Soybean Aphid in the Midwest: Looking Toward a Dynamic Threshold—Emerging Recommendations, Lingering Questions

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Last year, at the 2003 Illinois Crop Protection Technology Conference, Ken Ostlie (University of Minnesota) appraised the soybean aphid situation under the apt title "Gathering Storm or Dissipating Threat? Status, Prognosis, and Management of the Soybean Aphid". As has been widely reported, the soybean aphid, *Aphis glycines* Matsumura, was first observed in the Midwest in July 2000 (Gallepp, 2003). Given variable population levels of this emergent pest since its discovery, researchers, extension agents, growers, and crop consultants have just a couple of years of soybean yield response, economic injury level, and insecticide efficacy data on which to base treatment decisions. During summer 2003, soybean aphid was found at record high densities in most of the soybean-growing areas in the central and upper Midwest. Heaviest infestations were observed in Wisconsin, Iowa, Illinois, Michigan, and Minnesota with millions of acres receiving between one and two applications of pyrethroid and/or organophosphate insecticide throughout the region. Here we are, January 2004, still reeling (and interpreting data) from the effect of that storm Ken Ostlie alluded to at last year's conference.

The objectives of this symposium presentation are to 1) discuss the current status of chemical control tactics (foliar contact activity materials and insecticidal seed treatments) for soybean aphid; 2) present collective results and observations from University of Wisconsin foliar insecticide efficacy, seed treatment, spray timing and varietal trials; and 3) continue the dialogue on soybean aphid treatment thresholds, with reference to the potential for dynamic threshold development seemingly inherent in this crop–pest association.

Status of Chemical Control Tactics for Soybean Aphid (2003)

Soybean aphid causes both direct and indirect effects on soybean that can lead to yield loss and reduced seed quality. Direct feeding damage results in subsequent plant stress, stunting, and yield loss. Indirectly, soybean aphids have been found to reduce photosynthetic rate in soybean (Macedo et al., 2003). Winged soybean aphid morphs occur early in the growing season as females migrate from the primary (overwintering) host, buckthorn (*Rhamnus* spp.), to the secondary host, soybean (*Glycine max*), for the asexual development phase (Zhang and Zhong, 1982). A summer wing morph develops later in the growing season as females respond to crowding and decreased host quality by dispersal flight to uncolonized plants and fields (Steffey, 2003). It is the winged soybean aphids that are capable of transmitting soybean viruses as they probe and feed between infected and uninfected plants during movement between fields. Because soybean viruses can be transmitted rapidly by winged aphids, there are no thresholds to control this indirect damage (yield loss and seed mottling effects) caused by soybean aphid (Grau, 2003).

Soybean aphid chemical control tactics, and ultimately overall management strategies, should take into account both the direct and indirect effects of soybean aphid on the crop. As in the previous 3 years since soybean aphid emerged in the Midwest, the primary control tactic to manage direct effects of soybean aphid feeding during the 2003 growing season was to apply a pyrethroid foliar insecticide by ground or air. Examples of pyrethroids include Asana XL (active ingredient esfenvalerate); Warrior (lambda-cyhalothrin); and Mustang Max (zeta-cypermethrin). The organophosphates dimethoate and Lorsban 4E (chlorpyrifos), and the carbamate Furadan 4F (carbofuran) also are registered for soybean aphid.

Other than winged morphs, aphids are relatively sedentary on the plant as they feed with piercing-sucking mouthparts. Thus, they do not move quickly enough through the canopy after a foliar pyrethroid application (nor does their feeding mechanism permit) to encounter additional treated plant surfaces or ingest active ingredient. For pesticides that work primarily by contact activity, it is critical that a lethal dose be delivered to the site at which the aphid is located (Cullen et al., 2001). Contact activity materials are relied upon to manage direct soybean aphid effects by reducing pest population pressure and plant stress quickly. In the long term, contact activity materials are expected to be most effective if used in an integrated pest management (IPM) program for which soybean aphid economic thresholds, optimal spray timing, and delivery methods have been determined.

Insecticidal seed treatments applied to soybean before they are bagged and sold are another developing option for soybean aphid. This technology, already registered in field corn, has seen limited registration on soybean. Gaucho (nicotinoid active ingredient imidacloprid) was registered under a Section 18 emergency exemption in Wisconsin beginning March 28, 2003, for control of bean pod mottle virus transmitted by the bean leaf beetle. This exemption registration expired June 1, 2003, and nicotinoid seed treatments continue to be in the preregistration, development phase as of the 2003 soybean harvest at the time this article was written. Nicotinoid insecticides have systemic activity within the treated plant. When applied as a seed treatment, active ingredient is taken up into the germinating seed through developing root, stem, and leaf tissues. Three nicotinoid insecticidal seed treatment active ingredients currently in the trial phase on soybean are Cruiser (active ingredient thiamethoxam), Gaucho (imidacloprid), and Poncho (clothianidin). As in the corn seed treatment market, Cruiser is manufactured by Syngenta, whereas Gaucho and Poncho are manufactured by Bayer CropScience with Gustafson LLC.

Unlike the broad-spectrum contact activity materials discussed previously, nicotinoid seed treatments have selective activity against piercing-sucking insects with negligible effects on nontarget organisms (e.g., natural enemies important in regulating aphid population growth). This systemic mode of action means that soybean aphids ingest active ingredient during feeding, thus preventing further direct feeding stress and reducing virus transmission by protecting plants from potential vectors as winged aphids arrive in a field.

Nicotinoid seed treatments typically have activity within a growing plant for at least 4 to 6 weeks after germination, sometimes longer, depending on active ingredient, seed treatment rate, crop, and target pest susceptibility. Thus, nicotinoid seed treatments are expected to be best suited for early- to mid-season protection against the direct and indirect effects of soybean aphid. Soybean is treated on a grams of active ingredient per 100 kg of seed basis. For example, Poncho 62.5 and Cruiser 30 would equate to 62.5 g clothianidin/100 kg seed and 30 g thiamethoxam/100 kg seed, respectively. The situation is different for corn seed treatment where field corn seed can range in size (e.g., 1,400–2,800 seeds/lb) and seed is sold on a seed count basis. To obtain the same active ingredient rate per seedling, nicotinoid seed treatments are made to field corn on a milligrams of active ingredient per kernel basis.

2003 Insecticide Efficacy Trials – A Sampling of Wisconsin Data

Foliar insecticides and insecticidal seed treatments were evaluated in three different trials for efficacy against soybean aphid at the Arlington Agricultural Research Station, Arlington, WI. The foliar insecticide trial, designed to evaluate residual activity as measured by aphid counts at successive intervals post-treatment, included nine treatments (seven pyrethroids and two organophosphates) in a completely randomized block design (CRBD) with four replicates per treatment. Post-treatment aphid counts (Table 1) were significantly different ($P < 0.05$) by treatment at three post treatment sampling dates, suggestive of varying residual activity between treatments.

Two nicotinoid seed treatment trials, with aphid counts and yield data as response variables, were designed to investigate how long seed treatment systemic activity extends into the growing season. With the exception of cultivar (trial 1, NK S19-V2; trial 2, NK S240K4) and treatment variables, experimental design was the same for both seed treatment trials. Trial 1 included five treatments: Poncho 62.5 (clothianidin), Poncho 125, Gaucho 62.5 (imidacloprid), Cruiser 62.5 (thiamethoxam), and an

Table 1 Soybean aphid foliar insecticide trial. Mean aphids/plant 4 days, 1 week, and 2 weeks post-treatment[1]. Treated July 31 at R2 (>500 aphids/plant).

Treatment	4 days	1 week	2 weeks
Untreated	996.5 a	1518.8 a	1823.5 a
Warrior 1CS 3.84 oz.	26.3 f	22.2 e	72.6 e
dimethoate 1 pt.	36.2 e	45.5 d	147.0 c
Baythroid 2.8 oz.*	181.5 d	344.5 b	476.0 b
Mustang Max 4.0 oz.	203.2 d	200.3 c	307.8 c
Mustang Max + NIS	353.9 b	437.1 b	440.6 b
Capture 2.56 oz.*	1.1 g	9.6 f	50.8 f
Asana 6.4 oz.	330.4 b	346.5 b	349.3 b
Asana 9.6 oz.	204.6 c	368.3 b	168.9 c
Lorsban 4E 2.0 pt.	0.5 g	15.3 e	91.9 d

[1] Mean yields (bu/acre) within a column followed by a different letter are significantly different at $\alpha = 0.05$ (Fisher's exact test).
* Baythroid (See supplemental label for soybean aphid); Capture not currently registered for soybean aphid.

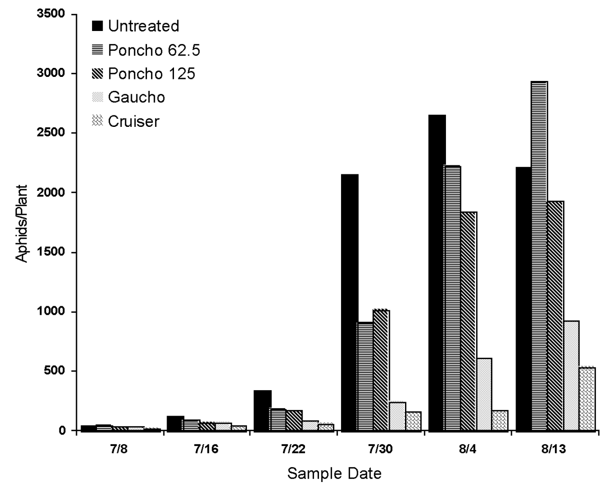

Figure 1 Nicotinoid seed treatment on soybean (soybean aphid trial 1). Mean aphids per plant across sampling dates.[1] University of Wisconsin, 2003.

[1] Mean aphids/plant significantly different across sample dates at a = 0.05 (Fisher's exact test):

July 8	$P < 0.0001$; $F = 8.38$; df = 4
July 16	$P < 0.0001$; $F = 17.8$; df = 4
July 22	$P < 0.0001$; $F = 28.96$; df = 4
July 30	$P < 0.0001$; $F = 69.42$; df = 4
August 4	$P < 0.0001$; $F = 54.74$; df = 4
August 13	$P < 0.0001$, $F = 52.05$; df = 4

untreated check. Trial 2 included four treatments: Cruiser 30, Cruiser 50, Gaucho 62.5, and an untreated check. Plots were seeded in 30-inch rows in a CRBD with four replicates per treatment on June 9, 2003. Each treatment replicate was 10 ft (4 rows) in width by 25 ft in length. To assess early through mid-season systemic activity of the seed treatments, aphid counts were taken from each plot beginning with initial aphid colonization in the plots (July 8) and continuing at weekly intervals through August 13, when untreated check plot populations began to decline. Whole plant aphid counts were taken on 10 plants per replicate, randomly selected from the middle two rows of each plot, and mean aphids per plant was determined for each plot across sampling dates. Yield data were recorded at harvest on 16 October.

Figure 1 illustrates a significant difference ($P < 0.05$) in mean aphids per plant between treatments at each sample date for trial 1. The same pattern was observed in trial 2 (Fig. 2). As measured by mean aphids per plant, Cruiser (thiamethoxam) at the 50 and 62.5 g ai/100 kg seed rates, and Gaucho (imidacloprid) at the 62.5 g ai/100 kg seed rate seemed to have the longest systemic activity into the growing season at approximately 65 days between seeding and the final aphid count on 13 August when plants were in the R3 stage. Mean separation results for yields in each trial reflected this same pattern with the highest yields corresponding to treatments with the lowest aphid counts on 13 August (Tables 2 and 3).

Looking toward a Dynamic Soybean Aphid Threshold

Little is known about interactions between soybean developmental stage and susceptibility and tolerance to soybean aphid injury in the Midwest. Soybean aphid is native to east Asia and China in particular, where a substantial body of literature on soybean aphid (e.g., sampling, thresholds, cultivar resistance, biological control) exists [Soybean aphid literature translation project, http://www.ksu.edu/issa/aphids/reporthtml/projectii.html]. Aphid density is dynamic in the field, aphids multiply as plants grow, and infestation can be enduring and continuous. The ratio of plant size to aphid density that the plant can tolerate is vital to understanding aphid damage (Dai and Fan, 1991). Chinese researchers successfully identified resistance of soybean to soybean aphid and obtained a batch of source breeding material (cited in He et al., 1995). On the basis of this work, researchers in east Asia have continued to document varying

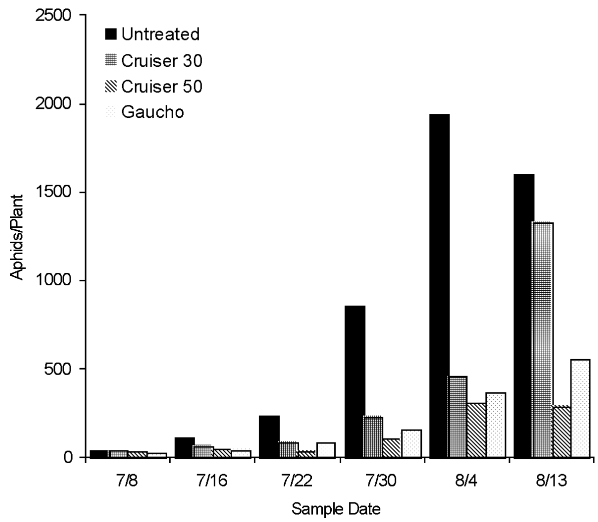

Figure 2 ■ Nicotinoid seed treatment on soybean (soybean aphid trial 2). Mean aphids per plant across sampling dates.[1] University of Wisconsin, 2003.

[1] Mean aphids/plant significantly different across sample dates at a=0.05 (Fisher's exact test):

July 8	$P = 0.0122$; $F = 3.00$; df = 5
July 16	$P < 0.0001$; $F = 18.66$; df = 5
July 22	$P < 0.0001$; $F = 30.54$; df = 5
July 30	$P < 0.0001$; $F = 41.77$; df = 5
August 4	$P < 0.0001$; $F = 446.93$; df = 5
August 13	$P < 0.0001$, $F = 313.33$; df = 5

Table 2 ■ Nicotinoid seed treatment on soybean (soybean aphid trial 1). Mean yield (bu/acre) by treatment.[1] ($P = 0.1151$, $F = 2.33$, df = 4). University of Wisconsin, 2003.

Treatment	Yield (bu/A)
Untreated	38.1 b
Poncho 62.5	42.2 ab
Poncho 125	44.3 ab
Gaucho	43.2 ab
Cruiser	52.8 a

[1] Mean yields (bu/acre) followed by a different letter are significantly different at a = 0.05 (Fisher's exact test).

Table 3. Nicotinoid seed treatment on soybean (soybean aphid trial 2). Mean yield (bu/acre) by treatment.[1] ($P = 0.1151$, $F = 2.33$, df = 4). University of Wisconsin, 2003

Treatment	Yield (bu/A)
Untreated	38.1 c
Cruiser 30	43.6 bc
Cruiser 50	49.7 ab
Gaucho	41.3 bc

[1] Mean yield (bu/acre) followed by a different letter are significantly different by at a = 0.05 (Fisher's exact test).

levels of potential resistance or tolerance among soybean cultivars to soybean aphid (Chung et al., 1980).

Collective University of Wisconsin results and observations from spray timing and varietal trials over the past couple of years are reviewed. Foliar insecticide and seed treatment efficacy trials such as those presented herein are important first steps in developing uniform treatment recommendations for soybean aphid throughout the Midwest. As discussed previously, in the long term, chemical control tactics (broad spectrum or selective) will be most effective if used in an IPM program for which soybean aphid economic thresholds, optimal spray timing, and delivery methods have been determined. We are not there yet, but the idea of a dynamic threshold has surfaced in discussions and observations with some growers and consultants and researchers, and can be traced back to the Chinese literature on soybean aphid in its native territory.

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