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Field Validation of Speed Scouting for Soybean Aphid

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Abstract
Agricultural professionals are spending increasing amounts of time making treatment decisions for soybean aphid, *Aphis glycines* Matsumura. In an effort to reduce the time required to make treatment decisions, a binomial sequential sampling plan called "Speed Scouting" was developed for soybean aphid. In 2005, we validated Speed Scouting using commercial fields in Minnesota and replicated small plot trials in four states in the North Central Region of the USA (Iowa, Michigan, Minnesota, and Wisconsin). In commercial fields, yield (bu/acre ± S.E.) was significantly higher in areas of the fields where treatment was applied based on Speed Scouting (50.7 ± 1.7) compared to untreated controls (46.9 ± 1.6). When comparing treatment decisions based on Speed Scouting and whole-plant counts, the same decision was reached 79% of the time. Results from 5 of the 6 small plot trials showed no significant yield difference when aphid control decisions were made using Speed Scouting compared to whole-plant counts using an economic threshold of 250 aphids per plant. Speed Scouting is a conservative sampling plan, and consistently recommended treatment before populations reached the economic threshold using whole-plant counts. Using either sampling method, soybean aphid management should rely on multiple samples over time to accurately assess population growth rates to avoid unnecessary foliar applications.

Introduction
Soybean aphid, *Aphis glycines* Matsumura, was first detected in North America in Wisconsin in 2000 (1) and has spread throughout the North Central Region (10). Economic injury level for soybean aphid is approximately 1,000 aphids per plant (10). The currently recommended economic threshold (ET) for soybean aphid is to treat within 7 days when aphid density exceeds 250 aphids/plant (10) and is valid from the onset of flowering (R1) through beginning seed set (R5) [see Fehr and Caviness (2) for plant stage descriptions]. This ET gives growers enough time to schedule a treatment before an increasing aphid population exceeds the economic injury level where irreversible yield loss occurs that exceeds the cost of control.

Currently there are over 61.5 million acres of soybean grown in the North Central Region (8) and all are at risk for soybean aphid damage. Before the arrival of the soybean aphid, foliar insecticides were rarely applied to soybeans in the North Central Region (11). Since 2000, significant soybean aphid damage has occurred yearly in some parts of the USA, with region-wide outbreaks occurring in 2001, 2003, and 2005 with a concomitant increase in foliar insecticide use (9). However, even during outbreak years, soybean aphid population dynamics are variable within a season and among fields. In light of this variation, crop consultants are scouting on average 36% more soybean acreage than before 2000 (E. W. Hodgson, *unpublished data*), and an accurate but rapid sampling method is needed to make management decisions. Here we validate a binomial sequential sampling plan, "Speed Scouting," as a rapid decision tool to assist agricultural professionals in their efforts to manage soybean aphid based on research conducted in Minnesota.

In 2004, Hodgson et al. (3) developed a fixed-precision, enumerative sampling plan for integrated pest management (IPM) and ecological studies in soybean, and from these data sets developed a binomial sequential sampling plan for making management decisions. Hodgson et al. (4) used the results of the binomial sequential sampling plan to develop Speed Scouting, which includes instructions, worksheets, and hypothetical examples available on the internet (4).

The binomial sequential sampling plan that underlies the Speed Scouting worksheets was derived from field-collected data in Minnesota from 2001 to 2003 and computer-simulation of the sampling effort was conducted using a software program, Resampling for Validation of Sample Plans (7). Speed Scouting is based on the mathematical relationship between the proportion of infested plants, the density of aphids per plant, and an ET of 250 aphids per plant (3). Instead of counting every aphid on a plant, a more convenient tally threshold (set at 40 or more aphids per plant) is used to score plants as infested or not infested. Only 11 plants are needed to make a treatment decision with Speed Scouting (3). Plants are sampled for the presence or absence of soybean aphid with three possible outcomes: treat, do not treat, or resample. If the decision is to resample, sets of 5 plants are sampled and scored as infested or not until a decision is made. If a decision cannot be made after sampling 31 total plants, the field should be resampled in 3 to 4 days because the aphid population is likely close to the ET of 250 per plant (4).

Objectives

The purpose of any binomial sequential sampling plan such as Speed Scouting is to provide a guideline for estimating pest populations with an acceptable level of error over a wide range of pest densities (6). The overall objective of this study was to validate Speed Scouting as a viable sampling plan for soybean aphid in the North Central Region. Commercial fields in Minnesota and small replicated plots in four states were used to compare yield between treatment decisions for Speed Scouting and whole-plant counts. The overall goal of this research is to provide a cost-saving sampling method for soybean aphid throughout the North Central Region.

Commercial Fields

Validation trials. To validate whether Speed Scouting made the correct decision when compared to whole-plant counts, 101 data sets were collected from 29 commercial fields (≥ 10 acres) in central and southern Minnesota. Each data set included a Speed Scouting sample and 30 whole-plant counts. For this trial, correct Speed Scouting decisions were based on a 95% confidence interval of the ET (250 ± 32 aphids) (10). For example, if Speed Scouting said to treat and the mean number of aphids was at least 218 aphids, then a correct decision was made.

Sixteen commercial fields (≥ 10 acres) at UMORE Park in Rosemount, MN were selected and each randomly divided into three treatment sections: untreated control, treat at the 250 threshold and treat according to the Speed Scouting decision. In all fields, the mean number of soybean aphids exceeded the 250 threshold and Speed Scouting resulted in a decision to treat; therefore, the majority of each field was treated and an untreated control section remained for yield comparison. Fields were treated with lambda-cyhalothrin (Warrior with Zeon Technology, 1.0 lb a.i./gal, Syngenta Crop Protection, Greensboro, NC), at a rate of 3.2 oz/acre using 20 gal of water per acre applied at 40 psi. Yield (bu/acre) was measured from the center of each section using a small-plot combine (2 rows by 100 ft) and adjusted to 13% moisture. Yield was analyzed using analysis of variance and the Ryan-Einot-Gabriel-Welsch multiple range test (PROC GLM) (v8.02, SAS Institute Inc., Cary, NC).

Speed Scouting in commercial fields. The mean densities from the 101 data sets ranged from 2 to 406 aphids per plant. The proportion of correct treatment decisions was 0.792 with a 95% confidence interval. In other words, using Speed Scouting made the same treatment decision as using the 250 threshold approximately 79% of the time (i.e., 80 of the 101 data sets collected). Incorrect treatment decisions (21%) from Speed Scouting were all more conservative than the 250 threshold resulting in a treat decision before one was actually needed.

For the 16 commercial fields used in the yield comparison trial, the Speed Scouting decision and the mean number of aphids per plant always fell within the 218 to 282 interval (250 ± 32) using whole-plant counts. Therefore, a direct comparison between the two sampling methods was not appropriate because treatment decisions did not vary. Analysis of variance indicated yield (bu/acre ± S.E.) was significantly higher in the treated commercial sections (50.72 ± 1.7) compared to the untreated control sections (46.94 ± 1.6) ($F = 5.78$; df = 1,15; $P = 0.0007$).

Small Plots

Validation trials. Six small plot studies were conducted across the North Central Region, with one location each in Michigan, Minnesota, and Wisconsin and three locations in Iowa (Table 1). All fields used a completely randomized block design with at least four replications of four treatments: untreated control, aphid-free control, 250 threshold, and treat according to Speed Scouting. Our designation of one treatment as "aphid-free" is actually a treatment where multiple applications of lambda-cyhalothrin were applied to keep aphids as low as possible. A fifth treatment (100 threshold) was included in Michigan, Minnesota, and Wisconsin to compare the potential yield difference for aphid densities treated below the recommended ET. All locations were planted with Round-Up Ready soybean (Table 1) and were chemically managed for weeds during the vegetative stage.

Plots were sampled weekly beginning at soybean emergence. Plants from each replication of the Speed Scouting treatment were randomly sampled according to the *Speed Scouting for Soybean Aphid* worksheet (4). A collective treatment decision was made for all Speed Scouting plots within a location. In addition, all plots were sampled weekly using whole-plant counts using a variable sample unit, beginning with 20 plants per plot and decreasing to 5 plants per plot when 80% of plants in plots were aphid infested. In all locations, lambda-cyhalothrin was applied within 1 to 3 days to all plots in a given treatment using ground equipment once a target aphid density was reached (averaged across all blocks). In the case of aphid-free plots, plants were treated one to four times to keep aphid populations from increasing. In Michigan, there was a soybean aphid outbreak where recolonization occurred frequently and it was difficult to maintain aphid-free plots. Yield samples from the center 2 rows from all plots at all locations were taken with a small-plot combine and adjusted to 13% moisture.

Since soybean aphid populations can occur on plants for more than 90 days, we used cumulative aphid-days to approximate the additive effects of a multigenerational insect. We used procedures described by Ragsdale et al. (10) to calculate cumulative aphid-days. Data from each location were analyzed separately to associate yield loss with cumulative aphid-days using analysis of variance and the Ryan-Einot-Gabriel-Welsch multiple range test ($\alpha = 0.05$; PROC GLM) (v8.02, SAS Institute Inc., Cary, NC).

Speed Scouting in small plots. The mean number of aphids per plant were calculated and shown in conjunction with plant growth stage (Fig. 1). All locations had untreated control plots with aphid densities near or above the range shown to cause economic loss (11) except in Wisconsin (Fig. 2). Peak aphid density occurred during the first two weeks of August for all locations except in Wisconsin where peak aphid density occurred mid-July (Fig. 1). Aphid pressure was low to moderate at the Minnesota and Wisconsin sites and populations never surpassed the 250 threshold. In comparison, the untreated control plots at all three Iowa locations had aphids increasing nearly until harvest resulting in cumulative aphid-days (± S.E.) that exceeded the economic injury level (Figs. 2D-F) (Ames 10,079 ± 1,202; Chariton 4,918 ± 609; and Nashua 10,648 ± 1,555).

Table 1. Field description, plot dimension and insecticide application information

Location	Plot dimension (# rows × length)[v]	Soybean variety	Planting–harvest dates	Insecticide applications
Iowa - Ames[w]	4 × 100	PB 2183RR	23 May – 22 Sept	aphid-free: 6 July; 20 Aug
				250 threshold: 20 Aug
				Speed Scouting: 20 Aug
Iowa - Chariton[w]	4 × 100	Stine 3532-4RR	10 May – 11 Oct	aphid-free: 4 July; 22 Aug
				250 threshold: 3 Sept
				Speed Scouting: 22 Aug
Iowa - Nashua[w]	4 × 100	Crows 2133RR	5 May – 22 Sept	aphid-free: 5 July; 4, 16 Aug
				250 threshold: 4 Aug
				Speed Scouting: 4 Aug
Michigan[x]	8 × 70	Pioneer 92B38RR	17 May – 18 Oct	aphid-free: 28 June; 12, 29 July; 3 Aug
				100 threshold: 27 July
				250 threshold: 1 Aug
				Speed Scouting: 1 Aug
Minnesota[y]	8 × 50	Pioneer 91B91RR	24 May – 21 Sept	aphid-free: 13 July
				100 threshold: 27 July
				Speed Scouting: 1 Aug
Wisconsin[z]	4 × 60	NKS19-V2RR	18 May – 21 Sept	aphid-free: 25 June; 18 July
				100 threshold: 11 July
				Speed Scouting: 11 July

[v] All plots had a 30-inch row spacing and were surrounded by at least 6-ft fallow border.

[w] Iowa-Ames was at Iowa State University Johnson Research Farm, Ames, Story County; Iowa-Chariton was at Iowa State University McNay Research Farm at Chariton in Lucas County; and Iowa-Nashua was at Iowa State University Northeast Research Farm, Nashua, Floyd County; lambda-cyhalothrin at 3.2 oz/acre using 20 gal of water per acre applied at 40 psi.

[x] Michigan State University Entomology Research Farm, East Lansing, Ingham County; lambda-cyhalothrin at 2.0 oz/acre using 21.6 gal of water per acre applied at 40 psi.

[y] University of Minnesota Outreach, Research and Extension Park, Rosemount, Dakota County; lambda-cyhalothrin at 2.0 oz/acre using 21.6 gal of water per acre applied at 40 psi.

[z] University of Wisconsin Agricultural Research Station, Arlington, Columbia County; lambda-cyhalothrin at 3.2 oz/acre using 20 gal of water per acre applied at 30 psi.

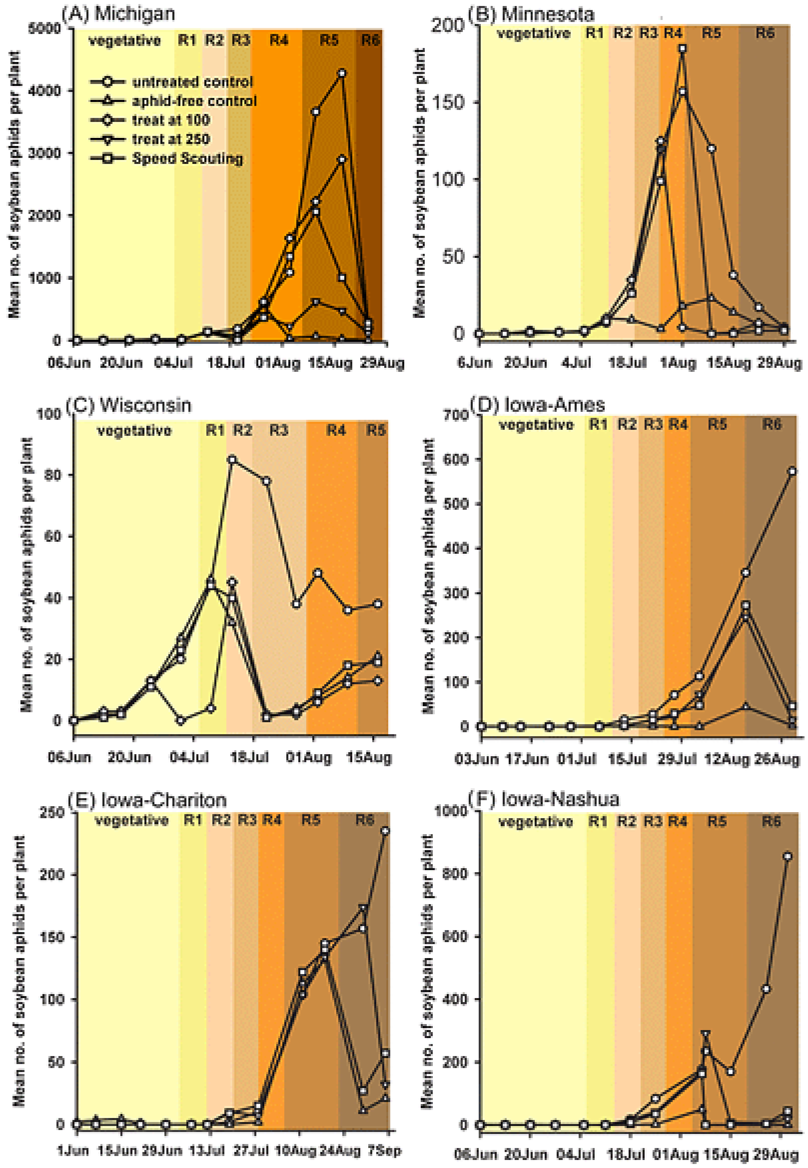

Fig. 1. Mean number of soybean aphids per plant by treatment in 2005. Soybean reproductive plant growth stage indicated by R(#) (6). Note: most locations do not include all treatments.

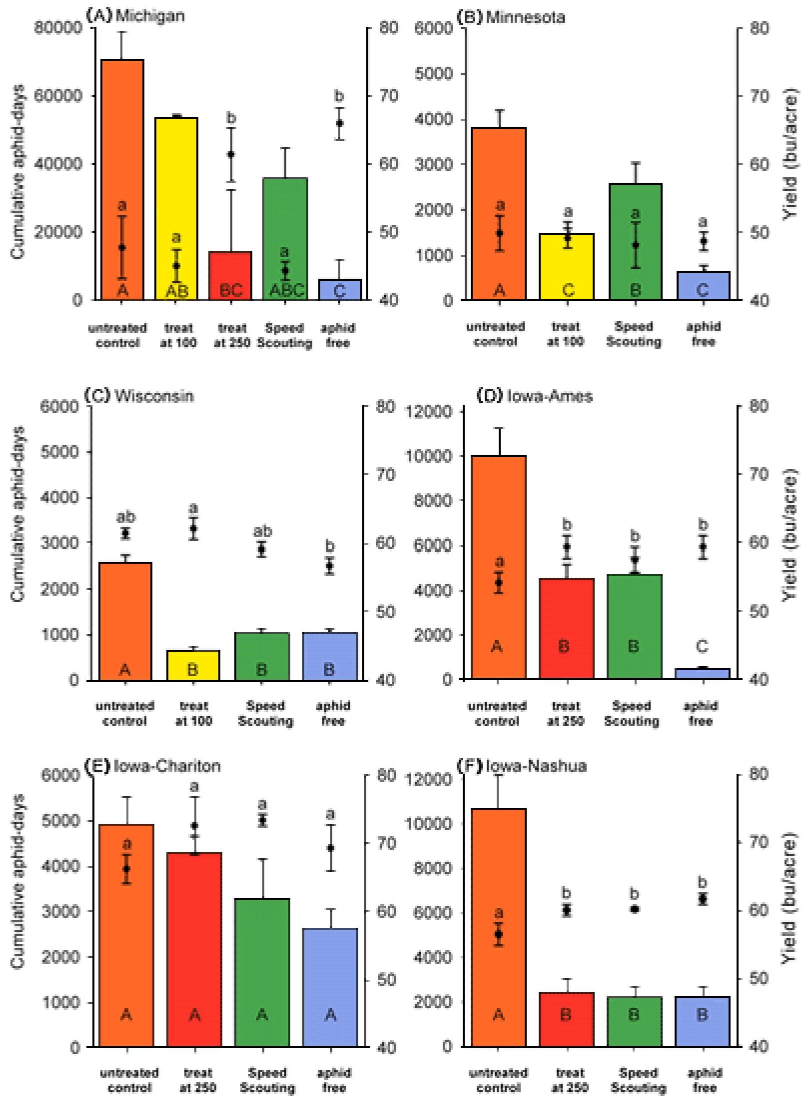

Fig. 2. Small plot trial results from 2005 estimating the mean number of cumulative aphid-days [bars] (± S.E.) and yield [circles] (± S.E.) for soybean aphid. Means with the same letter are not significantly different using a mean separation test (lowercase letters denote yield). Note: most locations do not include all treatments.

Aphid pressure at the Michigan location was extreme and represents what occurs during an aphid outbreak. Peak aphid density averaged over 4,000 per plant in the untreated control plots by mid-August (Fig. 2A). Soybean aphids re-colonized plots sprayed in July (100 threshold, 250 threshold, and Speed Scouting); and by mid-August, aphid density was high but these plots were not treated a second time (Fig. 2A). Cumulative aphid-day pressure were considerably less in the aphid-free control (5,824 ± 643) and 250 threshold (17,950 ± 8,924) plots; however these cumulative aphid-days are still in excess of the level shown to cause economic injury (10). Also, 2/3 of these cumulative aphid-days in these two treatments resulted from the deposition of first instars following a major immigration event of winged aphids, just prior to spraying on 29 July (C. D. DiFonzo, *personal observation*). After treatment, few additional aphid-days accumulated in the aphid-free and 250 threshold plots (Fig. 2A).

As expected with relatively low aphid pressure, there were no significant yield differences among any of the treatments at the Iowa-Chariton (F = 3.12; df = 3,15; P = 0.0613) and Minnesota (F = 0.15; df = 3,15; P = 0.9272) locations (Figs. 2B and E). There was a significant yield difference between untreated control plots and the other treatments at the Iowa-Ames (F = 7.82; df = 3,15; P = 0.0004) and Iowa-Nashua (F = 5.07; df = 3,15; P = 0.0451) locations (Figs.

2D and F). In all three Iowa locations, yield was not significantly different in the Speed Scouting plots and the 250 threshold plots. In Michigan, yields in the untreated control, 100 threshold, and Speed Scouting treatments were similar, and significantly less than yields in the aphid-free and 250 threshold plots ($F = 5.92$; df = 4,19; $P = 0.0102$). In contrast to the other sites, the Wisconsin location aphid-free plots had the lowest yield ($F = 4.13$. df = 3,15; $P = 0.0425$) (Fig. 2C).

Overall Conclusions and Recommendations

Maximum aphid density at all locations occurred during soybean reproductive growth, usually after pod formation (Fig. 1). These results were similar to a statewide survey of soybean aphid in Minnesota during 2002-2003 (6). As a general management guideline, sampling for soybean aphid should begin in the late vegetative stage; however, the most important sampling period starts at flowering (R1) and continues through seed set (R5) (6). Speed Scouting is a cost-effective sampling method and saves time especially at low aphid densities and at very high densities (3).

Economic injury is predicted for plots that accumulate between 4,175 and 7,667 aphid-days (10). For example, all locations except Wisconsin had more than 3,000 cumulative aphid-days in untreated control plots, so a measurable yield difference was expected. However, Minnesota and Iowa-Chariton plots were able to compensate for yield loss even though untreated control plots were in the range of economic injury (Figs. 2B,E). Although an insecticide was applied to Iowa-Chariton plots when soybean aphids exceeded the ET during the R6 stage (beyond the scope of ET calculations), populations were not increasing and therefore the treatment was not justified. Unnecessary or multiple insecticide applications may actually be more harmful than doing nothing at low infestation rates. For example, in Wisconsin multiple insecticide applications made to the aphid-free plots may have potentially flared other pests such as twospotted spider mites, *Tetranychus urticae* Koch, which were present in the Wisconsin plots under drought conditions in 2005 (EMC, *personal observation*) (Fig. 2C). These replicated plots demonstrate how sampling can reduce overall production costs by not treating when aphid populations are not economically damaging.

Iowa-Ames and Iowa-Nashua locations had plots exceeding the projected range of economic injury (4,175 to 7,667 cumulative aphid-days) and experienced significant yield loss in the untreated control plots compared to the other treatments (Figs. 2D and F). On average, treatment decisions based on *Speed Scouting* recovered 4.5 bu/acre compared to the untreated control plots at the three Iowa location (Figs. 2D and F) when cumulative aphid-days exceeded 5,000 in the untreated control plots.

In Michigan, aphids increased in the field quickly, resulting in spraying the 100 threshold plots in mid-July. Populations were fairly consistent across the field, thus the Speed Scouting method resulted in a spray decision on the same date as the 100 threshold. These applications were made two weeks prior to when the 250 threshold plots were sprayed and little recolonization occurred following the insecticide application to the 250 threshold plots. Insecticide residues in the treatment sprayed earlier (i.e., 100 threshold, Speed Scouting) had dissipated by this time and these plots were quickly and heavily recolonized resulting in yield loss. In a commercial setting, these 100 threshold and *Speed Scouting* treatment would have required an additional treatment.

In summary, Speed Scouting resulted in the same treatment decision as using the 250 threshold with whole-plant counts in more than 79% of commercial fields sampled in 2005. When incorrect (21% of the time), Speed Scouting was conservative and recommended a treatment before aphid densities reached the ET of 250 aphids per plant. These incorrect treatment decisions may not be as important during outbreak years when soybean aphid populations are increasing at exponential rates (i.e., 2001, 2003, and 2005), but may result in unnecessary insecticide applications in years when aphid populations are increasing slowly (i.e., 2002, 2004). To avoid over-application, some crop consultants base treatment decisions on two consecutive "treat" decisions from Speed Scouting because they believe it says to treat too early in some field conditions (C. D. DiFonzo, E. W. Hodgson, D. W. Ragsdale; *personal communications*).

In addition to making the same treatment decision, Speed Scouting is a cost-effective (i.e., time) sampling method compared to whole-plant counts. Hodgson et al. (3) showed the average person takes about 57 min to sample a field using whole-plant counts versus < 10 min to sample a field using Speed Scouting. This is especially important when crop consultants are visiting multiple fields per day during the time when aphid production is at its peak. Again, multiple samples through time will minimize error rates and prevent premature or unnecessary insecticide applications to soybean. Using a reliable sampling method, like Speed Scouting or whole-plant counts, with multiple sampling efforts through time is the most effective way to predict soybean aphid dynamics, and will translate into greater profit for producers who only treat when

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