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Introduction

The introduction of soybean aphid and soybean rust to North America led to numerous insecticides and fungicides becoming available for use on soybean. Frequent outbreaks of soybean aphid along with reports of increased yields due to fungicide application, even in the absence of foliar disease, has resulted in widespread use of tank mixes. The popularity of tank mixes (a co-application of insecticide and fungicide) as a management tool is increasing. Many pest management programs that recommend this strategy apply pesticides based on soybean growth stage.

Current recommendations by faculty at Iowa State University emphasize that pesticides should only be applied when pest pressure exceeds a pre-determined threshold. It is unclear whether growth stage-based applications of tank mixes provide greater economic benefits than a management strategy based on scouting and thresholds (e.g. integrated pest management).

Materials and methods

We conducted field trials to examine the impacts of a fungicide and insecticide applied together on soybean aphid populations and soybean yield. From 2008 to 2010, we established replicated, small plot experiments at three locations in Iowa (Floyd, O'Brien, and Story counties) where we anticipated variable aphid pressure. Plots were arranged in a randomized complete block design with five or six replications, depending on location. We tested nine treatments (see Table 1), consisting of a fungicide alone, an insecticide alone, or a fungicide-insecticide tank mix. Treatments were applied at soybean growth stages R1 or R3 (bloom and beginning pod set, respectively) or when warranted based on IPM recommendations (i.e. 250 aphids per plant).

Soybean aphid population determination

Soybean aphid populations were monitored weekly from mid-June to September. Plants were selected at random from the center rows of each plot. Depending on severity of aphid infestation, five to twenty consecutive plants within each plot were counted. All aphids (winged, wingless, immature, and adult) on each plant were counted.

Units of 'cumulative aphid days' were used to estimate the total exposure of soybean plants to soybean aphids over the course of the growing season. The calculation of cumulative aphid days is based on the number of aphids per plant counted on each sampling date. The exposure of the plants to aphids between two sampling dates is calculated using the following equation:

$$\sum_{n=1}^{\infty} = \left(\frac{x_{i-1} + x_i}{2} \right) \times t$$

where x is the mean number of aphids on the sample day i; x_{i-1} is the mean number of aphids on the previous sample day; and t is the number of days between samples i-1 and i.

Soybean yield determination

We harvested the center two rows of each plot and determined total seed weight and seed moisture. Seed weights were converted to bushels per acre at 13% moisture.

Table 1. Pesticide treatments and application details for 2008-2010 trials.

Timing	Active Ingredient(s) (Product)	Rate	Year(s) Used
N/A	Untreated control	N/A	2008; 2009; 2010
Fungicides			
R1	Prothioconazole + Trifloxystrobin (Stratego YLD, Bayer CropScience)	4 oz.	2008; 2009; 2010
R3	Prothioconazole + Trifloxystrobin (Stratego YLD, Bayer CropScience)	4 oz.	2008; 2009; 2010
Insecticides			
R1	Imidacloprid + Cyfluthrin (Leverage 2.7SE, Bayer CropScience)	3.76 oz	2008; 2009; 2010
R3	Imidacloprid + Cyfluthrin (Leverage 2.7SE, Bayer CropScience)	3.76 oz	2008; 2009; 2010
IPM*	Esfenvalerate (Asana, Dupont)	9.6 oz	2008; 2009; 2010
Fungicide + Insecticide			
R1	Prothioconazole + Trifloxystrobin; Imidacloprid + Cyfluthrin (Stratego YLD + Leverage 2.7SE, Bayer CropScience)	4 oz. + 3.76 oz	2008; 2009; 2010
R3	Prothioconazole + Trifloxystrobin; Imidacloprid + Cyfluthrin (Stratego YLD + Leverage 2.7SE, Bayer CropScience)	4 oz. + 3.76 oz	2008; 2009; 2010
IPM+**	Pyraclostrobin + Esfenvalerate (Headline, BASF; Asana, DuPont)	6 oz + 9.6 oz	2009
IPM+**	Prothioconazole + Trifloxystrobin (Stratego YLD, Bayer CropScience)	4 oz.	2010

* The IPM application of insecticide was made according to current recommendations, i.e. when soybean aphid populations exceeded 250 aphids per plant.

** The IPM+ treatment consisted of an IPM application of insecticide according to current recommendations, plus the application of a fungicide (Headline in 2009 and Stratego YLD in 2010) at the R3 soybean growth stage.

Economic analysis

To determine the economic viability of the tested soybean aphid management practices under the variety of conditions experienced over the three-year trial, we analyzed the data based on a break-even yield gain analysis. Based on insecticide and application costs, expected crop price, and expected yield, a yield gain threshold (GT) was calculated. We then calculated the probability of each management strategy being cost-effective. The lead author will present the results of this analysis at the ICM conference.

Results and discussion

Cumulative aphid days (CAD) and yields for all locations and years are shown in Table 2.

Aphid populations in 2008 and 2009 reached the economic threshold (i.e. 250 aphids per plant) at all locations and triggered the application of insecticide to our IPM treatments. Typically, this occurred in mid August. In plots that did not receive an application of insecticide, populations exceeded levels that are known to reduce yield (CAD> 5000); untreated controls in 2008 experienced CAD ranging from 18,800 to 92,200. In 2009, CAD ranged from 12,152 to 22, 577 in the untreated controls. In 2010, aphid populations did not reach the economic threshold at any of the locations; therefore, the IPM treatment was not applied at any of the locations.

In 2008 and 2009, aphid populations were generally lower when insecticides were applied at R3 or when warranted by IPM recommendations. Application of insecticides at R1 did result in lower CAD compared with the untreated control, but CAD for R1 applications was not as low as what occurred with insecticide applications at other timings.

In 2008 and 2009, the IPM treatments and R3 applications of insecticide alone and in tank mixes with fungicides had the highest yields. However, in 2010, when there was low aphid exposure (CAD< 1000), application of an insecticide alone for either plant growth stage (R1, R3) did not result in the highest yields. Furthermore, in 2010, CAD did not reach levels in any treatment that would suggest yield losses were attributable to soybean aphid. Incidence of foliar and root disease due to wet conditions likely contributed to higher yields in treatments that included a fungicide, particularly when applied at R3.

Our data suggest that insecticide-fungicide tank mix applications did not always result in the greatest yields. Yearly variation in pest pressure significantly affected the return on an investment for all treatment types.

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Table 2. The impact of insecticide and fungicides (alone and combined[a]) on soybean exposure to aphids[b] and yield[c]

		2008		2009		2010	
Treatment	**Timing**	**CAD**	**Yield**	**CAD**	**Yield**	**CAD**	**Yield**
Floyd County							
Stratego Pro	R1	39516 ±6818	52.89 ±2.64	20754 ±2483	62.56 ±2.91	129 ±318	51.03 ±1.62
Stratego Pro	R3	17311 ±2759	52.84 ±2.36	17981 ±2868	61.90 ±2.48	154 ±56	53.24 ±1.50
Leverage	R1	15595 ±2298	55.41 ±0.79	8494 ±832	66.87 ±1.98	86 ±28	49.28 ±1.54
Leverage	R3	1586 ±474	63.25 ±2.06	4408 ±441	58.64 ±1.65	66 ±27	54.82 ±1.93
Stratego Pro + Leverage	R1	11629 ±483	55.34 ±1.66	10682 ±1907	60.20 ±2.66	177 ±58	52.76 ±2.10
Stratego Pro + Leverage	R3	875 ±281	65.60 ±1.23	3980 ±612	65.43 ±2.03	88 ±32	52.57 ±1.79
IPM*	--	21799 ±5088	53.66 ±0.56	8683 ±2455	59.12 ±2.47	150 ±36	49.96 ±0.93
IPM+**	R3	N/A	N/A	13828 ±1422	60.73 ±3.40	121 ±27	53.44 ±1.56
Untreated Control	--	18851 ±3358	48.82 ±1.27	22577 ±2795	58.61 ±3.30	120 ±36	50.83 ±1.46
O'Brien County							
Stratego Pro	R1	55476 ±11018	37.66 ±2.73	14730 ±4240	55.37 ±2.58	458 ±107	56.00 ±0.72
Stratego Pro	R3	60877 ±8940	39.34 ±2.56	18676 ±7984	57.14 ±4.31	344 ±68	58.70 ±0.97
Leverage	R1	26096 ±3179	47.52 ±1.24	6531 ±1007	59.71 ±4.15	130 ±18	58.27 ±0.47
Leverage	R3	17472 ±6912	54.21 ±3.19	2565 ±730	59.02 ±2.15	112 ±70	59.00 ±1.20
Stratego Pro + Leverage	R1	23930 ±4611	48.84 ±0.37	5153 ±1137	54.81 ±1.86	162 ±41	54.64 ±1.60
Stratego Pro + Leverage	R3	9062 ±1260	56.67 ±2.14	3250 ±1105	53.42 ±2.08	152 ±99	60.79 ±1.47
IPM*	--	28331 ±6617	55.53 ±2.20	3805 ±535	60.67 ±2.75	391 ±90	55.37 ±0.81
IPM+**	R3	N/A	N/A	4339 ±710	56.21 ±1.66	420 ±55	58.09 ±1.33
Untreated Control	--	92281 ±14116	34.94 ±1.45	18566 ±3622	58.31 ±3.01	395 ±85	55.09 ±2.18
Story County							
Stratego Pro	R1	35061 ±3517	57.21 ±3.00	16576 ±4342	56.06 ±0.80	140 ±21	70.95 ±1.65
Stratego Pro	R3	32539 ±7133	61.26 ±2.42	20989 ±2063	60.13 ±1.67	108 ±24	72.45 ±2.63
Leverage	R1	14324 ±4097	62.44 ±1.68	13731 ±3186	64.15 ±1.49	88 ±26	66.52 ±3.03
Leverage	R3	4672 ±756	69.41 ±3.87	5987 ±687	67.51 ±1.09	139 ±19	67.68 ±3.94
Stratego Pro + Leverage	R1	13777 ±3328	63.77 ±3.48	10187 ±1999	65.12 ±0.69	71 ±13	70.79 ±0.61
Stratego Pro + Leverage	R3	1710 ±214	71.96 ±1.16	8311 ±1435	70.47 ±1.21	107 ±57	70.91 ±2.50
IPM*	--	23472 ±4534	64.08 ± 1.79	5300 ±909	67.92 ±1.93	93 ±23	64.20 ±1.20
IPM+**	R3	N/A	N/A	7421 ±2688	68.77 ±2.18	229 ±114	71.48 ±1.63
Untreated Control	--	36772 ±7035	53.28 ±2.08	12152 ±2017	57.70 ±2.11	120 ±19	64.07 ±1.73

[a] See table 1 for rates and active ingredients

[b] Soybean exposure to aphids measured in terms of cumulative aphid days (CAD) ± standard error of the mean (SEM)

[c] Converted to bu/ac at 13% moisture ± standard error of the mean (SEM)

* The IPM applications of appropriate pesticides were made according to current recommendations, i.e. when soybean aphid populations exceeded 250 aphids per plant.

** The IPM+ treatment consisted of an IPM application of insecticide according to current recommendations, plus the application of a fungicide (Headline in 2009 and Stratego Pro in 2010) at the R3 soybean growth stage.