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Studies on the Soybean aphid, *Aphis glycines* Matsumura

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Abstract: The soybean aphid is widely distributed among all major soybean growing regions in China. It causes severe damage in Jilin, Liaoning, and Helongjiang Provinces, and part of the inner Mongolian autonomous region, and those areas are often called aphid-stricken areas. Its hosts include wild soybean (*Glycine benth* forma *lanceolate* Makino), buckthorn (R*hamnus davuricus*) as well as soybean. Results of field investigation and inoculation experiments confirmed that the widely distributed buckthorn in the Northern Provinces is the over-wintering host for soybean aphids.

According to the life cycle of aphids and their characteristic damage to soybeans, three different periods of impact can be recognized: 1) starting from seedling stage to blooming stage (mid-July), the aphid population reaches its peak point. About 50-70% of the whole aphid population colonizes on the tender leaves and twigs on top of the soy plants. The soybean damage caused during this period has the worst impact on the plants. 2) During the third ten days of July when the soybean plants cease to grow, aphids then migrate from the top leaves and twigs to the middle or lower ones and feed on the underside of the leaves. At the same time, the young nymphs appear. The aphid population grows slowly, and their damage to soybean plants is at a low tide. 3) From late August -- the late pod bearing period -- to early September -- the yellow maturing period -- aphids start their late multiplying stage. In late Fall, aphids migrate back to buckthorn, their overwintering host, and oviposit overwintering eggs after mating. During Fall, the male aphids and the ovipositional female aphids are living on different hosts. Gynoparae live on buckthorn, and the male aphids live on soybean. Aphids reproduce 15 generations a year on soybean.

After analyzing the life cycle of aphids, their growth pattern in the field, as well as the meteorological data in recent years, we came to preliminary results about the growth and decline pattern of aphids and their affecting factors: 1) the more the overwintering eggs and aphids numbers were at the seedling stage, the more severe their impact on seedlings; 2) Average temperatures between 22-25 °C and relative humidity below 78% from late June to early July greatly favored the growth and reproduction of aphids. Even if the original aphid population is small, severe aphid epidemics still could occur during the blooming

period in July because aphids reproduced very quickly under those favorable weather conditions; 3) As the growth points ceased growing in late July and the nutrient condition deteriorated, the aphid population declined.

In summary, we may make long- or short-term predictions of aphid epidemics based on the number of overwintering eggs, meteorological data, and current and past aphid information.

Based on the results of several years' laboratory and field experiments, the following aphid control measures achieved very good results: 0.5% lindane (benzene hexachloride, or BHC), 1 to 300-400 diluted 6% BHC wettable powder, 1 to 15000 diluted E605 (parathion), 1 to 100 diluted tobacco leaf solution, and seed coating with 20% BHC. Among these methods, 0.5% BHC powder and seed coating with 0.7% of 20% BHC have been widely used in agricultural practice.

Soybean aphids are common in all the main soybean growing regions in China, and cause more severe damage in Liaoning, Jilin, Helongjiang, and Hebei Provices. According to records, there were severe soybean aphid epidemics in Jilin, South Helongjiang, and North Liaoning in 1948. In 1951, Jilin was very heavily stricken by aphids. There were huge aphid outbreaks during the seedling period in the whole Northwestern area, with heavier losses in the North of Liaoning Province. Again in 1955, there were big outbreaks in Jilin Province, south of Helongjiang Province, in Lingyuan Prefecture of Liaoning Province, and Yushu, Dehui, and Jiutai districts of Jilin Province were the centers of aphid outbreaks. Severe aphid outbreaks hit Jilin Province again in 1958.

In light of recent years' studies, we found that the soybean aphid is a social insect with strong tender taxis. At outbreaks during seedling period, about 50-70% of the aphid population colonized and fed on the top tender leaves and twigs of soybean plants, thus caused curling and shrinking of leaves and twigs, damage to their physiological functions, underdevelopment of roots, small leaves and stems, and consequently the plants stagnated with much fewer branches and pods. According to research into aphid damage in Yushu, Jiaohe, Dehui, Jiuzhan, and Dongfeng districts of Jilin Province in 1954 and 1955, soybean plants harmed by aphid only had 0.93 branches with a plant height of 55 cm and 11.8 pods on average. The yield from the damaged field was 771 kg per hectare. Under the same conditions of aphid outbreak, soybean plants might have had an average plant height of 77.4 cm with 2.7 branches and 55.8 pods, and yield 1634 kg per hectare if proper control measures had been taken. Based on our investigation, widespread aphid outbreaks such as those in 1948, 1951, and 1955 could cause huge losses if no control measures were taken, and yield losses could be as much as 50%. In order to control soybean aphids and increase soybean production, we conducted systematic studies on the host species of soybean aphids, patterns of their occurrences, and insecticidal control from 1953 to 1958. We basically elucidated the life cycle of soybean aphids, found some effective insecticides, set up investigation and prediction methods, and thus generated effective measures to control soybean aphids. These measures have been widely applied in soybean production in Liaoning, Jilin, Helongjiang Provinces and Inner Mongolia Autonomous region.

Host Plants

In searching for control methods for soybean aphids, we studied their host plants. After four years of repeated inoculation experiments and field investigation, we concluded that buckthorn (*Rhamnus davuricus*) is the overwintering host of soybean aphids.

Field Investigation: From 1953 to 1956, we started Spring observations when the overwintering eggs were hatched, and the Fall observations at the time soybean aphids migrated back to their overwintering hosts. These investigations were conducted on varieties of herbaceous, shrub, and arbor plants under different ecological environments such as graveyards, marshy grasslands, terra lattice, hillsides, and riversides. Sites of investigation were located in Haichen, Kaiyuan, Gaiping, Tieling, Jinzhou, and suburbs of Shengyang in Liaoning Province, Lishu, Shiping, Jiaohe, Dongfeng, Liaoyuang, Gongzhuling, Huaide, Yushu, Dehui, Jiutai, Jiuzhan, Yongji, Nongan, the suburb of Changchun in Jilin Province, Jiamushi and Shuangchen etc. in Helongjiang Province. During the critical stage of the investigation, identification work was performed at the same time as the research went on. We also set up host plant nurseries to explore the host plants of aphids by inoculating confirmation and control experiments at defined times. Among the over 100 species of plants investigated during our study period, soybean aphids only colonized on buckthorns during Spring and Fall, and on soybean and wild soybean (*Glycine benth f. lanceolate* Makino) during Summer.

Identification by inoculation experiment: Considering the living habits of soybean aphids, we performed our inoculating identification in Spring and Fall of 1955. In Spring, we inoculated the migrants to soybean seedlings with writing brushes. During Fall, we inoculated the gynoparae (winged female aphids) to buckthorns. When the progenitive female aphids matured, they were encouraged to mate with adult winged male aphids migrated from soybean plants to buckthorns and oviposit. Both the Spring and Fall inoculating experiments were conducted in cages made of 120 mesh copper screen with double doors to prevent other aphids from entering the cage and interfering with the results. Results of three years of inoculating experiments showed that soybean aphids from buckthorns could not only live on soybean seedlings, but also reproduce very well. In 1955, we inoculated winged nymphs from buckthorns to soybean seedlings because of the shortage of aphid sources. Although the survival rates were about 10% after inoculation, the surviving aphids grew and reproduced well in the following four months from June 2 to October 2. The aphid population in the inoculated areas increased dramatically since mid-June. According to the recorded figures between June 2 to July 14, aphids numbers increased from 92 to 87936 in those 42 days, that is, their population increased 956 times. They reproduced about 15 generations a year on soybean. We repeated the inoculating experiments by using adult, winged aphids in 1956 with the same method used in 1955. About 70 to 77% of the inoculated aphids were surviving and showed normal growth during their time on soybean plants. Results of the four inoculating experiments in three years all showed that the inoculated aphids could grow and reproduce normally on soybean plants, and completed their life cycle as they would do in the field. Thus, we can certainly say that buckthorn is the overwintering host for soybean aphids.

One aspect of the inoculating experiment deserves special attention -- we must follow the natural law and the biological habits of the specific aphid when we conduct host identification work by inoculation. Mandatory inoculation against the natural law will only lead us to incorrect conclusions from our experiments. For example, in the summer of 1954, we had inoculated several times both winged-aphids and wingless aphids from soybean fields to buckthorns, but none of these aphids survived. From this, however, we cannot conclude that the buckthorn is not the overwintering host for soybean aphids. It only told us that soybean aphids could not survive on the overwintering host in the summer because soybean aphids are insects with a complete life cycle. In addition, soybean aphids have another characteristic— male and female aphids occurr on different hosts. You may never succeed in the inoculating experiment if you do not add male aphids accordingly.

Table 1. Results of inoculating experiments in Fall   Gongzhuling, September, 1959

Treatment	Inoculated gynoparae (No.)	No. of oviparae	Inoculated male aphids (No.)	Gender ratio ♀ : ♂	Eggs oviposited (No.)
Replicate 1	45	30	43	0.7:1	21
2	40	35	5	7:1	24
3	45	30	33	0.91:1	18
4	50	50	12	4.2:1	29
5	55	60	15	4:1	48
6	40	30	5	6:1	25
7	55	100	54	2:1	135
8	45	35	18	2:1	25
9	60	130	60	2.2:1	115
10	55	145	0	all female	0
11	50	150	0	all female	0
12	50	100	0	all female	0

Regarding the hosts of soybean aphids, the works of Jinshi Zhiping and Zhou, Mingxiang et al. reported that achyranches (*Achyranches japonica*) was the overwintering host for soybean aphids. The publication, “Major Harmful Insects in North China”, also recorded that achyranthes, wild amaranth, and *Weiningcai* [Pinyin transliteration] were overwintering hosts for soybean aphids. We did a lot of research work on the overwintering host issue in both field investigation and inoculating experiments in recent years. Our results indicated that soybean aphids could not colonize and reproduce on these plants. They may occasionally appear on wild amaranths in soybean fields, but they cannot live on wild amaranths. The above facts confirmed that these plants have nothing to do with soybean aphids. Up untill now, buckthorn is the only overwintering host for soybean aphids. Buckthorn is widely distributed in Northeast China, North China, and East China, and is especially prevalent in the hilly areas of Eastern Jilin Province.

Development of generations: Different stages of development and the generation time in the life cycle of soybean aphids were observed on buckthorn or soybean plants. Inoculated plants were covered with screen cages, and aphids were grown in small groups. When one generation matured, all the adult aphids were removed and only a small number of young aphids were left on the plants.

From the fundatrices to the oviparae, soybean aphids reproduced 18 generations a year. Winged aphids (alatae) occurred at the second generation on buckthorn and began their Spring migration. When the gynoparae (winged female aphids) developed among the 17th generation on soybean plants, they migrated back to buckthorns, and the wingless aphids (apterae) stayed on soybeans and developed into male aphids. Oviparae and male aphids were developed at the 18th generation on buckthorns and soybean respectively. The generation time was 5 to 7 days when the average temperature reached 20 to 25°C; it became 11 to 12 days or 19 days at 16 to 17°C or 12°C. Nevertheless, exceptions may occur under different nutritional conditions. For example, from mid-August or late August to early September, although the average temperature may be between 20 and 25°C, the generation time could be extended because of the aging of soybean plants and the deterioration of their nutritional quality to aphids. In addition, the generation times for fundatrices and oviparae are always longer than that of other generations (Table 2).

Table 2. Development durations of different generations of soybean aphids

Generation	Host	Development period (D/M)	Average temperature (°C)	Average R.H. %	Duration of development (days)
1	Buckthorn	25/4-13/5	12.1	58	19 Fundatrices
2	Buckthorn	12/-245	17.1	55	12 Spring migrants
3	Soybean	26/5-5/6	16.2	68	11
4	Soybean	5-11/6	21.6	36	7
5	Soybean	12-17/6	21.3	64	6
6	Soybean	16-21/6	19.8	74	6
7	Soybean	22-28/6	19.8	59	7
8	Soybean	29/6-7/7	22.0	77	9
9	Soybean	8-13/7	23.4	82	6
10	Soybean	14-18/7	22.7	87	5
11	Soybean	18-22/7	25.1	82	5
12	Soybean	22-26/7	26.5	66	5
13	Soybean	27/7-2/8	25.4	80	7 young nymphs
14	Soybean	2-7/8	25.0	73	6
15	Soybean	8-15/8	25.5	80	8
16	Soybean	15-24/8	23.9	77	10
17	Soybean	25/8-5/9	20.0	77	12
18	Buckthorn	6/9-21/9	17.0	74	16 oviparae females

Life Cycle and Characteristics

I. **Life cycle:** Soybean aphids overwinter on the bud sides or in crevices of buckthorn branches in the Northeast China, North China, and Shangdong Province. In Spring, that is around April in Northeast China. The overwintered eggs hatch to fundatrices when the average temperature reaches 10° C and the first green appears on buds and buckthorns start to sprout. These female aphids reproduce parthenogenetically after growing up. At around the blooming time of the buckthorn (about middle or late May in Northeast China), winged-aphids (alatae) occur on buckthorns. Then they begin their Spring migration and start to infest soybean seedlings. According to the results of culturing studies and investigation at Gongzhuling, aphids reproduce 15 generations a year on soybean plants. The population of soybean aphids in soybean fields reaches its peak during late June to mid-July. After late July, the numbers of aphids in soybean fields declined because of the unfavorable nutritional conditions of aging soybean plants and high temperature, and huge amounts of pale colored, slow-growing nymphs appear on soybean plants. Since late August, the late reproduction of soybean aphids in the fields is adversely affected by conditions such as falling temperatures and ageing hosts. In the end, the winged female aphids (gynoparae) migrate back to their overwintering host and reproduce into oviparae. At the same time, winged male aphids develop on soybean plants and migrate to buckthorns, where they mate with the oviparae and the later oviposit their overwintering eggs (Figure 1). Another commonly observed phenomenon is that soybean aphids and the other aphids coexist on the buckthorn plants.

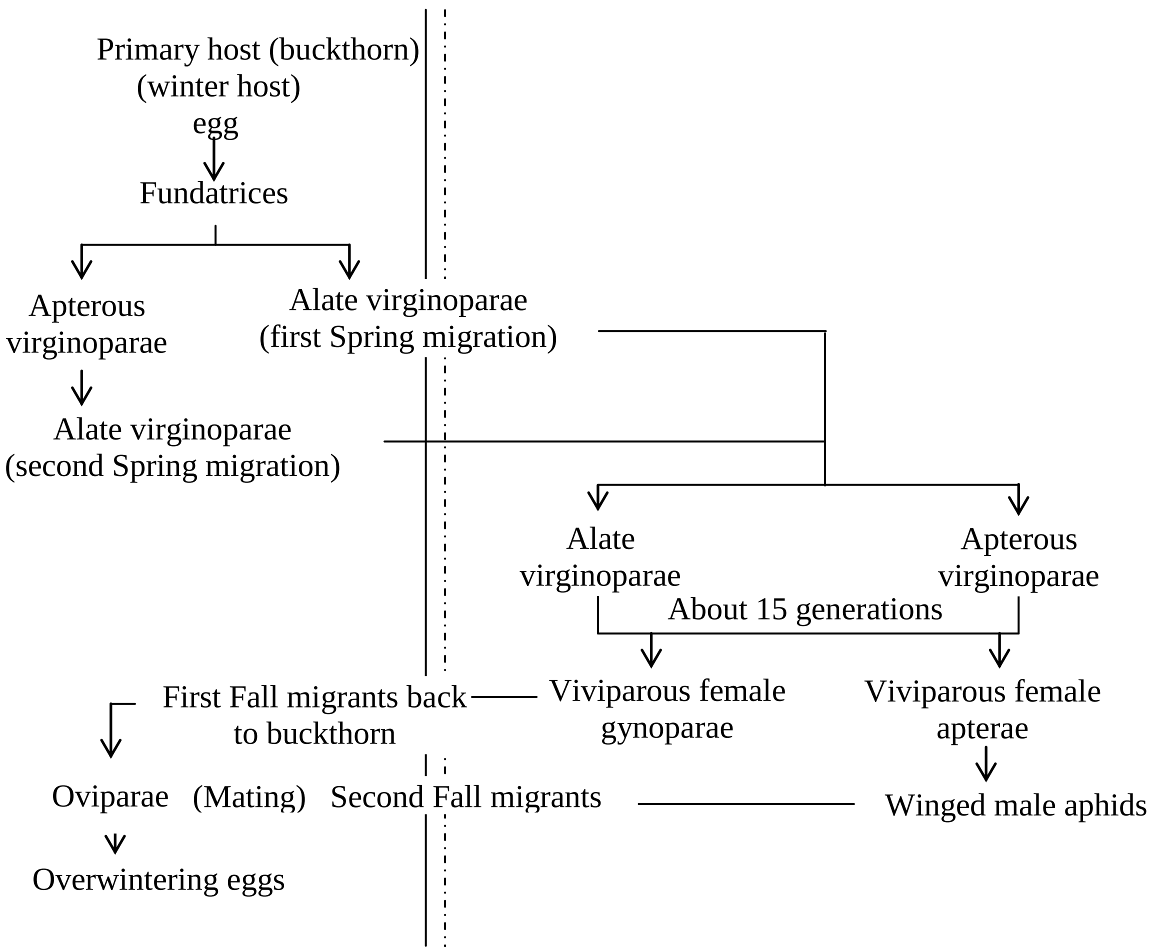

Figure 1. The simplified life cycle of soybean aphids

II. **Living habits**: After careful field observation in recent years, we divided the living habits of soybean aphids into two aspects: their characteristics on buckthorn and on soybean. Beginning with characteristics on buckthorn, most soybean aphids lived in the bottom branches of buckthorn plants, which was quite different from the other aphids on buckthorn (in addition to soybean aphids, there were three other species of aphids hosted on buckthorn plants). In spring, when the soybean aphids colonized on buckthorns, they would cause curling of tender leaves and twigs, which was also different from the symptoms caused by cotton aphid colonization. In fall, it was common to observe soybean aphids hybridizing with other aphid species on buckthorns. They mated and oviposited over wintering eggs. During their whole period on buckthorns, soybean aphids tend to stay in warm, not ventilated places. Therefore, small buckthorns on the sunny and leeward side of hills usually have soybean aphid colonization, whereas few aphids colonized on tall buckthorns, and no aphid was found on buckthorns in well-ventilated places.

On the other hand, the whole life cycle of aphids on soybean plants has three different stages, each with distinct characteristics. For example, important features such as migrating as winged forms and their vertical distribution in the soybean plants provide valuable information for taking proper control measures at appropriate times.

1) *the early spot and patches stage* In light of the results from recent years investigation, the number of overwintering eggs in normal years was low, and soybean aphids started their Spring migration after one to two generations on buckthorns; thus, not many aphids migrated into soybean plants during Spring because of their low starting numbers and few generations of reproduction in Spring. According to our investigation on spring migration in recent years, soybean plants infested with migrants only accounted for about 1% of the total plants, which was the reason that the early outbreaks of soybean aphids in the field showed the characteristic of sporadic spots or patches.

2) *Spreading stage to rampant stage* As the aphids reproduced and spread rapidly in the field, the aphid numbers on soybean plants increased dramatically. Most of the aphids were congregated on the top leaves or the tender leaves and twigs of the branches, which showed that soybean aphids had strong tender taxis. The aphid-infested plants quickly increased and caused the curling of leaves and twigs, thus forming the special pattern of aphid infestation-- starting at a few spots and quickly spreading to the whole field. This period is called the rampant stage of aphid infestation.

3) *Declining stage in field* As the growth point of soybean stopped growing and the temperatures increased, soybean aphids shifted from the upper parts of the plants to the undersides of leaves in the middle or lower parts of the plants. The aphids turned pale in color, became smaller in size, and their growth rate and reproductive capacity decreased markedly -- showing signs of over-summering. At this time, the stress of aphids on soybean crop was greatly alleviated, and the soybean plants quickly recovered to their normal growth and development.

4) *Pattern of migration* In the whole life cycle of soybean aphids, the migration of winged aphids is an important characteristic. Based on analyzing results from recent years' field investigation, four high tides of aphid migration could be recognized in the northeastern areas. The first migrating tide occurs when the soybean seedlings just come up out of the ground. That is the winged aphids migrating from buckthorns to soybean

fields, which is the source of aphids in the field and the beginning of damage to soybean plants. The number of migrants at that time is usually low, but this migrating tide was very obvious in 1954 when there was an early aphid outbreak. During that time, the number of winged aphids in the field was extremely high, and formed an epidemic and caused severe damage in a very short time. The second migrating tide happens in late June just before the blooming of soybean and the plants are young and tender. This migration greatly increases the numbers of infested plants in the field, and the infestation moves gradually from spots and patches to big patches or widespread infestation. This migration is not very important in normal years, but in years with early outbreak like that in 1954, it marks the time to take emergent control measures. We may quickly suppress the reproduction trend and reduce the number of aphids in field if proper control measures are taken before this migration. The third migration tide starts in the middle of July when the soybean plants are in full bloom. This migration results in the transition from spot infestation to extensive infestation in normal years. It could cause severe damage on soybean crops under favorable weather conditions. In order to prevent the spreading of aphids in fields, control measures must be taken before this migration. The fourth migration occurs in early September during the early yellow maturing period. There are two scenarios during this migration: first, the winged female aphids (gynoparae) migrate back to buckthorns and reproduce into ovipositional aphids (oviparae). As these oviparae develop and mature, the second migration appears-- winged male aphids migrate from soybean to buckthorns and mate with the oviparae, and then the oviparae oviposit overwintering eggs.

5) *Vertical distribution* During the whole life cycle of aphids, about 50-80% aphids are always colonized on the outer canopy of the soybean plants, which shows a strong tender taxis and causes the major damage during this period. As the growth points of soybean plants stop growing, their nutritional conditions deteriorate and as weather changes, aphids shift from the upper parts of the plants to underside of leaves in the lower parts of the plants. The aphid population decreases quickly, and their impacts on soybean plants also alleviate, thus the soybean plants gradually recover to their normal growth and development (Table 3).

Table 3. The vertical distribution of aphids in soybean plants 1957, Gongzhuling

Date of investigation	Aphid in the outer canopy of the plants (%)	Aphid in the other parts of the plants (%)	Comments
June 30	84.2	15.8	Proper time to take control measures
July 5	78.4	21.6	
10	71.1	28.9	
15	51.2	48.8	
20	63.9	36.1	
25	67.6	32.4	
30	8.9	91.1	
August 5	6.2	93.8	Great amount of nymphs emerge at this time, no control measure is needed.
10	6.1	93.9	
15	4.7	95.3	
20	8.9	91.1	
25	5.6	94.4	
30	5.2	94.8	

September 5	2.2	97.8	
10	2.0	98.0	

Pattern of Growth and Decline

According to the results of our five-year field investigation from 1954 to 1958, when the soybean plants just emerged from the ground, the alatae migrated from buckthorns to soybean seedlings, and these female aphids reproduced viviparously and fed on the soybean plants. During normal years with small numbers of original overwintering aphids as in year 1955, 1956 and 1957, the numbers of overwintering eggs were below 50 per 100 buckthorn branches, and the aphid numbers in the early spring fields were low and the damage very little. Whereas, if the numbers of overwintering eggs were very high as in the winter of 1953, with over 10,000 eggs per 100 buckthorn branches, which was 200 times more than normal years, then it was a different story. Huge numbers of overwintering eggs meant that a great amount of winged aphids (alatae) would be hatched in the following spring, which would migrate to soybean fields and cause early outbreaks and heavy damage to the soybean crop. Therefore, the widespread outbreak and severe damage stage would be half a month earlier than in normal years. Our field investigations at Gongzhuling, Jiuzhan, Jiutai and Haicheng etc. in June 1954 confirmed such early severe damage, and also showed that the number of original overwintering eggs determined the type of aphid outbreaks that followed (Table 4). As shown by the data of these years investigation, the spring aphid migration in the northeast areas occurs at the time soybean seedlings just emerge from the ground, which provides excellent nutrients for the aphids. Thus, under normal weather conditions, the greater the numbers of the overwintering eggs, the more severe the early aphids outbreak would be.

Table 4. Relationship between overwintering number, spring migration and outbreak

Year	Location	Overwintering eggs per 100 branches (No.)	Rate of migrant infested soybean plant in Spring (%)	Comments
*1954	Jiaohe	10,000	24-44	* aphid outbreaks prevailed in the whole Northeast areas this year and caused severe early damage
1955	Gongzhuling	35	0.5-1.0	
1956	Gongzhuling	9.8	0.5-1.0	
1957	Gongzhuling	10	0.5-1.0	
1958	Jiaohe	25	0.5-1.0	

According to our investigations, in years with normal numbers of overwintering eggs, the numbers of aphids in the early stage was low and would not cause widespread outbreaks and much damage before the second migration of alatae. Thus, no control measure was needed at this period of time. Whether there would be a severe aphid epidemic in July of that year depended on their multiplying rate from late June to early July. On the basis of our recent years' studies and analyses, if average temperatures in late June and early July were above 22 °C, R.H. was below 78%, and there were not many natural enemies of the aphids in the fields, then there probably would be severe aphid impact in July because these conditions and the nutritious, vegetative developing soybean plants favor the rapid reproduction and spread of aphids. Similar aphid infestation may also end up with quite different results of aphid damage under different weather conditions, which had been proved by our data in 1955, 1956, and 1958. Although the rates of migrant infested plants were similarly low between 0.5 to 1.0%, there were prevailing soybean aphid outbreaks in 1955 and 1958 because the weather conditions between late June and early July in 1956 were markedly different from those in 1955 and 1958 (Figure 2 and 3). Based on the results of culturing studies and the analysis of the rise and fall patterns in the last five years, we found that the aphid population naturally declined after late July because the growing points of soybean plants stopped growing and their nutritional conditions for soybean aphids deteriorated. No control measures are necessary from that time on and the soybean plants would recover and grow. High temperature and relative humidity are unfavorable to aphids. According to the results of our studies, massive aphids would die in the fields if the five-day average temperature was above 25 °C and R. H. was above 80%. The situation at Jiuzhan, Jilin Province in 1956 was an example of this case. The results of our studies also showed that natural enemies of aphids did not affect the growth and decline pattern of aphid population very much.

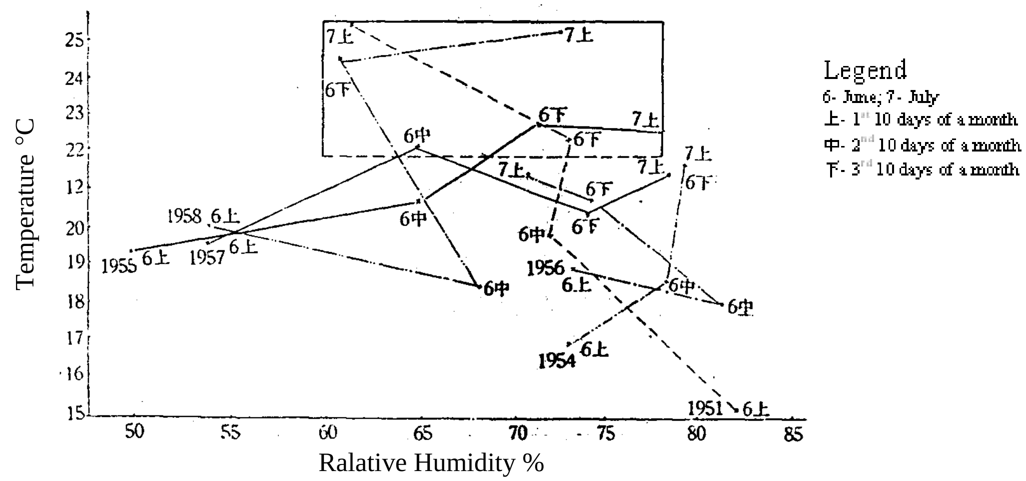

Figure 2. Comparison of climates among different outbreak years (Gongzhuling)

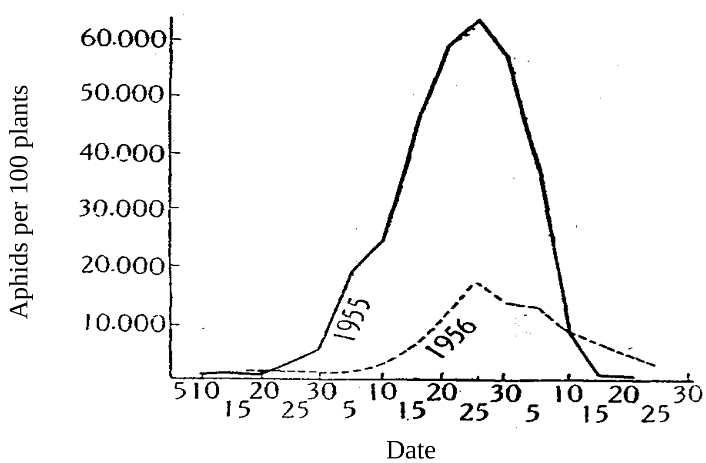

Figure 3. Rise and fall of aphid population in different years (Gongzhuling)

Natural Enemies

According to our field studies and observation in the northeastern areas of China, there are many kinds of natural enemies of soybean aphids. The most common ones include lady beetles: *Ptychanatis axyridis* Pallas, the 13-spotted lady beetle (*Hippodamia tredecimpunctata* L.), the 7-spotted lady beetle (*Coccinella septempunctata* L.), the propylaea (*Propylaea japonica* Thunberg); two species of aphid-eating wasps: (*Sphaerophoria indiana* Bigot) and another species (scientific name unknown); green lacewings: *Chrysopa septempunctata cognata* MacLachlan and C*hrysopa japana* Okamato; and two species of parasitic wasps (scientific names unknown);. There were also many *Leucopis* sp. during the late stages. Under favorable weather conditions, parasitic molds may also cause massive deaths of aphids. What happened at Jiuzhan in the late July of 1956 was a good example. Among all these natural enemies of soybean aphid, lady beetles were more common in fields with higher aphid numbers and they also were the most capable of killing aphids. In summary, natural enemies of soybean aphids may suppress the reproduction of aphids and alleviate their impact on soybean crop under suitable conditions. Under the actual situations in the Northeast China, the establishment of natural enemy populations was in the late period of aphid outbreaks, which means that they do not have significant effects in controlling aphid reproduction and its impact on soybean crops.

Control Measures

In order to control soybean aphids, we conducted our five-year studies from 1953 to 1957 at Jiaohe, Jiuzhan, Yongji, Gongzhuling, Yushu, and Dongliao in Jilin Province, and at Haichen of Liaoning Province. Insecticides such as 0.5% BHC powder, 6% BHC wettable powder, E605, E1059, derris extract, tobacco leaf solution, as well as seed dressing with 20% BHC had been applied in our aphid control studies. All were proven very effective in killing aphids. We also gained successful experience in large-scale field operations of aphid control. Among these methods, 0.5% BHC powder and 20% BHC seed coating techniques were especially welcomed by farmers because they were inexpensive, offered no special requirements of water source, were easy to operate, and not very toxic to human being and animals.

Table 6. Killing effects of different insecticides at different dilution levels

Insecticide & dilutions	Applying method	Tested aphids (No.)	Mortality (%)	Comments
0.5% 666 powder	Powdering	2227	96	
6% 666 wettable powder				
1 to 300 dilution	Spraying	1180	100	
1 to 400 dilution	Spraying	180	100	
46% 1605, 1:15000 dilution	Spraying	914	100	
50% 1059, 1:15000 dilution	Spraying	1200	100	effective for 7-10 days
3% Derris extract				
1:1000 dilution	Spraying	1228	99.7	with half soap
1:1200 dilution	Spraying	1621	99.9	with half soap
1:1500 dilution	Spraying	1336	100	with half soap
1:1800 dilution	Spraying	637	84.4	without soap
1:2000 dilution	Spraying	928	83.9	without soap
1:1500 dilution	Spraying	516	92.4	without soap
Tobacco solution (half soap)				
1 to 80 dilution	Spraying	670	100	
1 to 100 dilution	Spraying	601	99.1	
1 to 120 dilution	Spraying	3709	87	
Tobacco stem 1 to 25 dilution	Spraying	800	80	Left from tobacco leave harvest

I. Aphicidal effects of all insecticides on soybean aphids (Table 6)

II. Experiments on methods of applying insecticides

1. ***Spot and patches application*** The spot and patches outbreaks during the early stage of aphid epidemics have a characteristic which was demonstrated at Dongfeng County, Jilin Province, in 1955: even though the migrant-infested plant rate was as high as 94% in early July, there were no widespread outbreaks yet in the soybean fields. The aphid population was not evenly distributed, the most heavily infested plant having as many as 4690 aphids, and the least infested plant having less than 100 aphids. It looked like there were some severely infested "nests" in the fields, which only accounted for 4.6% of the whole soybean acreage. In order to control the spread of aphids in accordance with this characteristic of early aphid infestation, we applied 0.5% BHC powder on the infested spots and patches to see if this kind of application would control the tendency of spreading and achieve overall control effects. Data in Table 7 showed the control results of spot and patches application. The aphid population in the insecticide-applied areas decreased dramatically, whereas the aphid population in the control area was still as high as 4140 per plant. Therefore, we believe that the spot and patches application method can not only control the population and spread of aphids, but also save on insecticides and labor.

Table 7. Results of spot and piece application

Item	Aphids/plant before application (No.)	Aphids/plant after application (No.)
Applied area	10400	623
Control area	10662	4140

2. Large-scale control experiments with BHC powder

Results of several experiments proved that the 0.5% BHC powder had excellent killing effects on aphids. In order to systematize the period and method for insecticide application in aphid control, we conducted a large scale aphid control collaborative experiment with the Jilin Academy for Agricultural Sciences, Jilin Research Institute for Agricultural Sciences, the Jilin Provincial Bureau for Agriculture, and the Agricultural Bureau of Yongji County, and set up a large aphid control exemplary area at the Laxi district of Yongji County.

1) Situation of aphid outbreak and statistics Frequent scouting was performed in that district during late June and early July. Scouting results revealed that the migrant infestation rates were 5 to 10% in late June, and leaf curvature only happened in a few soybean plants. In early July, the results of a second scouting showed that the average infested rates increased from 5-10% to 30-80%. Among those infested plants, 7-10% were severely infested with curling leaves. Judging from this, the reproduction and spreading rate of aphids were really fast at that time. By the time of the third scouting on July 7, the infestation rates in some soybean fields reached 90% and above with 16.5% plants severely infested. The aphid-infested plant rates and aphid population increased by about 15 times in a period of half a month. Among the 1245 *mu* soybean field of the Yongshui agricultural producers' cooperative, more than 300 *mu* were heavily damaged by aphids. Regarding the above-mentioned situation, we set up a large-scale demonstration area at relatively severely infested fields in that producers' cooperative, and paid special attention to the infested center. In order to summarize and evaluate the technical measures, control effects and economic benefits of applying 0.5% BHC powder in large scale aphid control, we compared the aphid control effects and the growth of soybean plants, and determined the yield by separate cutting, transporting, and threshing.

2) Control effects The aphid control experiments at Yongshui agricultural producers' cooperative in Dashuihe town started on July 8 and ended on July 15. Results of comparative experiments and special investigation are listed in Table 8, which show that over 80% of the aphids were killed after the application of the insecticide, that multiplication rate of aphids was much lower than before the application, damage caused by aphids was restrained, and the growth of soybean plants recovered well. During the same period at the same location, the aphid population in the soybean fields without insecticide application increased by 2.2 times in five days and caused heavy damage on soybean plants. The effects of application on the growth of soybean plants are as follows: the average height of soybean plants in eight patches of soybean fields before applying insecticides on July 11 was 20-25 cm, and the average numbers

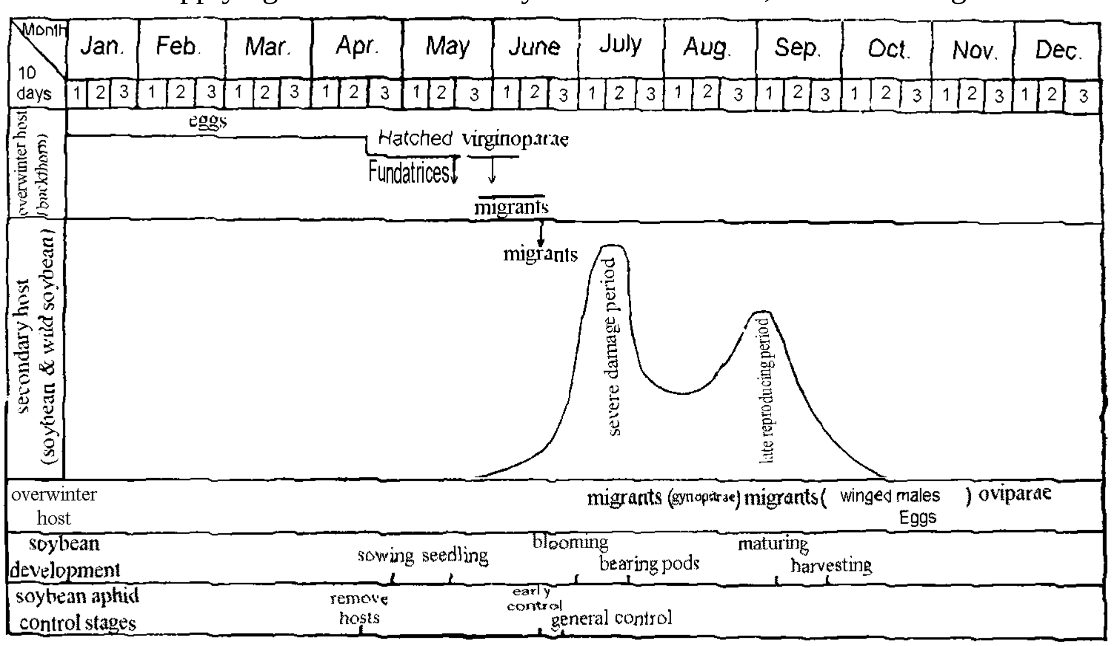

Figure 4. Calendar of development and control of soybean aphids

of branches were 2.3, which hardly showed any difference from those in the untreated control fields. However, the average height of soybean plants in the treated fields on July 29 reached 54.4 cm with an average of 3.5 branches; and those in the untreated control fields grew much slower and had an average height of 44.4 cm with only 2.2 branches. Thus it can been seen that considering the aphid development situation and applying insecticide before severe aphid damage occurred could rapidly curtail the increasing trend of aphid population, and significantly alleviate the aphid impact on soybean plants (Figure 4). Results showed that the average yields in the treated soybean fields were 7 to 11% higher than those of the untreated control fields (Table 9 and 10). The application of 0.5% BHC powder is now widely practiced in aphid control.

Table 9. Comparison on soybean growth after applying 0.5% BHC powder July, 1956, Yongji, Jilin

Pairs of treatments		Average height (cm)	Average branches (No.)	Pods/plant (No.)
1st pair	Treated fields	55.9	3.4	44.6
	Untreated fields	47.0	3.2	35.4
2nd pair	Treated fields	54.6	2.9	44.5
	Untreated fields	50.0	1.8	32.1
3rd pair	Treated fields	58.2	4.3	46.9
	Untreated fields	46.1	2.4	29.3

Table 10. Profit from applying 0.5% BHC powder in aphid control July, 1956, Yongji, Jilin

Treatment	Expenses (yuan)				Gain (yuan)			Net profit
	Labor	Convert into money	Insecticide fee	Total	Gained Yield Kg/hectare	Convert into money	Total	
1st pair area	1	1.50	3.50	5.00	199.7	32.00	32.00	27.00
2nd pair area	1	1.50	3.50	5.00	125.3	21.10	20.10	15.10
3rd pair area	1	1.50	3.50	5.00	194.7	31.15	31.15	26.15

Note: labor was calculated on the basis of hectare, insecticide dosage was 20 to 25 kg/hectare.

3. Control experiments by coating seed with 20% BHC

It was reported by former researchers that BHC could be systematically translocated in the plant tissues and act as a systematic insecticide. In order to make full use of the published data and achieve more effective control results with the simplest possible method, from 1955 to 1957 we performed our seed coating control research with 20% BHC in laboratory level, plot scale, and large scale field experiments.

Method of Experiments Soybean seeds (varieties including Jiti #5, Jiti #4, Xiaohuangjin #1, Mangcangjin, and Fengdihuang) were coated dry with 20% BHC and soybean nodule bacteria as well, and the three different dosages were between 0.3% to 1.0% of the seed weight. In both laboratory and field experiments, the rates of germinating and emergence were examined; the growth of the seedlings and effectiveness of the insecticide were also evaluated. The dosage of coating with 0.7% seed weight of 20% BHC was employed in the large-scale field control test.

Results of experiments

1) *The effects of BHC dressing on the growth and development of soybean plants*

a) Effects of seed dressing on germinating and growth and development of soybean plants

Judging from the germinating rates and the growth of seedlings, treatments of coating with 0.3% to 1.0% the seed weight of 20% BHC showed no harmful effects on the soybean plants. On the contrary, the coated insecticide had some good stimulating effects on the seedlings, which was displayed by the robust growth of the seedlings (Table 11). Results also showed that seed coating was effective for many soybean varieties (Table 12 and 13).

Table 11. Actual coated insecticide after dressing with 20% BHC powder

Soybean variety	Jiti #5	Jiti #4	Xiaohuangjin #1	mancangjin	Fengdihuang
Actual coated insecticide (% of the seed weight)	0.62	0.74	0.73	0.66	0.65

Table 12. Germinating and seedling development after dressing with 20% BHC 1955, Gongzhuling, Jilin

Dressing dosages	Average germinating rate (%)	Average length of root (cm)	Average diameter of root (cm)
1.0%	95	3.11	2.44
0.5%	97	3.08	2.52
0.3%	100	6.03	2.46
No dressing control	98	7.03	1.55

Note: calculated by weighing the left insecticide after dressing at the same dosage.

Table 13. Results of seedling emergency of different soybean varieties after dressing with 20% BHC

Soybean variety / Emergency rate / Treatment	Jiti #5	Jiti #4	Xiaohuangjin #1	mancangjin	Fengdihuang
Dressed seeds	93.3	100	93.3	86.6	100
Control	100	100	100	100	100

Note: dressing dosages were the actual coated amount on the seeds of all varieties.

b) Control effects of seed coating on different soybean varieties

2) *Aphid control effects by seed coating with BHC powder*

a) Laboratory experiment (Table 14)

Table 14. Aphid control effects by seed coating in laboratory experiments

Inoculating time	Within 24th day of emergence		27th day after emergence		31st day after emergence	
Results / Treatment	Average mortality (%)	Multiples of population 2 days after inoculation	Average mortality (%)	Multiples of population 2 days after inoculation	Average mortality (%)	Multiples of population 2 days after inoculation
1.0% dressing	100	0	100	0	10	2.0
0.5% dressing	100	0	70	0.4	20	6.1
0.3% dressing	100	0	30	4.4	0	6.0
No control	9	4.9	20	9.6	30	7.5

Note: 1. adult spring migrants were used for inoculation; each inoculation was repeated 3-5 times per treatment, and 9 inoculations were performed with 24 days of emergence; all aphids were killed in all the treated areas.
2. Mortality was calculated by dividing the dead aphid numbers one day after inoculation with the original inoculated aphids.

b) Field tests (Table 15, 16 and Figure 5, 6)

Table 15. Field control effects on aphids by seed coating with 20% BHC   Jun Jul, 1956, Gongzhuling, Jilin

Inoculating time	Within 7 days after emergence		10th day after emergence		13th day after emergence		17th day after emergence		21st day after emergence		26th day after emergence		31st day after emergence	
Results / Treatment	Average mortality (%)	Population multiplication rate	Average mortality (%)	Population multiplication rate 18 days after inoculation	Average mortality (%)	Population multiplication rate 16 days after inoculation	Average mortality (%)	Population multiplication rate 12 days after inoculation	Average mortality (%)	Population multiplication rate 10 days after inoculation	Average mortality (%)	Population multiplication rate 7 days after inoculation	Average mortality (%)	Population multiplication rate 2 days after inoculation
1.0% dressing	100	0	100.9	0	100	0	100	0	99	0.4	90	0.5	59	1.2
0.8% dressing	100	0	9.6	0.02	99.6	3.6	80	2.0	99	1.7	80	1.4	46	2.5
0.5% dressing	100	0	80	2.7	99.2	1.2	96.6	0.4	98	5.0	50	4.0	37	3.4
Control	21	44	38	703.1	50	39	40	43	41	50.4	50	18.2	19	4.8

Note: Inoculation was repeated 4-7 times in the treated areas, 6 inoculations were performed in 7 days after seedling emergency. All aphids died in the treated areas.

Table 16. results of studies on aphid spread, rise & fall pattern, and damage   1956, Gongzhuling, Jilin

Treatment	Rate of infested plants (%)				Average aphids on infested plants (No.)				Rate of plants with curvature leaves (%)		
	6/13	6/22	7/03	7/13	6/16	6/21	6/26	7/01	6/13	6/22	7/03
1.0% dressing	0.78	5.50	13.50	43.50	0	0	5.2	3.2	0	0.4	0
0.8% dressing	1.37	8.80	13.80	36.30	0	5	9.2	2.5	0	0.3	0
0.5% dressing	1.20	9.50	19.60	47.00	0	1	3.7	4.0	0	0.1	0
Control	44.05	52.0	45.20	55.90	32	34.5	65.4	5.2	9.5	8.3	0.8

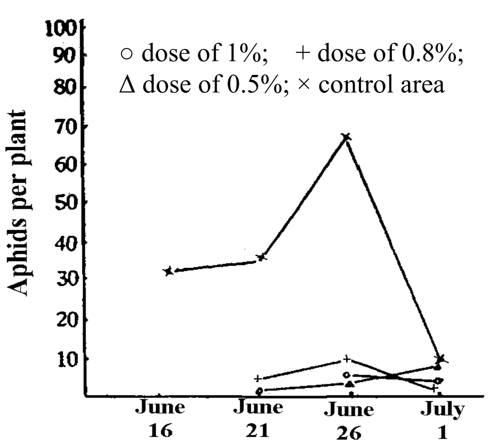

Figure 5. Rise & fall of aphids in fields applied with 20% BHC dressed seeds
1956, Gongzhuling, Jilin Province

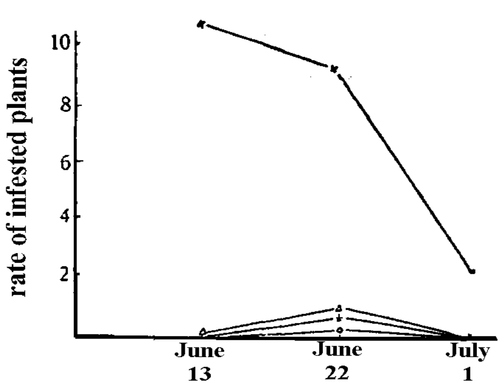

Figure 6. Aphid damage in fields applied with 20% BHC dressed seeds (1956, Gongzhuling, Jilin Province)

c) Large scale field tests

The large scale aphid control experiments were conducted at Hegaxiang and Changxinxiao, Wukeshu district, Yushu County, Jilin Province, which included 6 advanced producer cooperatives before being organized into a People's commune. The acreage of soybean fields was about one third of the total acreage in the experimental areas. All the experimental areas were applied with 20% BHC powder coated seeds, and the insecticide rate was 0.7% of the seed weight. There were also control areas both inside and outside the experimental areas. The results are as follows:

Table 17. aphid control effects with seed coating in large scale field experiments 1957, Yushu, Jilin Province

Treatment	Average infested rate (%)	Average aphid # per plant	Average rate of plants with curvature leaves (%)
0.7% BHC dressed seeds	26.5	4.7	0.8
Outside control areas	77.8	49.6	12.2

To sum up, based on the results of continuous inoculating experiments in both laboratory and field, and observation on the natural migrants, all the dosages of seed coating treatments showed control effects within 21 days after the emergency of the seedlings; in the first 7 days after emergency, no aphid could survive; It can also been seen from the aphid spread data and the rise and fall pattern in the treated fields (Table 14, 15, 16, and 17) that the early aphid damages in fields with BHC coated seeds were much lighter than in the control areas. As recorded on June 13, the aphid infested rate in the control areas was as high as 44.05% with 9.5% leave curled plants, and that in the dressed seed area was only 0.78-1.37% with no leave curled plant. Again, on June 22, the aphid infestation rate in the control field reached 52%, and that of the BHC dressed seeds fields were between 5.5 to 9.5%. The severity of damage between the treated and control fields was also significantly different. The rate of plants with curled leaves in the control areas was 8.3%, and that in the fields with dressed seeds were all below 0.5%, which indicated that seed coating treatment had significant control effects on inhibiting the reproduction and spread of aphids. However, the densities of natural enemies of aphids such as lady beetles and syrphid flies increased after late June, and started to feed on aphids in the experimental fields, which facilitated the spread of aphids from the control fields to other fields. The result was that the aphid population in the control fields dropped rapidly and was not obviously different from that in the treated fields during the late period of the aphid outbreak. Despite this fact, results of several scouting expeditions before mid-July showed that aphid damage in the treated fields was still much lighter than in control fields. These scoutings were conducted according to the characteristics of early aphid damage and development patterns -- early July is the pre-peak stage of aphid epidemic. The results of large-scale field control experiments in 1957 further proved that seed coating with BHC powder could strongly inhibit aphid reproduction during the seedling stage, which is important for controlling the early aphid damage on soybean seedlings and facilitating their health growth.

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(Author provided English summary)

STUDIES ON THE SOYBEAN APHIDS, *APHIS GLYCINES* MATSUMURA

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The soybean aphid, *Aphis glycines* Matsumura is widely distributed in the soybean growing regions of China, its damage has done severely in Kirin, Liaoning, Heilungkiang, and Inner Mongolia. The host plant of this aphid is quite limited, besides the cultivated soybean, so far only the wild soybean, *Glycine Benth* forma *lanceolate* Makino, and *Rhamnus davuricus* Pall. were found in Northeast China. Three periods of the damage on soybean can be recognized: 1) From seedling stage to blooming stage of soybean, the aphid population reaches its highest peak. Its colonies concentrate on tender leaves and branches. 2) In late July, the top growing point of soybean plant stops to grow, the aphid colonies alter their positions from the top to the middle or the lower part of the plant and feed on the underside of soybean leaves. At that time, minute form of aphids appears and its population usually turns down quickly. 3) From late August to early September, the aphid colony begins to multiply rapidly again. Afterwards, it migrates back to the overwintering host, *Rhamnus davuricus*. By mating of the sexuales, eggs are laid to pass winter. A total of 15 generations developed on soybean and all together 18 generations in a year.

Some aspects in relation to the fluctuations of aphid population are mentioned: 1) The norm of overwintering eggs and also the population size in the soybean seedling stage are directly related to the future size of the aphid colony. 2) During the period from late June to early July, the optimal range of temperature (22-25°C) and humidity (below 78%) are found combinatively favoring the aphid development. 3) After late July, the growth of soybean becomes depressing, the nutritious supply for the aphid becomes correspondingly poor, the population goes to be greatly decreased.

The results of laboratory and field tests revealed that 0.5% γ-666 dust, 6% wettable γ-666. (1:300-400), E605 (1:15000), tobacco leaf solution (1:100) and seed coating with 20% r-666 dust are very effective to control the soybean aphids.