

## **RESEARCH ON THE LIFE CYCLE PATTERNS OF SEVERAL APHIDS**

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Mordvilko (1928, 1934) summarized his research work on aphids more than thirty years ago, and proposed an evolutionary theory of aphid life cycle patterns, which has been accepted by most aphidologists. He determined that the ancestor patterns of aphids were sexuparae, oviparous and alate, belonging to Archescytinidae in the Permian Period, as revealed by insect fossil research. The real aphids appeared through gradual evolution around the Mesozoic Era, and the phenomenon of polymorphism such as partheno-oviparity, partheno-viviparity, and apterous patterns appeared. He assumed that the life cycles of aphids evolved into the alternation of parthenogenetic and sexual generations in the middle-latitude regions. When new plants appeared in the earth's history, aphids harboring on other older plants (the primary hosts of aphids) migrated to them, adapting to the environment and adopting them as the new, secondary hosts. In the beginning, the migration was incomplete, meaning that summer aphid populations could live both on the secondary and primary hosts. Later, the evolution of the transfer was complete, meaning that summer aphid populations could only live on secondary hosts. Then patterns changed to complete cycles on alternative hosts. Usually the primary hosts are relatively old woody plants, but secondary hosts are herbaceous plants. According to Mordvilko, there were two prerequisites for the appearance of the alternative-host complete cycle patterns: first, the generation cycle must have already been completed on primary hosts; second, the secondary hosts capable of surviving on earth or in a certain area must have already appeared. His contribution was the concept of the alternative-host complete cycle patterns evolving from same-host complete cycle patterns

However, his theory also has some disadvantages. For instance, he considered alternative-host complete cycle patterns as all at the end of life cycle evolution for any aphid species. Furthermore, he concluded that life cycles of some Adelgidae had evolved at the end depending on the secondary hosts (fir, pine, larch etc.), which had already existed in the Cretaceous Period on the earth.

In addition, Mordvilko (1934) thought that aphids with incomplete lifecycle patterns evolved from alternative-host complete cycle patterns. That is, in the Glacial Period the primary hosts of many aphids which include partial aphid ancestors disappeared, and secondary hosts of some aphids endured cold temperatures better than primary hosts. Thus, the secondary hosts could survive together with their aphids and became part of incomplete cycle patterns, which lost the primary hosts and sexual generations. Bodenheimer and Swirski (1957) praised this assumption as the incomplete cycle paleoclimate theory. Although this theory has already been accepted by most aphid experts, it has some obvious disadvantages. For example, it is hard to answer the question why aphids on secondary hosts in the Glacial Period were not killed by the low temperatures; did the incomplete life cycle patterns happen before the Glacial Period so they could survive, or were the incomplete life cycle patterns formed after the arrival of glaciers in the Glacial Period? Is it not possible that the incomplete life cycle patterns existed before the Glacial Period?

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Many aphids experts criticized the shortcomings of the above theory proposed by Mordvilko. Hille Ris Lambers (1950) pointed out it was possible that the alternative-host complete cycle patterns were lost, and aphids could evolve from the alternative-host complete cycle patterns on the secondary hosts into the same-host complete cycle patterns. Kennedy and Stroyan (1959) pointed out that the shortcomings of Mordvilko's theory were the phenomenon of the alternative-host complete cycle he observed, and that he regarded it as the end of the evolution of aphids. But actually, environmental circumstances change constantly, and the habitats of plants are also easily changed. Many of the species with the same-host complete cycle patterns recorded nowadays were not known by Mordvilko at that time. Moreover, Eastop (1973) also pointed out that the relations between aphids and plants were evolving as many new hosts have been found for aphids.

We think that the above critical suggestions are more convincing: the evolution of alternative-host complete cycles is still underway and will continue. We will discuss such issues based on our partial research work.

### **1. *Aphis gossypii* Glovers do not all follow incomplete cycle patterns, which lost the primary hosts and sexual generations**

So far, most aphid experts in Europe, the United States, Japan and other countries and regions still believe that cotton aphids have an incomplete cycle pattern, which lost the primary hosts and sexual generations (Borner *et al.*, 1957; Muller, 1977; Shaposhnikov, 1964; Palmer, 1952; Takahashi, 1966). Inaizumi (1970) once reported that some plants such as hibiscus, Japanese cascara etc. were primary hosts of cotton aphids and that potatoes and melons were secondary hosts. Eastop (1977) once reported that the primary host of cotton aphids also included the Bignoniaceae plants. Our research (Zhu and Li, 1958) over many years shows that there could have evolved three different life cycle patterns in the same cotton aphids species in the same region, which is quite unusual in Aphididae.

#### **(1) Incomplete cycle patterns could lead aphids to evolving into incomplete cycle patterns.**

Mordvilko (1934) thought that the appearance of the incomplete cycle patterns resulted from the change of the macroclimate in one certain region; namely, he explained this phenomenon using the paleoclimate theory. But the experiment done by Bonnemaïson (1950) proved that the alternative-host complete cycle patterns of aphids *fabae* Scop and *Myzus persicae* (Sulzer) were able to switch to incomplete cycle patterns via breeding for 12~50 generations under high temperatures and continuous sunshine. We observed the vegetables (spinach, celery) in **windbreaks, cached cabbage and *Myzus persicae* (Sulzer)**, on which the parthenogenesis continued on the greenhouse plants **in winter in Beijing and Xuchang, Henan (Li, Zhang and Zhu, 1963)**. Because they lived as parthenogenesis for a long time, they still didn't produce sexupara, female and male aphids to follow the incomplete cycle patterns of parthenogenesis in a whole year under the low temperature and shorter sunshine in autumn. The feeding habits of the patterns have been specialized. The transplant experiments showed that they could only live on plants such as cabbages etc., but could not live on tobacco plants any more.

	Number of transplant (VI. 1)	Average number of propagation per unit (VI. 14)
Greenhouse cucumber	Cucumber (20)	155.0
	Watermelon (20)	123.0
	Vegetable marrow (20)	105.0
	White gourd (20)	82.5
	Melon (20)	57.5
	Cucumis melo L.var.conomon Makono (20)	29.0
	Cotton (20)	12.3
	Towel gourd (20)	6.3
	Cushaw (20)	1.3

Fig. 1 The transplant experiment from greenhouse cucumber aphids to melons

Note: The greenhouse cucumber aphids in this transplant are all alate aphids. Similar transplant experiments were conducted 18 times with 178 processes from 1964 to 1965. Totally, we transplanted 1,910 alate partheno-aphids and 3,775 apterous sexuparae aphids. The above figure only represents the results of one experiment.

Our experiments in Beijing proved that the cucumber aphid patterns of cotton aphids were also incomplete cycle patterns. They live as parthenogenesis on cucumber fields in summer, then they were transferred into a greenhouse, a vinyl house, and lived as parthenogenesis on cucumbers in autumn until the next summer. **After living as parthenogenesis** for an extended time, their feeding habits had been specialized to some degree, and their life cycles were also changed. Our transplant experiments 18 times with 178 processes from 1964 to 1965 proved that <sup>1)</sup> the feeding habits of cucumber aphids patterns had been already almost as specialized as cucumber, which could live on vegetable marrows and pumpkins (Fig. 1) and most of which could not survive on cotton plants (Fig. 1 and 2). Most of these patterns could not produce sexupara, female and male aphids under the low temperature and shorter sunshine time in autumn whenever they lived on cucumbers, vegetable marrows, pumpkins or even fewer cotton plants (Fig. 3). This could prove that cotton aphids could lead incomplete cycle aphids pattern while living on cucumbers with long-term incomplete cycles. Because conditions of microclimate temperatures found in windbreaks, greenhouses, vinyl houses and vegetable cellars etc. are common, the generational conditions of aphid incomplete cycle pattern are easily satisfied. So it seems that the main factor forming the incomplete cycle patterns is microclimate, but Mordvilko explained it using the effects of paleoclimate.

1) The detailed experiment results will be published separately.

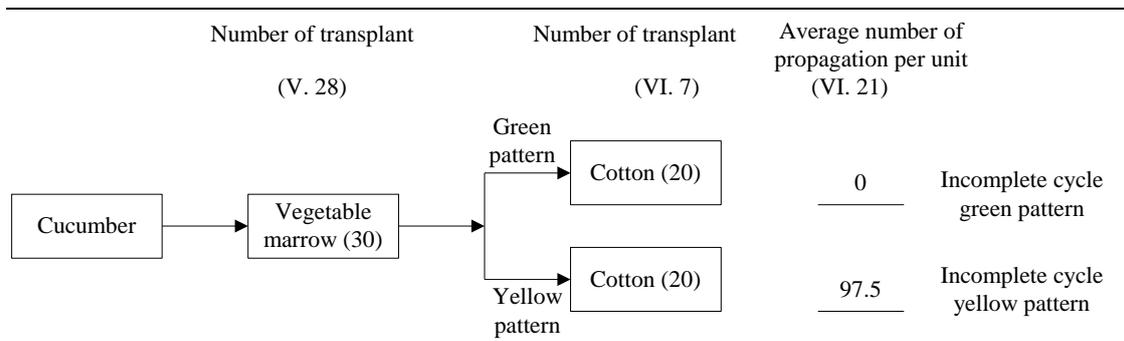


Fig. 2 The transplant of cucumber aphids to cotton plants via vegetable marrows (Beijing, 1965)

Note: Similar transplant experiment has been conducted for two times The above figure just represents the results of one experiment.

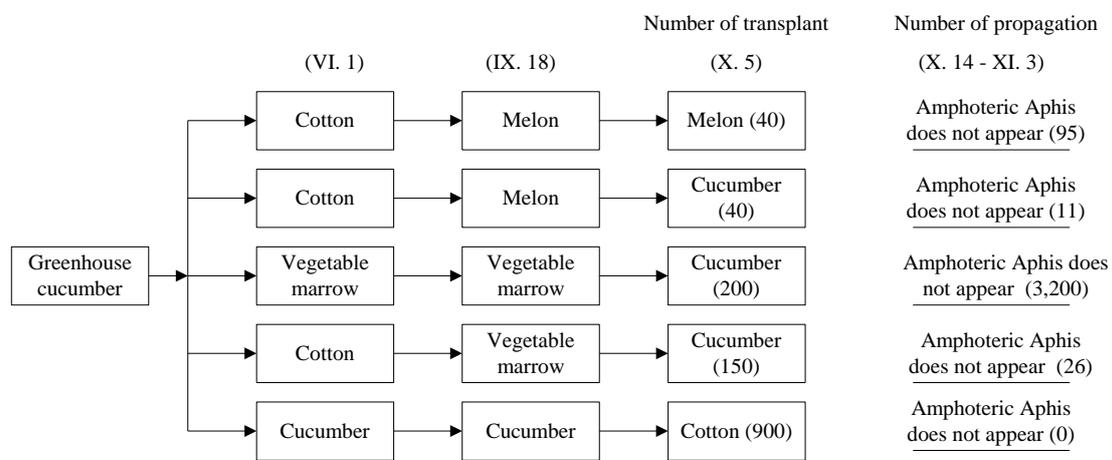


Fig. 3 The incomplete cycle pattern doesn't produce sexuparae aphids at the end of autumn. Beijing, 1965

The cucumber aphid pattern with incomplete cycles could be further divided into two sub-patterns: the first one is cucumber green pattern  $A_1$  (Fig. 2 and 4), which could only live on cucumbers and vegetable marrows etc., but could no longer live on cotton plants, the feeding habits being more specialized; the second one is cucumber yellow pattern  $A_2$  (Fig. 2 and 4), which could not only live on cucumbers and vegetable marrows etc. but also could transplant with difficulty to cotton plants and survive on them, or transplant easily to cotton plants through vegetable marrows and survive on them. This deserves further research into whether the difference between the colors and feeding habits of cucumber green patterns and yellow patterns account for the fact that these two patterns are of different levels of evolution or not.

The transplant experiments proved that cotton aphids with the complete cycle patterns H could live normally on the cotton and vegetable marrows (Fig. 4 and 5), but could not live on cucumbers easily. The cucumber patterns of cotton aphids with incomplete cycles  $A_1$  and  $A_2$  have parthenogenetic reproduction all year round; it seems that there has been lack of communication with the cotton aphids with complete cycle patterns (parthenogenetic and sexual generation alternation) on propagation; so will they evolve into different species after a long time? But it is very difficult to distinguish the above patterns according to the present methods of pattern classification. Is it possible to distinguish them if we use the methods of biochemical or numerical

classification? This problem deserves further research.

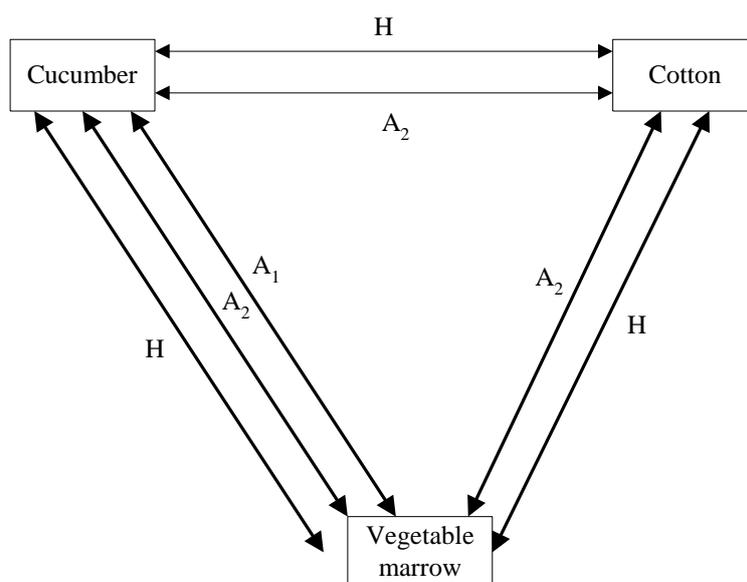


Fig. 4 Illustration of several patterns of the cotton aphids on the secondary hosts

Note: H is alternative-host complete cycle pattern; A<sub>1</sub> is incomplete cycle green pattern; A<sub>2</sub> is incomplete cycle yellow pattern.

## (2) The discovery of the alternative-host complete cycle patterns of cotton aphids.

Many authors have reported that cotton aphids follow the incomplete cycle pattern that loses the primary hosts and sexual generations. But Muller (1977) researched this further: he found female aphids among cotton aphids on the cascaras, but it was a pity that he didn't explore further where the male aphids were, so he still regarded as correct the view that cotton aphids follow the incomplete cycle pattern. After doing transplant experiments and pattern-identification for many years (Zhu and Zhang, 1958), we found that pricklyash peel, cascaras and pomegranates were the primary hosts of cotton aphids, and that cotton and melons were secondary hosts. The pterate female sexupara transplants via flight from secondary hosts to primary hosts at the end of autumn to produce female aphids<sup>1)</sup>. The apterous male sexupara produces pterate male aphids on secondary hosts, and the pterate male aphids will transplant to primary hosts; the male and female aphids mate with one another and spawn. It is very easy for this alternative-host complete cycle pattern to transplant from primary hosts to cotton plants, and also transplant to vegetable marrows and pumpkins. And the sexupara and sexuparae aphids could be produced on these secondary hosts in autumn (Fig. 5 and Fig. 6). This pattern fits best on the primary host – pricklyash peel. The number of the eggs laid on the 5-inch dishes was relatively high. The growing period of pricklyash peels fits the hatching period of fundatrices well, and the viable eggs and non-viable fundatrix fecundity are relatively high (Table 1), which shows that pricklyash peel is the host plant

1) Female Sexupara is one of the patterns of *Aphis*, which is partheno-viviparity, the next generations are all female *Aphis*, thus it is the mother of female *Aphis*, called female *Aphis* mother. In the same principle, male *Aphis* mother is the mother of the male *Aphis*, which is also one of the patterns of *Aphis*.

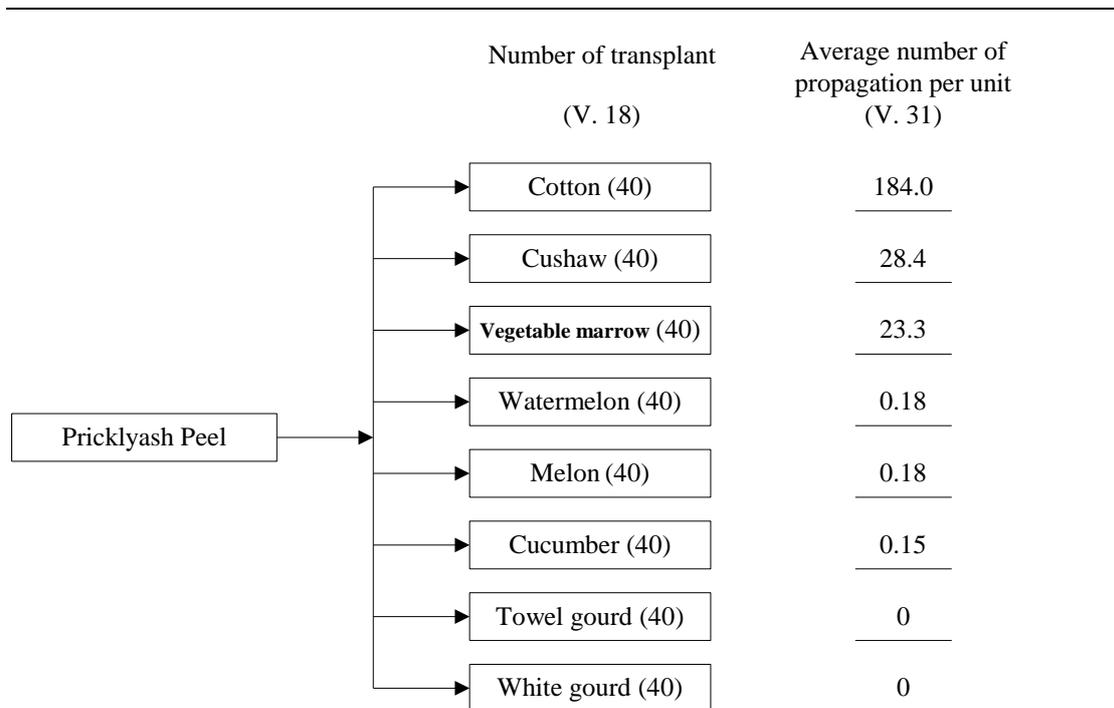


Fig. 5 The experiment of transplant from the alternative-host complete cycle pattern of cotton aphids to melons (Beijing, 1965)

Note: The cotton aphids in this experiment are all apterous partheno-aphids. A similar experiment has been conducted 6 times with 61 processes. Totally, they transplanted 1,620 pterate partheno-aphids and 330 apterous partheno-aphids. The above figure represents the results of only one experiment.

Table 1. The adaptability of cotton aphids on its hosts living through the winter

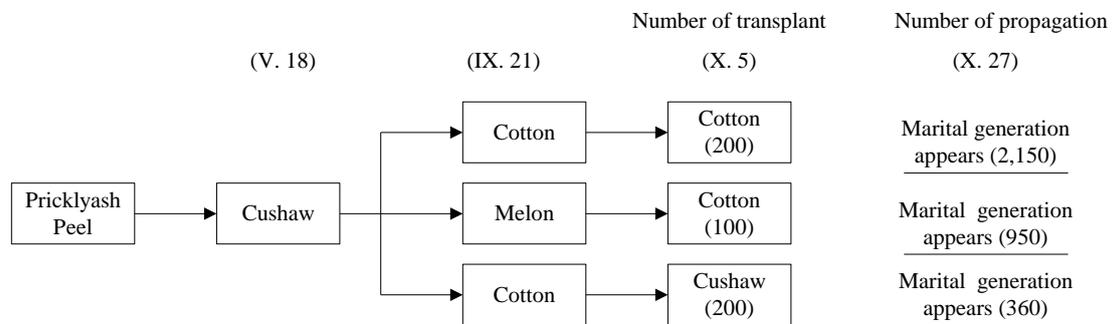
Year	Pricklyash Peel			Vegetable marrow			Hibiscus		
	Egg Number	Fundatrix Number	Egg viability percentage (%)	Egg Number	Fundatrix Number	Egg viability percentage (%)	Egg Number	Fundatrix Number	Egg viability percentage (%)
1956	220	48.9	21.8	20	0	0	0.1	0	0
1957	1380	17.4	1.26	711	0.34	0.0048	423	1.9	0.45
1958	1400	13.4	0.96	274	11.0	4.02	128	14.5	11.4

Note: The egg number and the fundatrix number mean the average numbers obtained on the 5-inch wattles.

According to research from paleoecology, which includes biological fossils, the primary plants are conifers, ferns and cycad etc. in the Paleozoic Era Permian Period. At that time, the ancestor patterns Archescytinidae and Permaphidopsidae of aphids have already appeared. The conifers etc. were very common until the Mesozoic Era; in addition, angiosperms appeared in Cretaceous Period and gradually predominated, then the real aphids appeared at this moment such as Genaphids, Canadaphids and other fossil aphids. Many of today's existing plants were formed until the third age of Cenozoic Period, which formed the kingdom of angiosperms. Many existing animals were also formed in this period. Many representatives of fossil aphids were also

formed in this period, which were very similar to aphids, for example, *Mindarus Aphidopsis*, *Anconatus*, *Siphonophoraoides* and so on (Xianxiao Hu, 1954; Heie, 1967; Polovinkin, 1948; Darkubgtib, 1957). Therefore, the evolution of the cotton aphid life cycle patterns should be traced to these periods, especially to the third age of the Cenozoic Period.

Rue (including Pricklyash Peel) appeared earliest among the primary host plants for three kinds of cotton aphids in terms of the evolution system of angiosperms. In addition, cotton aphids did not find conditions suitable for life on pomegranates because pomegranate wattles often died from the low temperatures in winter and grew relatively late in spring (the last ten days of March). But fundatrices usually died due to the relatively early hatch (the middle ten-day of March) or died with the death of pomegranate wattles. And the survival rate of fundatrices was very low. This is quite compatible with the fact that pomegranates (Myrtaceae) appeared later than the Pricklyash Peel (Rue) in Earth History. It could be regarded that pomegranates were obtained by cotton aphids as the secondary hosts in the beginning, and just evolved to be primary hosts recently.



(This transplant experiment has been done for 5 times, the figure just shows partial results)

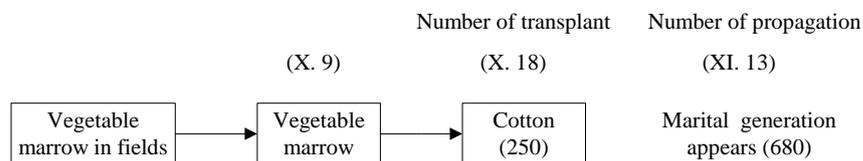


Fig. 6 The alternative-host complete all produce sexual generations, Beijing, 1965

### (3) The discovery of the same-host complete cycle patterns of cotton aphids.

Hibiscus is the spawning host of cotton aphids, which lives through winter, and it is also a summer host. Both hibiscus and cotton belong to Malvaceae; the Malvaceae appeared later than Rue in the earth's history (Xiaoxiao Hu, 1954). According to Mordvilko's theory, the hibiscus that appeared later should be a secondary host. It has been proven by experiments that the habitat of cotton aphids living on hibiscus is almost the same as that living on cotton. Usually, cotton aphids could live on both cotton and hibiscus throughout summer and autumn. Not only pterate female sexupara and apterous female aphids but also apterous male sexupara and pterate male aphids could appear at the end of autumn. The female aphids and male aphids could lay eggs on hibiscus and live through winter after mating. The egg could be hatched the next spring. The difference is that only cotton plants could not grow and fundatrices could not live in spring, but hibiscus could grow and fundatrices could live. Thus, the cotton aphids on hibiscus is actually a same-host

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complete cycle pattern. If compared with Pricklyash Peel and cascara, the growing and developing circumstances of cotton aphids and hibiscus still have the aspect of incompatibility. In some years, the leaves fall down earlier on hibiscus in autumn, partial sex-aphid could not develop maturely. However, in some other years, Pomegranate young wattles often died due to the low temperature in winter, and usually, the growing period (the last ten-day of March in Anyang, Henan province) is even later than the hatching prosperous period of fundatrices (the middle ten-day of March). So, the survival rate of fundatrices was relatively low. This is also quite compatible with the fact that pomegranates (Myrtaceae) appeared later than the Pricklyash Peel (Rue) in Earth History. It could be regarded that this same-host complete cycle pattern evolved from the alternative-host complete cycle pattern with the same species.

## **2. *Aphis glycines* Matsumura belongs to the alternative-host complete cycle pattern**

Takahashi (1966) reported that it was still unknown which pattern the life cycle of aphids *glycines* Matsumura belongs to. We cooperated with Chenglun Wang from The Northeast Academy of Agriculture Sciences, and investigated more than one hundred plants from 1953 to 1956. Our pattern-identification and four transplant experiments from 1955 to 1957 proved that cascara was the primary host of *A. glycines*. *A. glycines* follows one alternative-host complete cycle pattern (Wang, Xiang, Zhang, Zhu, 1962).

## **3. The species crossbreeding between two alternative-host complete cycle patterns – the crossbreeding experiment of cotton aphids and *A. glycines***

Both cotton aphids and *A. glycines* follow alternative-host complete cycle patterns. Although their secondary hosts are different, they have the same primary host – cascara. Although both of them have some similarity in patterns, they still have obvious differences. The results of numerical analysis show that the similarity coefficient reaches above 0.81 (Zhu, Zhang, Zhong, 1975). They are two allied species. Therefore, both of them might have the same ancestral patterns.

Two species might crossbreed occasionally in nature, but they can easily crossbreed under experimental conditions. At the end of autumn, two kinds of female sexupara transplant back to cascara successively in natural conditions and produce their own female aphids. Two kinds of apterous male aphids also transplant back respectively from their own secondary hosts, thus two kinds of male and female aphids occasionally coexist. We observed in the 1950's that both of two kinds of species had the phenomenon of occasional crossbreeding in natural conditions in Beijing and Gongzhuling, Jilin Province, but natural crossbreeding was very low. The crossbreeding egg could be hatched, fundatrices could be alive and partheno propagates offspring continuously until the end of the autumn under experimental conditions from 1963 to 1965. But whether it is cotton aphids female  $\times$  *A. glycines* male or *A. glycines* female  $\times$  cotton aphids male, their offspring could only live on the secondary hosts with which its parent female aphids is familiar; namely, the offspring crossbred by the female cotton aphids crossbreed species could only live on cotton, the offspring crossbred by the female *A. glycines* crossbreed species could only live on soybeans. Their patterns are also similar with that of their parent female aphids. Both of two crossbreed species could produce sexupara and sexuparae aphids in cages in fields at the end of 1965, and

they could mate and lay eggs normally.

Table 2. The experiments of cotton aphids and *A. glycines* (Beijing, 1964)

Crossbreed Date (mm/dd)	Number of female cotton aphids	Number of male <i>A. glycines</i>	Number of good egg	Number of shrunken egg	Sum	Annotation
10/19	15	20	3	0	3	See mating
10/19	14	20	4	2	6	See mating
10/24	20	20	0	13	13	See mating
10/24	20	20	0	4	4	See mating
10/24	20	20	0	0	0	Often see mating
Sub-sum	89	100	7	19	26	
10/26	150	20	-	-	100+	
10/26	150	20	-	-	100+	
Comparison 10/24	20 (Cotton aphids female)	20 (Cotton aphids male)	19	0	19	

Table 3. The experiments of *A. glycines* and cotton aphids (Beijing, 1964)

Crossbreed Date (mm/dd)	Number of female cotton aphids	Number of male <i>A. glycines</i>	Number of good egg	Number of shrunken egg	Sum	Annotation
10/13	30	20	77	16	93	Often see mating
10/16	20	28	216	25	241	Often see mating
10/19	30	28	0	0	0	Often see mating
10/24	20	20	0	9	9	Often see mating
10/24	20	10	3	1	4	Often see mating
10/24	15	10	2	0	2	Often see mating
10/24	25	20	13	10	23	Often see mating
Sum	160	136	311	61	372	
Comparison 10/23	20 (female <i>A. glycines</i> )	20 (male <i>A. glycines</i> )	92	6	98	

Seasonal isolation of crossbreeding: the significant results are that the success rate of the *A. glycines* × cotton aphids is relatively high at around the cold dew period and the success rate of cotton aphids × *A. glycines* is relatively high after hoar frost period (Table 2 and 3). This is because soybean plants are aging earlier, and should be harvested earlier (the period from the autumnal equinox to cold dew is the middle ten days of September to the first ten days of October). Therefore, the sexuparae aphids of *A. glycines* appears earlier than the cotton aphids. For example, it has already reached its peak period in the first ten days of October 1964. But cotton plants are aging and pull haulm much later (the period from the hoar frost to the beginning of winter is the last ten days of October to the first ten days of November). The sexuparae aphids of cotton aphids appear later than those of *A. glycines*; there are still not many male cotton aphids, even by the middle ten days of October, which just makes up 1% of the pterate aphids at that time (Table 4) and will be in an inferior position in the competition of natural crossbreeding. But if the

opportunity for crossbreeding arises, the success rate of crossbreeding is relatively high because the female aphids of *A. glycines* still do not start to age. Although the number of pterate male cotton aphids has been increased, the female *A. glycines* has aged, thus the success rate of crossbreeding will decrease. Otherwise, female cotton aphids will begin to age gradually. So, the chance of successful crossbreeding is relatively little.

Table 4. The seasonal isolation of crossbreed (Beijing, 1964)

Date (mm/dd)	Male aphids out of the pterate aphids (%)		Annotation
	Cotton aphids	<i>A. glycines</i>	
10/10	0.1	64	Cold dew period is in the first ten-day of Oct.
10/19	1	64	
10/24	15	91	Hoar frost descends period is in the late ten-day of Oct.

The habitat isolation of crossbreeding.

Because primary hosts of cotton aphids still include Pricklyash Peel and pomegranate, the cotton aphids could also live as the complete cycle with hosts on the hibiscus. The female cotton aphids could appear on the previous two plants at the end of autumn, the male cotton aphids transplanted from the secondary hosts. But both female and male cotton aphids could appear on the hibiscus, and they mated with each other and lay eggs. In such habitats, the sexuparae aphids of *A. glycines* do not appear, and no crossbreeding occurs. Thus the crossbreeding between two species has the habitat isolation because of primary hosts.

The propagation isolation of crossbreed.

The crossbreeding experiment between cotton aphids and *A. glycines* shows that the average number of eggs laid by the crossbreeding is a little lower than that laid by the self-breeding, and the number of shrunken eggs were a little more frequent if we compare them in terms of the same date (Oct. 13) under the artificial control conditions (Table 3). The difference was not very obvious. The crossbreed experiment of the cotton aphids × *A. glycines* showed that the average number of eggs laid by the crossbreed was relatively lower than that laid by the self-breed, and the number of shrunken eggs was relatively more if we compared in terms of the same date (Oct. 24). They mated with 261 female cotton aphids and 110 female *A. glycines* under the artificial control, no eggs were laid to compare. It can be seen that the crossbreed could impel the female aphids to lay partially viable eggs and non-viable eggs. It seems that there is the phenomenon of propagation isolation of crossbreeds.

Therefore, two species crossbreed with each other occasionally in nature, but there are still seasonal isolation and propagation isolation etc. between the breeding periods of the two species. At present, researchers still regard these two allied species as two independent species.

The Pricklyash Peel (Rue) appeared earlier than the cascara (buckthorn) in the earth's history (Xiaoxiao Hu, 1954). But does the widely distributed cotton aphids appear earlier than the *A. glycines*, which is specially distributed in Asia? Do the new secondary hosts obtained from the

cotton aphids in the beginning evolve into the primary host when the cascara appears? Does the first branch of cotton aphids on cascara obtain soybean as secondary host when the soybean appears? Afterwards, because the aging periods of soybean and cotton are different, it produces the seasonal isolation between the first branch of cotton aphids on cascara and its ancestors, and then *A. glycines* appears. The above parallel evolution relationship between plants and aphid species deserves further research. Is there any significance, and what is the significance of the evolution of species that two independent species crossbreed occasionally in nature? Since both cotton aphids and *A. glycines* are two of the most serious agricultural pests, is there any significance, and what is the significance of their occasional crossbreeding in agricultural production? These issues deserve further research.

#### 4. *Longiunguis sacchari* (Zehntner) follows the same-host complete cycle pattern

Japanese aphid expert Sorin (1970) still divided the aphids on the Sweetcane flower, silvergrass and sugar canes as two independent species, but did not know which pattern the life cycle of broomcorn aphids belongs to. We cooperated with the Northeast Academy of Agriculture Sciences, Jilin from 1953 to 1956. Our pattern-identification and 106 transplant experiments proved that broomcorn aphids belongs to the same-host complete cycle pattern. The hibernation hosts are Sweetcane/flower silvergrass grass; and summer hosts are jowars and sugar canes (Wang, Pu, Gui, Zhang, Zhu, 1961).

The evolution theory of the aphids life cycle proposed by Mordvilko is presented in figure 7; but our research results are presented in figure 8.

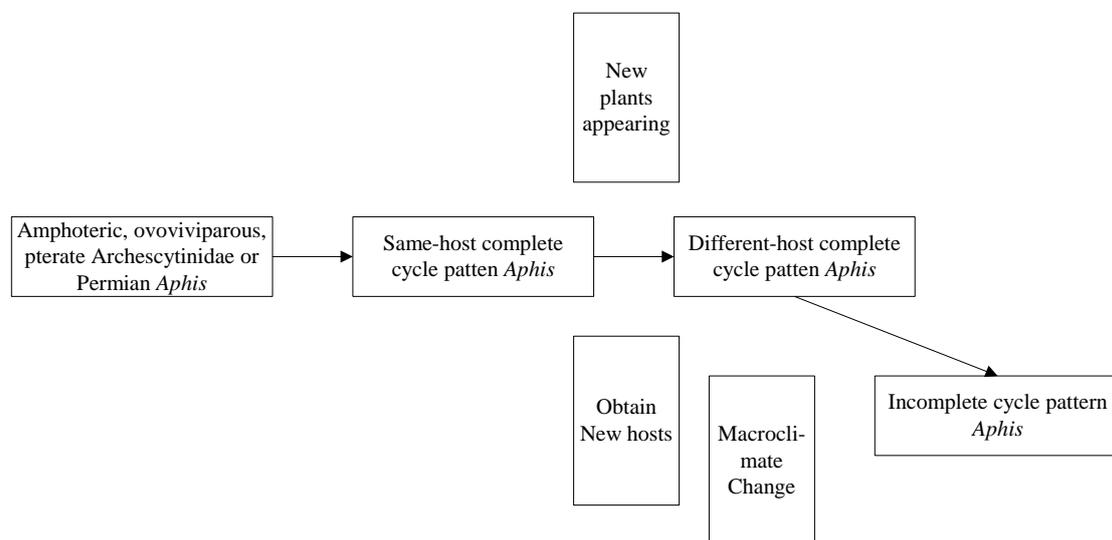


Fig. 7 Illustration of the evolution theory of the aphids life cycle proposed by Mordvilko

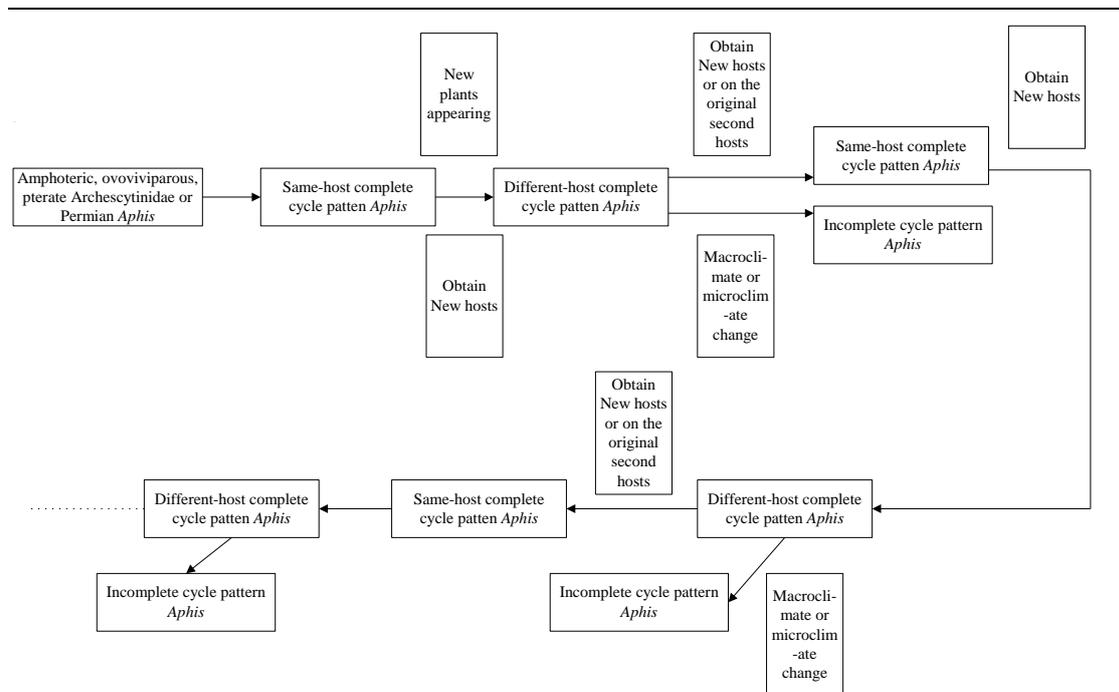


Fig. 8 Illustration of our research results regarding the life cycle evolution of aphids

Regarding the problem whether the evolution of the life cycle goes on with the generation of new species or not, it depends on whether the evolution of the life cycle leads to the propagation isolation of two species or not. If the propagation isolation is not produced, one same species could have several different life cycle patterns. Otherwise, new species will be produced whether it is the isolation of the outer propagation patterns, the isolation of propagation habitat (the primary host is different), the isolation of propagation seasons, the isolation of geography, the isolation of genetics, or other isolations.

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