread of the alates of soybean aphid included the average daily temperature and relative humidity for the early period of soybean development, e.g., when temperatures varied between 20°and 24° and the relative humidity was lower than 78%, the aphids reproduced in large quantities, resulting in poor growth of host plants, then they migrated to find more hosts. For the soybean aphids, winged aphids were the majority among migrating aphids causing the movement of those aphids to other plants. In the later period, especially in the late flowering of soybeans, because of aging host tissues, some aphids migrated to feed on younger plants.

The soybean virus disease was originated mainly by seed. Therefore, using the uninfected seeds in production is the key to preventing virus disease. The soybean virus disease can be prevented effectively by eradicating the infected plants before soybean aphids migrate from winter hosts to soybean fields, and by eradicating alates of soybean aphid just before they spread to plants of whole fields. By doing so, the prevalence of soybean disease can be avoided.

In conclusion, the relationship between fluctuation of soybean aphid alates and the epidemic level of soybean virus disease is complex. Migration of soybean aphid alates from wintering hosts to the field, along with the forecast of the number of aphid alates, is most important to the prevention and cure of the virus disease.