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Study on Soybean Resistance to Aphids

He Fugang, Liu Xiaodong, Yan Fanyue, Wang Yanqin(Institute of Plant Protection, Academy of Agricultural Science of Liaoning Province)

Soybean is the principal oil-producing crop in Liaoning Province and northeast of China. Soybean aphid (*Aphis Glycines* Matsmura) is a common insect pest and occurs almost every year. Aphid damage causes shrinking of young leaves, hampering of roots, dwarfing of stems and leaves, and reduction of pod and kernel numbers in the soybean plant. More than half of yield is lost in a severely damaged field. It is becoming one of the most important constraints to stable and high soybean yield. At present, spraying chemical insecticide is the major method for aphid control. Although it has taken effect, it requires numerous manpower, material and financial resources every year. Furthermore, it causes environmental pollution, is poisonous to people and animals, and injurious to natural enemies of soybean aphid. Pest resistance to constantly used chemical pesticides will reduce control efficiency and will cause an outbreak of pests again.

In 1951, Painter, an American scientist, suggested the theory of plant resistance to insect pests after analyzing a large amount of research data, and he aroused the interest of scientists in different countries. Selection and breeding for plant resistance to insects have become basic modes of integrated pest control presently and for the future. From 1979 to 1985, Guo et al. successfully identified the resistance of soybeans to aphids and obtained a quantity of source material. On the basis of that work, this study on plant resistance to aphids was developed.

1. Materials and method

1.1 Aphid population dynamics and structure on soybean varieties having varying resistance in the field.

1.1.1 Soybean varieties

Guoyu 98-4, Guoyu 100-4, Zhe 455, Xiongyue yellow small grain, Liao 81-5052, 8433, Tie 79163-5, Wenfeng 5, Liao 84-5018, Liaodou 3, Amsoy, Tiefeng 20, Liao 83-5020, Tiefeng 24, Shen 702 and Jilin 3.

1.1.2 Experimental method

Two rows in one plot were prepared for each variety, having row length of 5m, row spacing of 60cm, and plant spacing of 10cm. The plots were randomly arranged in triplicate. Sowing time was April 25, seeding mounds with 2 grains. Only 1 seedling per mound was maintained after emergence. Regular field management was maintained without aphid control aphid during the growing season. From June 10, 10 plants in each plot were randomly marked and the population was investigated every 5 days until aphid numbers declined. On the 1st of July, the peak period, the leaves with about 200-500 aphids on the upper, middle and lower parts of plants from each variety were collected randomly and dipped into 75% alcohol. The aphids were brushed off and observed under the microscope. The numbers of apterus aphids in different instars and pterygote aphid were recorded separately.

The levels of significance of difference were calculated by LSR (least significant range) test. Aphid population dynamics and structure were analyzed with intrinsic rate of natural increase (Huges, 1963), namely:

$$e = \frac{a_1 + a_2}{a_2 + a_3}$$

a_1, a_2 and a_3 represent aphid numbers in the 1st, 2nd and 3rd instar separately.

1.2 Tolerance of soybean varieties with different resistance to aphid

1.2.1 Soybean varieties

Xiongyue yellow small grain, Wenfeng 5, 8433, Liao 81-5052, Tie 79163-5, Amsoy, Liaodou 3, Liao 83-5020 and Liao 84-5018.

1.2.2 Experimental method

Two rows per variety were prepared in one plot, having row length of 5m, row spacing of 60cm and plant spacing of 10cm. Checked plots controlled with insecticide were set up for each variety. The plots were arranged randomly in triplicates. Sowing time was April 25, mound seeding with 2 grains. Only 1 seedling per hill was kept after emergence. Regular field management was maintained without aphid control during the growing season. In checked plots, 2000 X dilution of 5% Esfenvalerate was spread once before the peak period of aphids. From June 10, 10 plants of each variety were marked randomly and populations were investigated each 5 days until the aphid number decreased. After maturing, the plant samples of each variety were collected from 2m of the rows. The yields and seed grains were analyzed in lab.

1.3 Repellency of different soybean varieties to aphid

1.3.1 Soybean varieties

Liaodu 3, Guoyu 98-4, Guoyu 100-4, Zhe 455, Tiefeng 20, Xiongyue yellow small grain, 8433 and Jinling 3.

1.3.2 Experimental method

4cm thick screened soil was placed on the bottom of a 25x25x20 cm cage. A circle 10 cm in diameter was drawn on special paper and 8 equidistant holes 0.6cm in diameter were made along the circle. After watering, the paper was covered with soil. Eight germinated seeds, one from each variety, were sown in the 8 holes randomly. 40 starved aphids were put on the center of the circle at 2-4-leaf stage of seedling. The cage was covered with nylon mesh and plastic film to prevent the escape of aphids. The work was repeated 9 times. After inoculation, the adults were investigated and newborn nymphs were removed daily for 6 days.

2. Results

2.1 Aphid population dynamic on soybean varieties with different resistance in the field.

The investigation results demonstrated significant differences among different varieties. Aphid populations on resistant varieties were much lower than on susceptible ones. In 1989, the year of aphid outbreak, the average aphid number per plant was 97.4 on resistant varieties (Guoyu 98-4 and Guoyu 100-4) while 640.4 on susceptible varieties (Amsoy, Tiefemg 20 and Wenfeng 5) at the stage of flower bud differentiation on June 20,which was 6.6 times higher than on the resistant ones. On June 25, the average aphid number per plant was 166.2 on resistant varieties and 1,086.7 on susceptible ones, or 6.5 times higher. On June 30, at the beginning of flowering stage, an average of 234.2 aphids was recorded on resistant varieties and 1,819.4 on susceptible ones, or 7.8 times higher. In 1990, a year of medium to severe infestation, the aphid population changed following similar patterns as those of 1989. This provided further verification of significant differences among varieties as reported before (Table 1-1 and 1-2).

2.2 Aphid population structure and intrinsic rate of natural increase on different varieties in the field

The field investigation showed distinct differences of aphid population structure existing between resistant and susceptible varieties. The population was younger with a large ratio of nymphs on susceptible varieties. Nymph numbers at the 1^{st} and 2^{nd} instar were 81.82% of the total, 8.9% higher than on resistant varieties. On the contrary, pterygote aphid numbers were 1.15% of the total, 54.72% lower than on resistant varieties (Table 2). Similarly, intrinsic rate of natural increase was obviously higher on susceptible varieties than on resistant ones, with 1.13% on the former and 0.83% on the later, respectively. This indicates that susceptible varieties were suitable for growth, development and propagation of aphid, where the rate of aphid increase was much higher. Some factors might affect aphid population in resistant varieties.

2.3 Tolerance of different soybean varieties to aphid

2.3.1 Yield reduction of soybean varieties with different tolerance

Few varieties showing tolerance were observed in the field. Although a large number of aphids infested plants, the symptoms were mild. Infested plants recovered quickly from leaf curling after the population declined. More severe symptoms were caused on non-tolerant varieties, such as plant dwarfing and the shrinking of new leaves. After population decline, infested leaves recovered slowly and turned yellow. Heavy yield loss was caused by decreased pod number. In 1989, the outbreak year, compared with check plots controlled by insecticide timely, 20-45% output was lost for non-tolerant varieties. But only low reductions of output occurred in tolerant varieties, such as 8433 and Wenfeng 5. In 1990, the year of medium to severe infestation, a similar tendency in yield reduction was showed. This indicated a significant difference in different varieties not only for resistance, but for tolerance as well. The latter was expressed more noticeably in severely infested years (Table 3).

2.3.2 The compensation of tolerant varieties of soybean

Field experiment on damage of soybean by aphid was conducted for 2 years. The results showed that big difference in kernel number (knl no.) and weight (knl wt.) per plant, weight of 100 kernels, plant height, branch number and yield reduction. Correlation was analyzed from yield components and yield loss. The results showed the yield loss was positively correlated with kernel number and kernel weight of single plant. It meant the level of tolerance in different soybean varieties could be expressed by reduction extent of kernel number and weight per plant.

The yield loss was negatively correlated with the increase of branches. Some tolerant varieties compensated loss caused by yield components from increasing branches to reduce the drop in production (Table 4 and 5).

2.4 Repellency of different soybean varieties to aphid

In the experiments, the aphids moved frequently to different varieties 24 hours after inoculation. 48 hours later, obvious differences were shown on taxis of aphids. Some aphids moved to susceptible varieties from resistance for settlement and reproduction, and the numbers increased there. The amount of aphids was much higher on susceptible varieties 72 hours after inoculation (Table 6). But there was no significant difference between tolerant and non-tolerant varieties. This meant that tolerant varieties did not inhibit aphid from selecting further hosts.

Fewer newborn nymphs on resistant varieties and adults escaped, while more adults gave birth to a large number of nymphs observed during investigation. Repellency of soybean was becoming effective in a closed habitat as time increased. This phenomenon showed that aphids preferred susceptible varieties for remaining, feeding and propagating.

3. Discussion

3.1 Research over the years has proven that China is rich in germplasm resources of soybean. The resistance of soybean varieties to aphid varies greatly and some good germplasm resources exist. The resistant variety with lower aphid population at the plants' complete development stage does not cause significant yield reduction. Meanwhile, the stable resistance to aphids provides persistent genetic material for resistance breeding.

3.2 China is the originating country of soybean plants. Except for resistance resources, only a small minority of varieties are tolerant to aphids. Fewer economic losses are caused because of stronger capacities to compensate for aphid damage. Chemical insecticides need not be applied to reduce their density, even in larger aphid populations. Meanwhile, tolerance will not cause selective pressure and produce new biotypes of aphid. This guarantees the efficiency of this control method. This spontaneous regulation of host plant for aphid damage offers a better value for utilization.

3.3 At present, agronomic characteristics of some identified resistant varieties, such as Guoyu 98-4 and Guoyu 100-4, are inferior and difficult to use directly since some bad characteristics may be obtained in the course of the resistance transfer. But some tolerant germplasm materials with very good agronomic characteristics possesses good prospects for utilization, if suitable methods of breeding are followed.

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Table 1-1. Aphid Population Dynamic in Field (1989)

Varieties	Aphid Number / Plant					
	June 20		June 25		June 30	
Guoyu 98-4	91.7	a	152.3	a	206.7	a
Guoyu 100-4	103.0	a	180.0	a	261.7	ab
Zhe 455	373.3	b	430.0	ab	476.7	ab
Xiongyue Yellow	526.6	b	655.0	c	1076.7	c
Amsoy	593.3	bc	953.3	d	1768.3	d
Tiefeng 20	518.0	b	960.0	d	1628.3	d
Wenfeng 5	810.0	cd	1346.7	e	2061.7	d

Table 1-2. Aphid Population Dynamic in Field (1990)

Varieties	Aphid Number of Single Plant											
	June 10		June 15		June 20		June 25		June 30		July 5	
Guoyu 98-4	1.5	a	7.2	a	7.7	a	11.5	a	16.0	a	42.0	a
Guoyu 100-4	2.4	a	6.0	a	9.9	a	7.4	a	59.0	ab	47.3	a
Xiongyue Yellow	34.0	ab	73.0	ab	163.7	b	97.0	bc	11.3	b	198.0	ab
Amsoy	105.5	bcd	224.3	bc	470.0	c	266.3	fgh	375.3	fg	516.0	de
Tiefeng 20	95.7	bcd	191.2	bc	225.0	b	202.3	efg	214.3	cde	330.0	bcd
Wenfeng 5	94.2	bcd	182.8	bc	185.0	b	152.3	cde	259.0	de	411.3	cde
8433	97.7	bcd	180.7	bc	443.0	c	271.3	gh	246.3	de	301.3	bc
Liao 81-5052	72.2	abc	180.5	bc	476.0	c	181.7	def	206.7	cd	289.3	bc
Tie 79163-5	106.3	bcd	197.3	bc	482.0	c	306.3	h	307.0	ef	450.0	cde
Liao 83-5-20	155.0	d	279.2	c	168.7	b	443.0	i	487.3	h	596.0	e
Shen 702	54.1	ab	148.2	abc	429.0	c	75.0	abc	132.0	bc	170.7	ab
Liaodou 3	131.5	cd	251.5	C	461.3	c	324.7	h	397.7	g	577.3	e
Liao 84-5018	73.6	bc	152.3	Abc	185.7	b	316.0	h	253.3	dc	214.7	ab
Jiling 3	77.0	bc	151.8	Abc	191.0	b	52.3	ab	93.7	ab	212.7	ab

Table 2. Aphid Population Structure and Intrinsic rate of Natural Increase in Field (%) (1989)

Varieties	1st instar	2nd instar	3rd instar	4th instar	Apt	Ala	Rate of Natural Increase (λ)
Guoyu 100-4	54.99 a	18.89 bcd	19.38 a	1.53 a	2.52 a	2.68 b	0.85 a
Xiongyue Yellow	54.99 a	20.99 d	14.30 c	2.02 a	3.12 a	4.58 c	0.78 a
Guoyu 98-4	55.77 ab	17.60 bc	15.74 c	2.34 a	5.88 a	2.39 b	0.80 a
Wenfeng 5	60.05 bc	17.22 b	10.00 b	6.83 d	3.10 a	1.36 a	1.05 bc
Tiefeng 20	61.22 c	20.20 cd	10.08 b	4.53 bc	3.17 a	0.97 a	1.00 b
Liao 81-5052	61.72 cd	16.53 b	10.38 b	4.82 bc	4.67 a	1.39 a	1.07 bc
Amsoy	61.74 cd	16.65 b	11.31 b	5.46 c	3.45 a	1.40 a	1.08 bc
Liaodou 3	63.80 cd	17.68 bc	10.52 b	5.25 bc	7.29 a	0.81 a	1.06 bc
Tie 79163-5	64.18 cd	24.47 e	4.43 a	1.80 a	3.51 a	0.51 a	1.15 bc
8433	66.44 de	13.89 a	9.74 b	5.12 bc	4.71 a	0.78 a	1.21 c
Liao 84-5018	69.58 e	16.56 b	5.95 a	4.01 b	3.63 a	1.42 a	1.37 d

Table 3. Yield Reduction of Tolerant Varieties (%)

Varieties	1989		1990	
Xiongyue Yellow	0	a	0	a
Wenfeng 5	0	a	5.67	b
8433	0	a	6.33	b
Liao 81-5020	4.13	a	6.70	a
Tie 79163-5	8.03	a	0	a
Amsoy	18.93	b	2.50	a
Liaodou 3	25.47	bc	9.47	c
Liao 83-5020	29.87	c	13.57	d
Liao 84-5018	44.03	d	9.47	C

Table 4. Reduction and Compensation of Yield Components (1989)

Varieties	Yield Loss (%)		100 knl wt dec. (%)		knl wt dec. / pt (%)		knl no. dec. / pt (%)		Plant Height dec. (%)		Branch Inc.
Wenfeng 5	0	a	2.00	a	0	a	0	a	8.83	ab	+ 0.70
Xiongyue Yellow	0	a	3.37	ab	0	a	0	a	15.97	abc	+ 4.77
8433	0	a	9.33	cd	0	a	0	a	21.97	c	+ 0.43
Liao 81-5052	4.13	a	1.07	a	3.93	a	2.97	a	7.60	a	+ 0.86
Tie 79163-5	8.03	a	0	a	14.37	b	13.60	b	14.30	abc	- 0.23
Amsoy	18.93	b	11.47	d	38.43	d	27.20	c	37.23	d	+ 0.30
Liaodou 3	25.48	bc	1.33	a	43.90	d	43.03	d	41.63	d	- 0.23
Liao 83-5020	29.87	c	6.40	bc	0	a	0	a	20.27	bc	+ 0.37
Liao 81-5018	44.03	d	6.70	bc	32.10	c	27.07	c	24.63	c	- 0.10

Table 5. Correlated Coefficient of Yield Component (1989)

Item	100 knl wt Decrease (%)	knl wt Decrease / pt (%)	knl no. Decrease / pt (%)	Plant ht. Decrease (%)	Branch Increase (%)	Yield Loss (%)
100 knl wt dec. (%)						
knl wt dec. / pt (%)	0.0645					
knl no. dec. / pt (%)	0.0004	0.9952**				
Plant ht. Decrease (%)	0.4724	0.7343*	0.7320*			
Branch Increase (%)	- 0.0545	- 0.4113	- 0.4055	- 0.1557		
Yield Loss (%)	0.1080	0.9470**	0.9430**	0.6220	- 0.4317	

*: 8 varieties, square transformation of (%) before correlated analysis

Table 6. Repellency of Soybean Varieties to Aphid (1990)

Varieties	Aphid Number / Plant											
	24 hr		48 hr		72 hr		96 hr		120 hr		144 hr	
Guoyu 98-4	4.75	a	3.75	a	1.50	a	1.50	a	1.25	a	1.25	a
Guoyu 100-4	4.75	a	4.25	ab	0.75	a	0.75	a	0.75	a	1.00	a
Zhe 455	4.25	a	3.25	a	1.25	a	1.50	a	1.00	a	1.00	a
Tiefeng 20	5.25	a	6.00	c	9.00	a	7.75	b	8.50	b	8.25	b
Liaodou 3	5.25	a	5.75	c	8.00	bc	8.00	b	8.25	b	8.00	b
Xiongyue Yellow	5.50	a	6.00	c	6.25	b	7.00	b	7.00	b	7.75	b
8433	5.00	a	6.25	c	6.00	b	6.50	b	6.25	b	6.75	b
Jiling 3	5.00	a	4.75	abc	7.75	bc	7.00	b	8.00	b	7.00	b

Note: figures in the table means of 4 replicates