Effects of resistance genes and insecticidal seed treatments on soybean aphid population growth and development

Jiaqi Guo, Christian Krupke[1]

[1]Department of Entomology, Purdue University, 901 W. State St., West Lafayette, IN, 47907, USA.

Introduction

Soybean aphid (*Aphis glycines*) is an introduced pest first reported in 2000 and has been a major problem in soybean planting areas in United States and Canada (Ragsdale et al. 2004). Heavy infestation of aphids causes distortion of leaves, reduction of seed pods and yield loss (Sun et al. 1990). In addition, soybean aphids are important vector of diseases (Hill et al., 2001), and promote development of sooty mold which grows on the honey dew (Hirano et al. 1996) and reduces photosynthesis (Diaz-Montano et al. 2007). To control aphid infestations, the resistance gene Rag1 was found in several varieties and proven to be a single dominant gene (Hill et al. 2006). The gene expresses an antibiotic defense toward aphids, which leads to stunting and death. Also, the morphology of Rag1 soybean is different from regular cultivars by having more and longer trichomes, but the effect of the trichomes as physical defense is undetermined.

Another common control method is using insecticidal seed treatment. The chemicals used as seed coat are in neonicotinoid family, which includes imidacloprid and thiamethoxam (Tomizawa and Casida 2003). This group of insecticides acts as agonists at the postsynaptic acetylcholine receptor and results in the insects ceasing feeding after ingesting the chemicals. Previous research shown the seed treatment was effective in eliminating insects early in the growing season (McCornack and Ragsdale 2006).

Material and Methods

Four types of soybean seeds were planted in pots in the middle of January, 2011. They were regular soybean (12 pots), regular soybean with thiamethoxam (trade name Cruiser) (12 pots), Rag1 soybean (24 pots) and Rag1 soybean with thiamethoxam (12 pots). The pots were set randomly and given optimal environmental conditions for growth (16h daylight and 21°C). After the seeds emerged and the seedlings grew to the V1 stage, half of the healthy soybean plants were chosen for the next process. Six of the Rag1 soybean plants had their trichomes partially shaved with a single-sided razorblade and randomly arranged with other chosen pots. Five adult female aphids were placed on the back of the leaves of each plant with wet paintbrush and were enclosed with gauze to prevent aphids escaping. The number of aphids was counted every 2 to 3 days and recorded. Four rounds of infestation were conducted in the research and the infestations were on the youngest leaves of V2, V3, V4 and V7 stages (Table 1-4).

Results

1. Functions of the trichomes

As the abundances of aphids over time (Figure 1) showed in all four rounds of tests on Rag1 soybean plants, the expression of the gene led to strong resistance and eradicated the aphids shortly after infestation compared to the regular cultivar. The aphids could not colonize Rag1 soybean plants. The growth rates of aphids on both shaved and unshaved plants were negative (Figure 2). When comparing the shaved and on unshaved Rag1 soybeans, the decreasing rates of aphids showed the shaved plants were less resistant towards aphids than the unshaved plants, this may becaused by lacking of trichomes as primary defense.

2. Effects of combining Rag1 gene and seed treatment

The number of aphids on soybean plants on the combined treatments decreased much faster than either of the single treatment as well as the non-treated soybeans (Figure 3). The effect of thiamethoxam was very strong early in the growing season. However, the resistant effects of thiamethoxam wore out gradually during the growth of the plants, and the time needed to eradicate all the aphids increased with age of plants. The growth rates of aphids showed the same pattern (Figure 4). The chemical defense (as measured by aphid population growth) disappeared after around 8 weeks after planting. The combined treatments increased the resistance of soybean toward aphids for a longer time and remained effective after the thiamethoxam stopped working, allowing for more durable resistance than the Rag1 soybean plants.

Discussion

The results from the experiments demonstrated that Rag1 soybean has antibiotic effects of resistance to soybean aphids, which caused the delay of reproduction and death in a short time. The trichomes on soybean leaves provide primary mechanical defense to aphids in addition of physiological resistance. The removal of trichomes offered a feeding site for the aphids and reduced the resistant effects of Rag1 soybean. Also, both the Rag1 gene and the insecticidal seed treatment had negative impact on soybean aphid population growth rates. Combining the Rag1 gene and the seed treatment enhanced the resistance of soybean. But since the efficacy of seed treatment would wear out in less than two months, the use of seed treatment and the cost that goes with it in actual production must be considered with an estimate of when aphid infestation will occur.

The method used for trichome removal could be modified in future research to use abrasive powder for overall removal, which may be more thorough and simpler than the method used in the study. At the same time, the trichomes on regular soybean can be removed for comparison. There are also other behavioral characteristics, including the tendency of movement and reproduction of apterous or alate offspring that may be valuable to study the resistance of each treatment. After the investigation of aphid mortality in each treatment, further questions may include: how treatments affect the growth of the soybean and the actual yield in the field, and use of the economic threshold as indication of further control.

Table 1: Number of aphids on V2 trifoliate enclosure

	2/13/11	2/15/11	2/17/11	2/22/11	2/24/11	2/26/11	2/28/11	3/2/2011	3/4/2011
RC1	1	0	0	0					
R15	5	3	3	1	0				
N2	4	3	1	0					
C2	2	0	0	0					
C12	2	0	0	0					
RC4	2	0	0	0					
R19*	3	2	0	0					
N3	2	1	2	4	3	2	2	1	1
R21*	3	1	0	0					
RC12	2	0	0	0					
N9	3	3	2	2	1	1			
R16	3	1	0	0					
RC10	1	1	0	0					
R11*	2	1	0	0					
R18	0	0	0	0					
C1	0	0	0	0					
R3	3	2	0	0					
N11	3	4	4	6	4	1	2	1	1
R17*	0	0	1	0					
RC7	0	0	0	0					
N8	0	3	2	2	6	3	1		
R5	3	1	0	0					
C9	3	0	0	0					
R22*	1	0	1	0					
C8	1	0	0	0					
N6	5	4	4	5	2	3	5	4	
R12*	4	5	4	2	2	1	2	1	0
RC8	2	0	0	0					
R10	2	1	0	0					
C6	1	0	0	0					

R1--R24: Rag1 soybean

C1--C12: Non-Rag1 soybean with seed treatment

RC1--RC12: Rag1 soybean with seed treatment

N1--N12: Untreated soybean

Table 2: Number of aphids on V3 trifoliate enclosure

	2/24/11	2/26/11	2/28/11	3/2/2011	3/4/2011
RC1	2	1	0	0	0
N2	6	7	9	6	8
C2	5	2	0	0	0
C12	2	1	0	0	0
RC4	2	0	0	0	0
R19*	5	5	1	1	0
RC12	1	0	0	0	0
R16	1	1	0	0	0
R11*	3	3	3	1	0
R18	3	2	1	0	0
C1	3	0	0	0	0
R3	2	0	0	0	0
R17*	2	0	0	0	0
RC7	1	1	0	0	
R5	2	2	0	0	0
R22*	3	2	0	0	0
C8	4	2	0	0	0
N7	3	4	3	1	0

R1--R24: Rag1 soybean

C1--C12: Non-Rag1 soybean with seed treatment

RC1--RC12: Rag1 soybean with seed treatment

N1--N12: Untreated soybean

Table 3: Number of aphids on V4 trifoliate enclosure

	3/6/2011	3/8/2011	3/11/2011	3/13/2011
RC1	3	0	0	0
R15	0	0	0	0
N2	1	0	2	3
C2	4	2	1	0
C12	4	3	2	0
RC4	1	0	0	0
R19*	3	3	1	0
N3	4	3	4	7
R21*	4	1	0	0
RC12	3	1	0	0
N9	4	0	0	0
R16	2	0	1	0
RC10	2	0	0	0
R11*	2	1	0	0
R18	1	0	0	0
C1	2	2	0	0
R3	0	0	0	0
R17*	2	1	0	0
RC7	2	0	0	0
N8	4	2	0	0
R5	4	1	0	0
C9	2	0	0	0
R22*	3	2	0	0
C8	4	0	0	0
N6	7	1	4	2

R1--R24: Rag1 soybean

C1--C12: Non-Rag1 soybean with seed treatment

RC1--RC12: Rag1 soybean with seed treatment

N1--N12: Untreated soybean

Table 4: Number of aphids on V7 trifoliate enclosure

	3/21/2011	3/23/2011	3/25/2011	3/27/2011	3/29/2011	3/31/2011	4/2/2011
RC1	5	7	0	0	0	0	0
R15	5	5	0	0	0	0	0
C2	5	4	4	3	1	4	6
C12	5	4	1	0	0	0	0
R19*	5	5	4	3	2	2	0
RC12	5	2	0	0	0	0	0
N9	5	18	36	30	26	19	19
R16*	5	12	12	6	3	3	0
C1	5	12	7	4	0	0	0
R3	5	5	1	1	0	0	0
N11	5	15	33	48	74	39	28
R17*	5	12	24	6	1	0	0
N8	5	13	24	31	20	39	48
R4*	5	9	7	4	0	1	0
C8	5	7	1	2	0	0	0
RC8	5	10	0	0	0	0	0
R10	5	2	1	0	0	0	0
N7	5	11	18	32	32	37	35

R1--R24: Rag1 soybean

C1--C12: Non-Rag1 soybean with seed treatment

RC1--RC12: Rag1 soybean with seed treatment

N1--N12: Untreated soybean

Figure 1. Number of aphids in each infestation (function of trichomes, comparing the aphid mortality on the shaved and un-shaved Rag1 soybean).

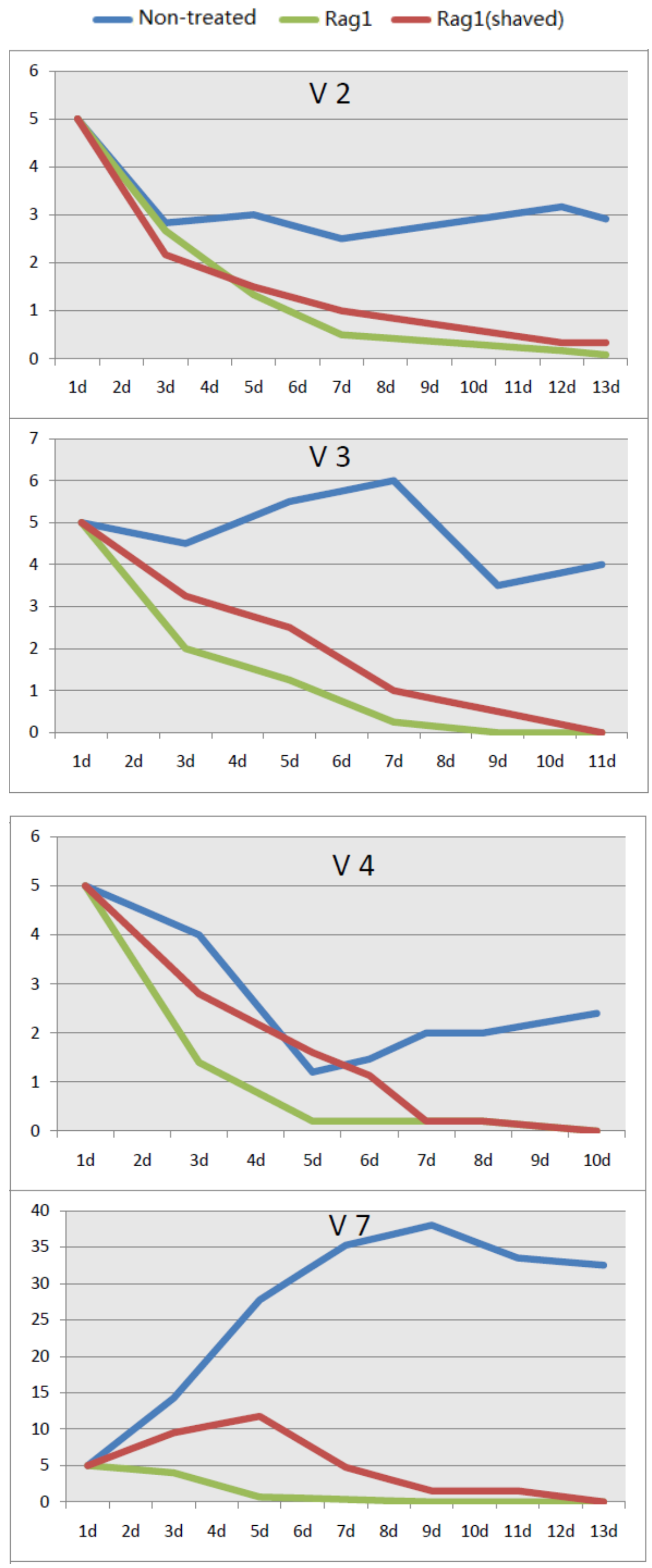


Figure 2. Population growth rates of aphids in each infestation (function of trichomes, comparing the aphid mortality on the shaved and un-shaved Rag1 soybean).

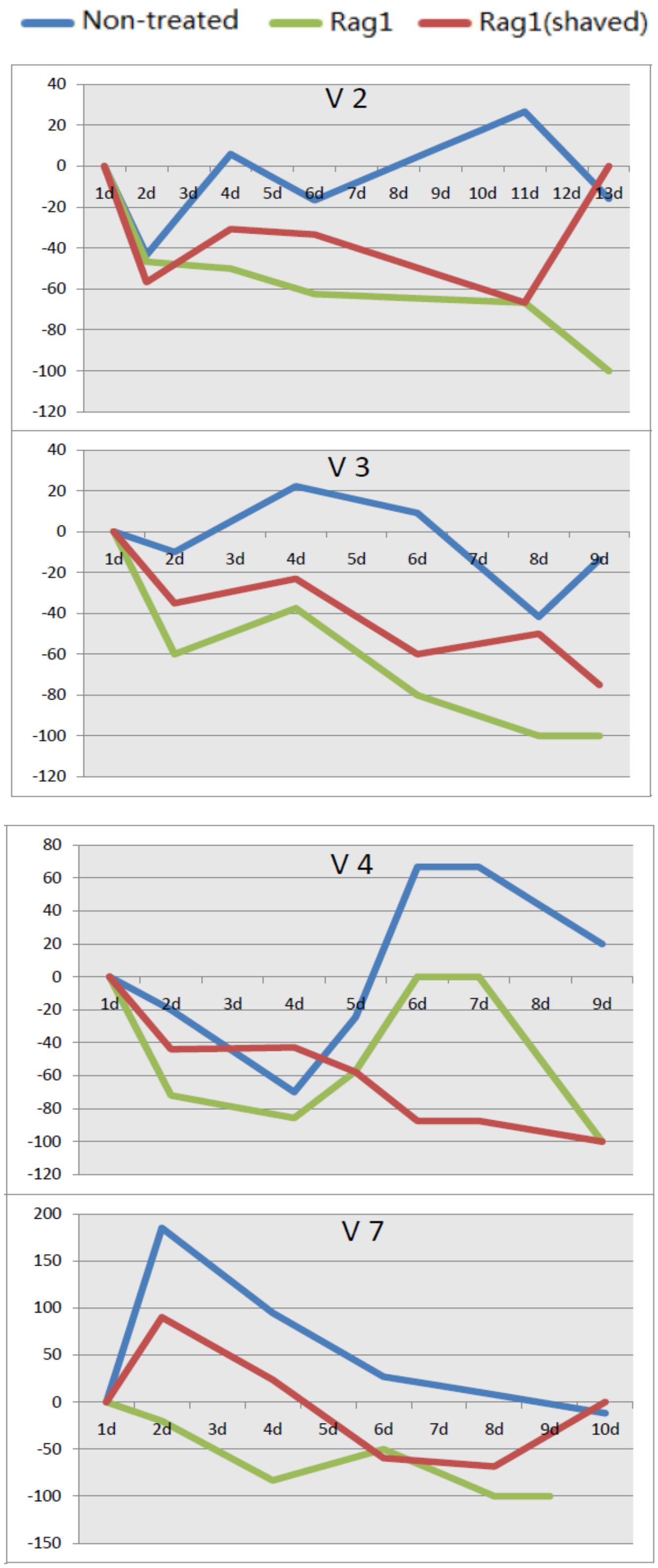


Figure 3. Number of aphids in each infestation (combining the resistance Rag1 gene and insecticidal seed treatment).

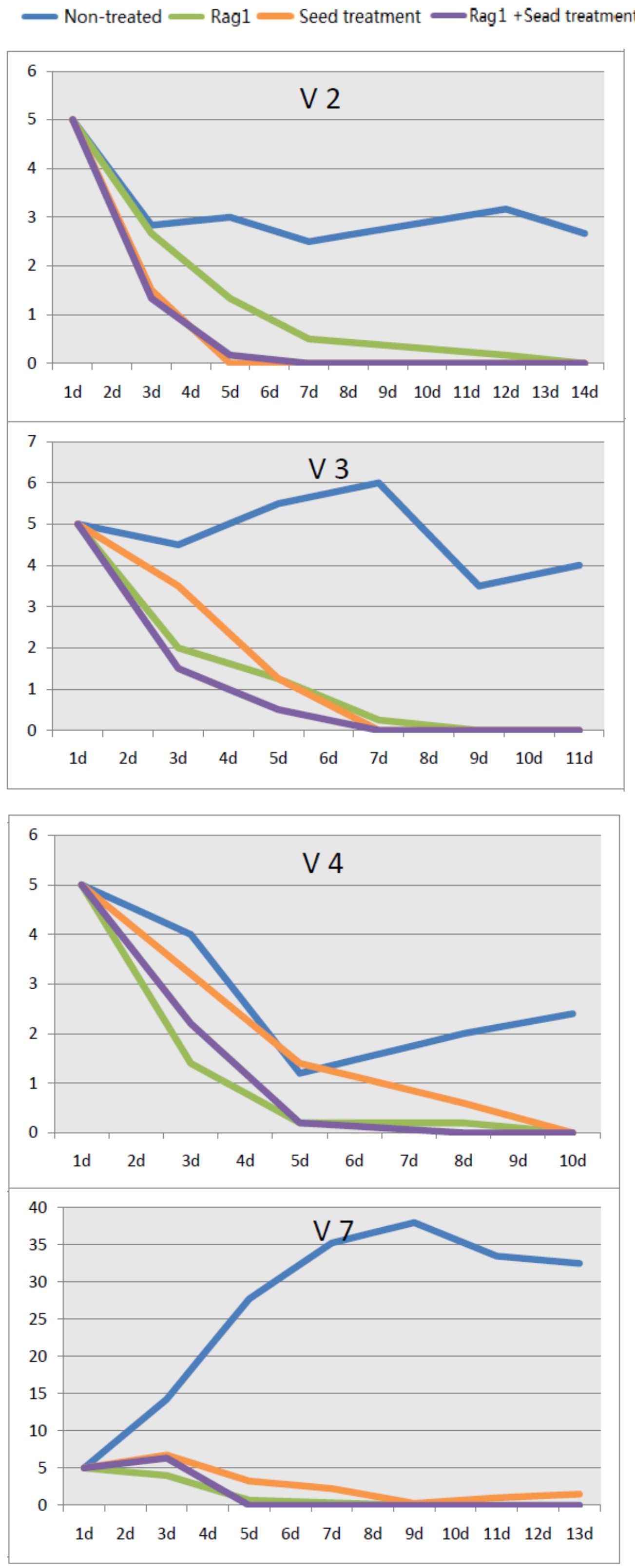
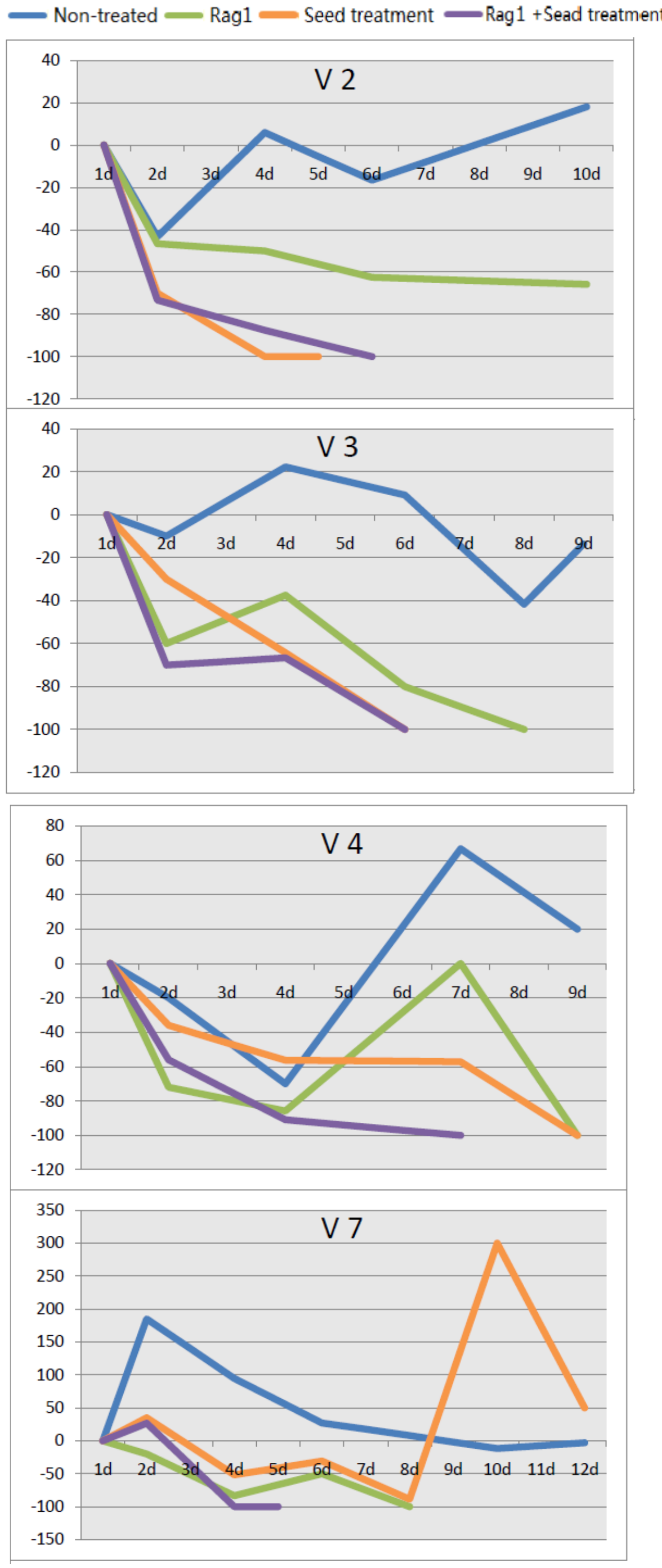


Figure 4. Population growth rates of aphids in each infestation (combining the resistance Rag1 gene and insecticidal seed treatment).



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