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Study on aphid control by applying *Harmonia* (Leis) *axyridis*

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The larvae of the varied color ladybug *Harmonia* (Leis) a*xyridis* eat aphids. The first larval instar can eat 32 aphids a day. The second larval instar can eat 85 aphids per day. The third and the fourth larval instars can consume 169 and 203 aphids every day, respectively. Each larval instar can eat 120 aphids on average. The adult can eat 160 aphids every day.[1] The amount of aphids consumed by the adult of the varied color ladybug *Harmonia* (Leis) *axyridis* is higher than that of other ladybugs. The ladybugs have a broad appetite (wide eating patterns). They can eat almost all kinds of aphids. They aggregate during hibernation. The population of this ladybug is very large. Therefore, it is a natural enemy worthy of development and utilization.

Since the aggregation habit of the ladybug in hibernation was reported in the 1960's, [2] many valuable studies about the ladybug have been done. The investigation on site hibernation[3], occurrence and habits[4-5] and the study of controlling cucumber aphid and cotton aphid etc. were included in this research. However, because the adult has a habit of disperal toward higher elevations, it is difficult to establish a source of ladybug colonies in flatlands. Moreover the larvae are suicidal. It is not easy to raise the ladybug on a large scale. Therefore, for a long time the ladybug has not played an important role in controlling aphids in the field.

Changbai Mountain is a region with the largest quantity of hibernating ladybugs [3]. It is also the place where the aggregation habit of adults in hibernation was first discovered [1]. We have done some experiments and research in Changbai Mountain since 1987 on biological characteristics of the varied color ladybug *Harmonia* (Leis) a*xyridis*, such as oviposition of hibernating adults and hatching behavior from eggs to larvae. While we summarize previous research evidence, we base our work on the principle of "taking from nature, applying to field, developing in laboratory and releasing to nature". We have done some release experiments to control soybean aphid and have simulated experiments for farmers rearing ladybugs by themselves. Now the data is presented as follows.

1. Materials and Methods

Ladybugs collected in October 1987 and hibernated in a basement were used for the experiment in February 1988. Sixty hibernated ladybugs were divided evenly into two parts. The first 30 ladybugs were put in a constant temperature of 23^{o}C, and the second

30 ladybugs were put in a varying temperature of 9~15°C to observe their behaviors of recovering from winter, mating and oviposition.

Fifteen mated females of ladybugs were raised at 23°C in feeding jars (glass containers for fruit preserves were used for ladybug rearing). Each glass jar had 1-2 mated female ladybugs and a glass lid cover. The females were fed on vegetable aphids and rice long-pipe aphids. Fresh food was changed once daily and at the same time egg masses were removed. The number of egg masses and eggs were recorded every day until the adults died. The results are presented in Table 1.

Table 1 Oviposition of the hibernated female ladybugs (1988.3.4 Hailong)

Investigation item	The order of females in numbers												Average
	1	2	3	4	5	6	7	8	9	10~11	12~13	14~15	
Development period (d)	31	35	45	83	37	29	40	27	26	49	43	22	38.1
Number of egg masses (mass)	29	43	21	48	32	35	45	40	19	83	81	42	34.5
Number of eggs (eggs)	528	767	479	1061	664	815	1100	645	439	1749	1875	887	934.6
Average of eggs (eggs/mass)	18.2	17.8	22.8	22.1	20.8	23.3	24.7	16.1	23.1	21.1	23.1	21.1	21.3
Number of egg masses per day	0.94	1.19	0.47	0.58	0.86	1.21	1.18	1.48	1.19	1.19	0.85	0.95	0.91
Number of eggs per day (eggs)	18.2	17.4	22.8	22.1	20.8	23.3	24.7	16.1	23.1	21.1	23.1	21.1	19.4

The egg masses produced by the 15 females were classified according to the amount of eggs. The egg mass with 1~10 eggs was classified in grade I. The egg mass with 11~20 eggs was classified in grade II, etc., up to egg mass with 61~70 eggs classified in grade VII , as presented in Table 2.

Table 2. Classification of egg masses (1988.5 Hailong)

Grade in amount of eggs	The order of females in numbers												Total	%
	1	2	3	4	5	6	7	8	9	10~11	12~13	14~15		
I. 1~10 eggs	3	10	3	8	5	2	5	11	1	19	9	2	78	25
II. 11~20 eggs	14	18	4	13	12	12	10	18	10	19	29	21	180	14.8
III.21~30eggs	12	14	9	16	11	16	16	8	2	29	25	17	172	33.2
IV.31~40eggs			5	10	3	3	10	3	5	13	12	5	69	13.3

V. 41~50 eggs	1			1	2	2		1	3	8	1	14	2.7
VI.51~60eggs			1			2						3	0.6
VII.61~70egg										2		2	0.4

The 513 eggs were divided into 11 groups and exposed to a constant temperature of 23°C and varying temperature of 9~15°C, respectively. Hatching period and the amount of larvae were recorded. The rate of hatching from egg to larva was calculated. The results are in Table 3.

Table 3. Ladybug hatching from egg to larva (1988.3 Hailong)

Temperature condition	Constant temperature at 23°C								Changeable temp. from 9~15°C		
Group number	1	2	3	4	5	6	7	8	9	10	11
Number of eggs	21	20	107	125	74	22	29	30	26	24	35
Number of hatched larvae	9	15	52	67	55	13	20	20	23	20	30
Hatching rate (%)	43	75	49	54	70	69	69	67	88	83	86
Hatching period (d)	3~4	3~5	4	3~4	3~4	3~4	3~4	3~4	13	12	15

After the larvae had hatched from eggs, 20 larvae were reared under the condition of constant temperature at 23°C and another 20 larvae were put in the condition of varying temperature from 9~15°C. Vegetable aphids were fed to the larvae 1-2 times a day to make sure that the food supplied was sufficient. Still period of larvae just hatched from the eggs, development period of each instar and whole larva period were observed and recorded. The results are in Table 4.

Table 4. Period of larva development (1988.3~4 Hailong)

Temperature	Still period of the larva just hatched out from eggs (d)	1st instar (d)	2nd instar (d)	3rd instar (d)	4th instar (d)	Whole period of larva development (d)
Constant at 23 °C	0.5~1	1~1.5	1.5	2~2.5	4~6	8~10.5
Changeable from 9~15 °C	1~2	7	5~6	4~5	11	27~29

At the beginning of June, soybean plants with and without aphids were chosen for introducing just hatched larvae of ladybugs. 20 aphids were placed on each plant. After 4h and 24h, the distances of direct and indirect diffusion were checked. The average of the distances were calculated.

Trials of ladybug release for aphid control were carried out in soybean fields in 1988 and 1989 successively. The release method was to introduce ladybugs on the third ridge in the field in every two interval of ridges. On the ridgeline, one mass of just hatched larvae was placed on the soybean plants, every 1.5 meters. Before release, the amount of aphids on the plants had been checked and recorded. Records were taken after 5 and 10 days of release. The reduction in number of aphids was calculated after checking. Revised reduction rates were calculated compared to a control, to present the impact of ladybugs in the field. The findings of the two years are shown in Table 5.

Table 5. The development period of larvae (1988.3~4 Hailong)

Year	Difference (treatments)	Area (ha.)	Released date (m/d)	Number of aphids per plant before releasing	After 5d		After 10d		Effect (%)
					Number of aphids per plant	Decreased rate (%)	Number of aphids per plant	Decreased rate (%)	
1988	Releasing region	?	6/27	16.5	23.2	-40.6	26	-57.5	93.7
	ck	?		16.5	85.9	-418.8	81.6	-394.5	
1989	Releasing region	?	6/13	98.4	17.1	82.6	5492	-458.1	95.6
	ck	?		13.3	43.3	-2256	14.3	-10448.9	

In 1990 we made simulation experiments for farmers to show them the techniques of ladybug propagation. We guided a farmer in his house for adult rearing and larva hatching from eggs. The trial was done in the experimental fields, orchards and vegetable gardens in our institute. The experiment was designed according to crops and land area of farmers' responsibility. On a 0.33 ha land, 0.2 ha was for corn, 0.13ha was for soybean, 0.22 ha was for cucumber, bean and other vegetables. Three plum trees and two hawthorn trees were planted on the land of 0.02 ha too. The 480 hibernated ladybugs were collected on the 2nd and the 3rd in June and reared until the 29th of July. During the rearing period 230 mated males were moved onto 5 fruit trees. The remaining 250 females were kept for oviposition. The mated females produced 5200 egg masses. When the larvae just hatched out from the eggs and were in the still period, released out the larvae on the plants with aphids in the fields. No pesticides were applied in the experimental fields for the whole year.

2. Results and Analysis

The hibernated adults recovered quickly from wintertime and fed soon on aphids under conditions of 9~15^{o}C, but they moved slowly and did not mate. While the temperature was at 23^{o}C, they began to mate in the second day and oviposit after ~7days mating. A couple can mate 1~3 times a day. The mating time varied from 1 to 10 hours each time. One female can oviposit 1~2 times a day. According to the habit of ladybug females mating once and remaining fertile for life, the mated males were removed during rearing, which was benecial to female oviposition and food saving. The optimal temperature for female mating and ovipositing was 23~25^{o}C.

It is shown in Table 1 that the period of oviposition was 38.1days. The averages of egg masses and eggs per day were 0.91 and 19.4, respectively. Each egg mass had 21.3 eggs on average. One female in its whole life could produce 34.5 (19~45) egg masses and 734.6 (439~1110) eggs on average. The 15 female adults produced 518 egg masses in total.

The classification of egg masses are shown in Table 2. Among the 518 egg masses, there were 180 egg masses with 11~20 eggs, which accounted for 34.5%; and 172 egg masses with 21~30 eggs, which account for 33.2%. These two grades were the largest quantity, which accounted for 68% of the total.

Table 3 shows that the hatching period was 3~5 days and the hatching rate was 43~70% at the condition of 23^{o}C, whereas the period of hatching was 12~15 days and the rate of hatching was 83~88% in the condition of 9~13^{o}C. Within a certain range, there was an inverse proportion between temperature and hatching period and hatching rate.

The temperature had an inverse proportion with the still period of just hatched larvae and with the developmental period of every instar, which are shown in Table 4. Under proper conditions, the higher the temperature, the shorter the developmental period and the faster the larval development. On the other hand, the lower the temperature, the longer the developmental period and the slower the larval development. The regularity described above was very important while rearing ladybugs. Regulating temperature could be used to control the development speed of eggs. Knowing this, we could calculate the development period of larvae after they were released to the fields according to natural temperature.

The results of field investigation on larva diffusion showed us, after 4 hours the larvae did not diffuse on the plants with aphids, but diffused 0.3 meters on average on the plants without aphids. The larvae dispersed 0.1 meters on aphid plants and 0.9 meters on aphid-free plants after 24 hours.

In Table 5 we demonstrate the release effect on controlling soybean aphids in the field. The results show that after 10 days releasing 45,000 larvae per hectare the control effect reached up to 93% and more than 95% in the two years of experiments in 1988 and 1989, although release could not have the effect immediately on controlling aphids on soybean plants.

The simulation experiment in 1990 was successful. All kinds of aphids on different crops in the experimental fields were controlled by the ladybugs. No pesticides had been sprayed in the whole year, and there was no leaf-rolling symptom on the experimental plants.

3. Summary

There is a large quantity of varied color ladybug in Changbai Mountain. We can catch a flock of ladybugs in the period of starting and finishing hibernation. As long as farmers know the techniques one family can raise 300-400 hibernated females in 30-40 glass jars every spring. This amount of ladybugs can control the damage caused by all kinds of aphids on all crops in farmers' responsibility fields. This not only cuts down the expense on pesticides but also does not pollute the environment. Therefore it is a good method of "killing two birds with one stone". It is also very good to have a biological control method accepted by farmers.