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Effects of Aphid Population Dynamics and Damage Period on Soybean Yield

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Abstract: We studied the effects of aphid density and damage period on soybean yield by controlling the damage period and level. Results of 1988 and 1989 showed that soybeans have a remarkable ability of compensation and tolerance to aphid damage. Yield losses caused by aphids were related to aphid density, the period of aphid development, and the coincidence between the damage period and soybean developmental stage. In the early stage, minor or heavy damage did not cause yield reduction if aphids were controlled immediately. The result was similar if aphids appeared in the fields later. However, continued and heavy injury caused 20-30% yield loss.
Key words: soybean, aphid, tolerance to aphid, soybean yield.

The soybean aphid, *Aphis glycines* Mat., is one of the important pests of soybeans in northeastern China where soybeans are grown. In heavily infested years, farmers treat for soybean aphids 3-4 times annually. However, soybeans have the capability to tolerate soybean aphids and to compensate for aphid damage. Little is known about interactions between soybean developmental stage and susceptibility and tolerances to aphid injury.

The injury threshold of soybeans to aphids can be studied in many ways, some of which have been reported for *Aphis gossypii*, rape aphid (translator: no species name given here), *Macrosiphum avenue* and *Melanaphis sacchari*. Commonly used methods include cumulative aphid density, percentage curled leaves and index of aphid injury. These methods are not very suitable for the soybean aphid due to its infestation characteristics. To study the effect of aphid density on soybean yield and the relationship between dynamic aphid density and soybean yields, we inoculated aphids at different stages of soybean growth and maintained aphid density at various injury levels in 1988 and 1989.

1. Materials and Methods

1.1 Materials

The cultivar Tiefeng 18 is widely planted in Liaoning Province. Three damage levels (minor, medium and heavy), five damage periods (7-day intervals between treatments) and three replicates were designed in our experiments. Treated and untreated plots were used as experimental controls. Six rows of soybean plants were planted in each plot with row length of 6 m and row spacing of 0.6 m. Blank space between plots was 1 m.

1.2 Design of standard levels of aphid infestation

Based on aphid development in the soybean fields in 1982-1984, and the division of infestation level index (see Table 1), we set up the standard levels of aphid development. The heavy infestation levels were normally produced by inoculating of extra aphids in the field. Aphids at the medium levels developed naturally and suitable aphids were added or removed if necessary. To establish the minor infestation levels, aphids were removed by hand in the early stage of the plants if they developed earlier or heavily on some plants. Only soybean yields of two middle rows were determined. Inoculation and adjustment were applied only on two middle

rows in the plots.

Table 1 Development of aphid density index

Aphid density	Aphid density index									
	0	1	2	3	4	5	6	7	8	9
Range	0	1-20	31-50	51-100	101-200	201-500	501-1,000	1,001-2,000	2,001-5,000	5,001-10,000
Represen-tative	0	10	35	75	150	350	750	1500	3500	7500

1.3 Methods

The numbers of aphids were counted prior to establishing aphid densities. In each plot, aphid numbers per plant on two middle rows was determined and ranked based on the aphid density index (Table 1), and then the mean aphid number per 100 plants in each plot was calculated. If aphid density in the field was far away from the designed density, adjustments outlined above were applied. In the late stage of aphid development, aphids spread in the soybean field and all plots had similar aphid density.

We recognized five damage periods. In 1988 (translator: misprinted as 1989), the first treatment was applied on June 17th and then aphids were treated every 7 days. Prior to control, aphid density and plant percentage with curled leaves were recorded. In 1989, the first treatment was on June 11th. Dimethoate (200 X) was spread on the stems of the plants on all six rows in the plot. Ten to fifteen days later, pesticide was used one more time if aphids were present again on the plants. Soil in the control plot was treated by Carbofuran in 1988, and Dimenthoate was applied twice in 1989.

Soybean plants within 4 meters in the middle from the two middle rows were harvested and the rest of the plants of both ends were discarded. A total of 46-48 plants were harvested and seeds were threshed together. The yield of one plot that lost many soybean plants was adjusted according to the percentage of lost plants. In 1989, to reduce the yield error caused by the lost plants in the plot, in addition to the mixed threshing, individual plants were also randomly chosen to determine the yields from which total yields were measured in comparison with yields from mixed threshing.

Other aspects of field managements were standard. When seeds were sown, weeds were controlled by dragging ropes through the field, Phoxim was used to control soil pests, and soil was shoveled and turned once. In mid August, *Leguminino*ra *glycinivorella* Matsumura was controlled by insecticide application.

2. Results and Analysis

2.1 Effects of aphid damage on soybean plant height (Table 2)

In the first treatment of which the earliest aphids were present, plant height was affected by aphid damage even with aphid control (Table 2). Plants were 1.8-11% (measured on July 14th) and 3.5-14% (measured after harvest) shorter than those in the control plots, respectively. The most heavily infested and surviving plants were 18.3-33.7% (measured on July 14th) and 17.6-36.1% (measured after harvest) shorter than those of the control plants. Early aphid damage somehow reduced plant height, but slight injury by aphids restrained the unnecessary soybean growth to a certain extent, resulting in increasing branches, and soybean yields that increased slightly in some plots.

Table 2 Effect of aphid damage on soybean plant height

Damage level	Control period									
	1		2		3		4		5	
	Plant height (cm)	Decrease (%)	Plant height (cm)	Decrease (%)	Plant height (cm)	Decrease (%)	Plant height (cm)	Decrease (%)	Plant height (cm)	Decrease (%)
Measure before bloom										
Heavy	66.2	11	66.9	10.5	62.7	16.1	50.6	32.3	48.9	33.7
Medium	69.2	7.3	69.7	6.8	64.7	13.4	64.6	13.5	55.3	26.0
Minor	73.4	1.8	69.2	7.3	68.3	8.6	67.6	9.5	61.1	18.3
CK	74.7	-	-	-	-	-	-	-	-	-
Measure after harvest										
Heavy	82.6	13.9	83.9	12.6	74.9	22	70.4	26.7	61.3	36.1
Medium	90.3	5.9	87.5	8.9	81.3	15.3	81.2	15.4	75.2	21.5
Minor	92.6	3.5	90.6	5.6	89.6	6.6	80.2	16.4	79.2	17.6
CK	95.9	-	-	-	-	-	-	-	-	-

2.2 Effects of aphid damage on soybean yields (Tables 3 and 4)

2.2.1 Relationship between injury duration and soybean yields

In 1988 (translator: misprinted as 1989), the second and third control periods with minor injury and the second period with medium injury had slightly higher (about 5%) yields than control plots (Table 3). Yields similar to control plots were observed appeared in the third period and first period with medium injury, and the first and fourth periods with minor injury. In 1989, soybeans developed and aphids infested earlier (Table 4). The stages with slightly higher or the same yields as controls were also observed earlier than in 1988, i.e. the first and second periods with minor injury and the second periods with medium and heavy injury. Thus, results of two years of experiments revealed that slight aphid infestation in early soybean stages did not reduce soybean yields even aphid density per 100 plants reached 70,000-80,000 in late June (1988). Early injury by aphids to a certain extent constrained the unnecessary soybean plant growth and increased branching. In 1989, aphid density per 100 plants went up to 100,000 and all plants had curled leaves in the first period with heavy injury. Soybean yields were not declined due to timely treatment and rapid soybean growth after chemical application.

Continuous high aphid density has the greatest effect on soybean yield. Results from two years were consistent. The third and fourth control periods with heavy injury and the fifth periods with medium and heavy injury in 1988 (Table 3), and the fourth period with heavy injury and fifth periods with medium and heavy injury in 1989 had yield reduction between 10 and 30% (Table 4). Aphid infestation in 1989 was worse than that in 1988 with higher yield decrease. Yield reductions in other treatments ranged from 5 to 10%. The magnitude of yield reduction was correlated strongly with aphid density and the duration of aphid injury. The following treatments produced similar soybean yields: the second period with heavy injury, the third period with medium injury, the fourth period with medium injury, the fourth period with minor injury and the fifth period with minor injury. Nevertheless, the difference between treatments sometimes was unstable or insignificant due to the difference of years, replicate sites, and aphid density.

Table 3 Relationship between aphid infestation and soybean yields in 1988

Yield rank	Control period	Injury level	Mean yield ($g/4.8m^2$)	Aphid density (10,000/100 plants) at different time					Yield reduction
				6/15	6/22	6/29	7/5	7/15	
1	Second	Minor	1,065	0.2-0.36	0.6-0.7				
2	Third	Minor	1,043	0.33-0.42	0.5-1.3	7-12			Slight increase, about 5%
3	Second	Medium	1,020	0.7-0.9	1.7-2.7				
4	Third	Medium	1,013	0.4-1.0	1.0-3.6	8-19			
5	First	Medium	1,006	0.4-0.5					
6	First	Minor	1,005	0.13-0.22					Same yield
7	Fourth	Minor	1,000	0.2-0.7	0.3-0.9	4-11	12-18		
	CK		996						
8	Fifth	Minor	985	0.2-0.4	0.5-1.2	3-9	10-24	32-35	
9	Second	Heavy	981	0.5-0.7	3-4.4				Slight reduction, about 2-5%
10	Third	Medium	945	0.35-0.4	2-3	13-15	10-33		
11	First	Heavy	930	0.5-0.7					
12	Fourth	Heavy	924	0.6-0.8	2.4-3.8	14-15	33-36		
13	Fifth	Medium	908	0.4-0.7	1.2-1.8	10-12	10-19	30-43	Serious reduction, about 10-22%
14	Third	Heavy	895	0.8-1.0	1.8-4.2	7-18			
15	Fifth	Heavy	776	0.7-0.9	1.5-5.3	14-21	30-34	28-35	
16	All damaged		780						

Table 4 Relationship between aphid infestation and soybean yields in 1989

Yield rank	Control period	Injury level	Mean yield ($g/4.8m^2$)	Aphid density (10,000/100 plants) at different time						Yield reduction
				6.6	6.10	6.15	6.24	7.4	7.14	
1	First	Minor	1,257	0.89-1.7	3.0-4.8					Same yield or minor increase, about 5%
2	Second	Minor	1,242	0.83-3.2	3.6-8.4	3.9-9.5				
3	First	Medium	1,217	2.9-3.6	5.7-8.1					
4	First	Heavy	1,193	9-10	13.3-18.8					
5	Third	Minor	1,176	0.28-0.56	1.1-3.2	4.4-6.5	47-54			Slight reduction, 2-5%
6	Second	Medium	1,258	1.4-2.7	2.5-8.4	8.9-13				
7	Third	Medium	1,146	1.1-2.0	2.6-7.1	6.4-95	39-60			
8	Second	Heavy	1,142	6.2-10	11.1-14.6	26-28				
9	Fourth	Minor	1,135	0.32-0.86	0.9-2.4	3.8-13	45-64	75-264		Reduction, 5-15%
10	Fifth	Minor	1,110	0.55-1.6	1.7-2.7	3.6-5.5	44-60	178-250	104-150	
11	Third	Heavy	1,077	7-10	11.7-17.4	24.7-29	57-69			
12	Fourth	Medium	1,057	0.44-4.5	1.0-7.4	25-78	40-60	201-250		
13	Fifth	Medium	1,010	1.3-2.5	4.3-6.1	4.8-9.6	42-63	208-244	150-160	Serious reduction, 15-30%
14	Fourth	Heavy	862	7.7-10.4	8.1-11.8	9.7-24	56-67	241-247		
15	Fifth	Heavy	800	3.2-7.4	13-15	12-24	61-64	240-250	150-158	
	CK		1,201							

2.2.2 Relationship between aphid density, soybean development stage and soybean yield

Aphid density is dynamic in the field. Aphids multiply as plants grow and infestation by aphids is enduring and continuous. The ratio of plant size to the aphid density that the plant can tolerate is vital to understanding the aphid damage. With the same aphid numbers, there is a smaller effect of aphids on larger plants than that on smaller plants. Therefore, it is difficult to evaluate the correlation between aphid density and soybean yields if only aphid density or cumulative aphid density is used and plant growing conditions and development stages are not considered in the analyses.

We analyzed continuous aphid damage at various aphid densities and drew a conclusion about the effect of continued aphid density on soybean yield.

(1) Enormous yield losses result from continued high aphid density, while continued low aphid density has less or no effect on soybean yields.
(2) High aphid density for a short time during early plant stages has less or no effect on soybean yields when aphids are controlled timely.
(3) Low aphid density during early plant stages and high aphid density during late plant stages has a relatively lower effect on soybean yields.

3. Discussion

Of many factors affecting soybean yields, the infestation by soybean aphids is one of the main factors and it is complicated. There is not always a negative correlation between aphid density on individual plants and the yield produced by those individual plants. Aphids start to develop on individual plants, then spread to the adjacent areas. Aphid injury affects the growth of the earlier infested plants. Plants that are seriously damaged fail to compete with neighbors and become small afterwards. However, after the aphid colonies collapse, some early infested plants develop rapidly with high a capacity of competition, and become tall and robust plants. Once these plants are infested again by aphids, they are able to accommodate many more aphids than small ones. If only aphid density on individual plants is used to analyze the correlation between aphid density and soybean yields, plants with high aphid density will have higher yields than those with low aphid density. Soybeans have strong abilities of competition and compensation, and the increase in soybean yields relies on the yields of individual plants and the yield of all plants as well. Thus, studying the effect of aphids on soybean yields should include the relationship between aphid density overall and total soybean yields. Our experiments showed that total soybean yields were closely related to the development time of aphids, the lasting period and the coincidence between the aphid damage period and the soybean development stage. In order to avoid unnecessary insecticide application in the early stage of soybean development and reduce the number of times insecticides are applied, we designed a dynamic injury threshold and set up a certain insurance index for real practice. Certainly, further studies are required to improve this threshold in the real world.

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