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Treatment Decision in Soybeans

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# A Bioeconomic Model of the Soybean Aphid

## Treatment Decision in Soybeans

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Since its first detection in the North Central region in July 2000, the soybean aphid (*Aphis glycines* Matsamura) has caused considerable loss in soybean (*Glycine max* L.) yield, bean quality, and producer income. Discovered first in Wisconsin and then in adjoining states, it is currently distributed in 21 US states and parts of Canada. In 2003, over 42 million acres of soybean in the North Central US were infested and over 7 million acres were treated with insecticides to control soybean aphid (Landis et al. 2003). Populations exceeding 24,000 aphids per plant and 40% losses in seed yield have been reported (DiFonzo & Hines 2002). Even prior to the outbreak of 2003, the Soybean Strategic Pest Management Plan identified soybean aphid as one of the *key drivers of insecticide use in the North Central region* (Smith & Pike 2002).

This paper first describes the interaction with and impacts of the soybean aphid on soybean. Then the treatment decision model is developed and impacts analyzed. In the last section, some comments are made on how the results of this work on soybean aphids can be adapted to the impact of soybean rust (*Phakopsora pachyrhizias*), another new pest of soybean.

## **Soybean aphid growth and impact on soybean**

Unlike other corn-soybean insect pests, the soybean aphid treatment decision is more complex than growers are used to making. The presence of pests such as weeds, diseases, nematodes, and other more common pests is usually known before planting decisions are made. These pests also are slower to reproduce and more predictable in their growth rate than soybean aphid. Thus treatment and timing decisions to control them are made within a more stable situation. With soybean aphids, however, growers face a pest with unpredictable colonization and a long window of crop susceptibility. Also, soybean aphids are not like other pests in that their populations are capable of doubling every 2-3 days and can rebound after insecticide applications.

The soybean aphid affects plant growth and reproduction. Direct physiological effects are sap removal, stunting, photosynthesis, and transpiration. Indirect physiological effects are honey dew and sooty mold, soybean mosaic virus and potassium deficiency symptoms. Eventually, soybean yield can be affected at high populations. At the present time, entomologists are not certain about what defines a minimum population that is high enough to impact yield. Since it is a relatively new pest in the U.S., entomologists do not have a strong understanding of soybean aphid biology.

The impact of aphids depends on many factors, the most important being: initial date of aphid colonization, aphid population growth rates, length of colonization, soybean plant growth stage, treatment timing and efficacy, the lag between the decision to treat and application of insecticide, aphid population regrowth, aphid recolonization, and weather. Aphid colonization may occur as early as late June or as late as late August and even September. Soybean is more susceptible to aphids in the earlier reproductive stages

of plant growth (R1-R5) compared to later stages. Aphid colonization is rare in earlier vegetative stages and may not occur until the most susceptible period is over. On a calendar basis, soybean susceptibility can be described as highest during July and into August with potential but lower impacts into September. Currently available insecticides are highly effective, but with essentially no residual effect, aphids populations can regrow in or recolonize the same field. If the first colonization occurs early in the susceptible stage, two or more treatments may be needed.

### **Soybean aphid treatment model**

Following the early work by Hueth and Regev (1974) and Hall and Norgaard (1973) and incorporating concepts from recent unpublished AAEA selected papers, the treatment decision model is developed and potential impacts and treatment options are analyzed.

The farmer's decision to treat for soybean aphid is based on whether the value of the difference in the estimated net return between treating and not treating is greater than the cost of treatment.

$$P_s \cdot (S_c - S_u) > T_c$$

where  $P_s$  = price of soybean,  $S_c$  = expected soybean yield with treatment,  $S_u$  = expected soybean yield without treatment for aphids, and  $T_c$  = treatment costs for aphids. The impact of the soybean aphid on yield is described as a function of plant growth stage and cumulative aphid days (CAD) with CAD described as a function of the date of colonization, growth rate, and insecticide application(s) and efficacy. The aphid growth

rate is a function of temperature. The estimated soybean yields are estimated using response functions estimated by Robert Venette, et al. (personal communication) in the Department of Entomology at the University of Minnesota.

$$S_c = f(S^*, CAD_c \mid \text{all other inputs such as nutrients, weed pressure, weather, } \dots)$$

$$S_u = f(S^*, CAD_u \mid \text{all other inputs such as nutrients, weed pressure, weather, } \dots)$$

where  $S^*$  = expected soybean yield given all other inputs and no aphid damage occurs,  $CAD_c$  = cumulative aphid days when a treatment is applied, and  $CAD_u$  = cumulative aphid days when no treatment is applied.

The damage coefficients vary by plant stage. During the early vegetative stages, the coefficient of loss per CAD is zero. During plant growth stages R1-R4, the yield loss is 0.000009 per one aphid day. During subsequent growth stages, the yield loss is estimated to be 0.000002 per aphid day. These loss coefficient estimates are estimated from Minnesota and Indiana data.

CAD is calculated in the following ways.

$$CAD_c = \int_0^T app_{ct} \, dt$$

where  $app_{ct}$  = aphid count per plant on day  $t$ ,  $t = 0$  on first day of aphid infestation,  $t = T$  on day when soybean plant reaches growth and no further significant yield damage will occur. The aphid growth rate is an exponential function as is often used in entomological models.

$$\text{app}_{\text{ct}+1} = \text{app}_{\text{ct}} \cdot e^{r_t} \cdot (1 - k\delta_s)$$

where  $r_t$  = aphid growth rate on day  $t$ ,  $k$  = treatment kill rate, and  $\delta_s$  = treatment decision variable with  $\delta_s = 1$  on treatment day  $s$ , and 0 otherwise.

$$\text{CAD}_u = \int_0^T \text{app}_{\text{ut}} \, dt$$

where  $\text{CAD}_u$  = cumulative aphid days when no treatment is applied and  $\text{app}_{\text{ut}}$  = aphid count per plant in field where aphids are not treated.

$$\text{app}_{\text{ut}+1} = \text{app}_{\text{ut}} \cdot e^{r_t}$$

Field observations by entomologists show that aphid populations do not increase exponentially without limit. At some population level, for reasons yet to be fully understood (perhaps food availability, population pressure, or other factors), the aphid population reaches a maximum point and starts to decline rapidly. This maximum appears to be in the range of 18,000 to 23,000 aphids per plant. However, insufficient data limit the quantification of the full growth model. Consequently, following the advice of entomologists at the University of Minnesota, the aphid population was monitored within the model and forced to decline once the population entered the estimated maximum range.

To reflect the uncertainty associated with infestation and the impact of different temperatures affecting aphid growth, the model is used to estimate the net value of aphid treatment for an example field in Minnesota with three initial infestation or colonization dates (July 1, July 14, and July 28) and three growth rates (population doubling in 2, 3, or 4 days). The common recommendation of an economic threshold of 250 aphids per plant

for treatment is also compared to other potential thresholds: 3, 100 and 500. The maximum potential soybean yield is 50 bushels without any aphid pressure. The expected soybean price is \$6 per bushel; and the treatment cost is \$10 per acre including material and application costs. The lag between the treatment decision and actual application is 7 days which can be quite realistic if an outbreak occurs and all applicators are busy. The change from the most susceptible to less susceptible plant growth state (R4 to R5) is estimated to be August 6.

## **Results**

When aphids colonize a field early in the season (exemplified by July 1 in this study) and the temperatures are optimal for aphid growth (doubling every 2 days), the untreated soybean yield was estimated to be 6.6 bushels per acre which represents an estimated loss of 43.4 bushels. Using an economic threshold of 250 resulted in two treatments during the growing season with a treated yield of 35 bushels and a net value of the treatments at \$151 per acre (Table 1). Decreasing the economic threshold to 100 increased the number of treatments to 4 but the net value also increased to \$198. Lowering the threshold even more to only 3 aphids per plant increased the net value of treatment again, to \$220. The highest threshold, 500, had the lowest net value of treatment.

When aphid colonization occurs on July 1 but the temperature is not optimal, the population doubles every 3 days instead of 2, the impact on yield decreases but the resulting net value of treatment is still higher for lower thresholds. The untreated yield is estimated to be 33.5 bushels per acres. Using a threshold of 100 aphids per plant resulted

in 2 treatments and a net value of \$71.02 per acre. The lowest threshold of 3 has a net value of \$76.8 and the higher level of 250 has a net value of \$59.77. Only two treatments are estimated to be needed with any threshold when colonization occurs on July 1 and the aphid population doubles every 3 days.

When temperatures are lower and the growth rate declines to a doubling of every 4 days, the number of treatments decline to 1 for all thresholds. The net value of treatments also decline in absolute terms. The same story of higher net values for lower thresholds still holds as with faster growth rates, but the differences in net values diminishes.

When colonization occurs later in the susceptible period (July 14 in this example), a similar story can be seen: the lower thresholds result in higher net values (Table 2). Also, as would be expected, the number of treatments decreases compared to when colonization occurs earlier. Following the strict rules of treatment timing, lower net values result when temperatures are optimal for rapid aphid growth (doubling in 2 days) compared to a doubling in 3 days.

When colonization occurs quite late in the growth stage (July 28 in this example), the net value of treatment is positive only when the aphid population doubles every 2 days (Table 3). Again, the net value increases as the threshold decreases, but the differentials are smaller. Treatment is not profitable when colonization occurs late in the season and temperature are not optimal for rapid aphid growth.

## **Discussion**

These results indicate that the current economic threshold of 250 aphids per plant accepted by many but not all entomologists may be too high. Earlier and more frequent treatments may be needed when aphids colonize earlier and enjoy good reproductive weather. Late season colonization may not need to be treated except with fast growth conditions.

### **Adjustment of the decision model to the soybean rust treatment decision**

The soybean rust is a soybean fungal disease that causes premature defoliation, fewer pods, and lighter seeds. It is a new pest in the US having been first discovered here in November 2004. It was first discovered in Japan in 1902 and is widespread in Brazil.

The treatment decision for soybean rust offers a great deal of challenge for many reasons. First, this pest is not easily identifiable and can be confused with other foliar diseases. Second, over 90 species of legume (crops and weeds) are host for the soybean rust. Third, the soybean rust is very mobile because of wind and storms that move spores from plant to plant and leaf to leaf. Consequently, plants are susceptible at any stage after emerging.

The complexity of the soybean rust situation requires substantial monitoring and control efforts so that the treatment decision can be made accordingly. In fact, the soybean rust can cause yield losses in the range of 10% to 80% depending on weather conditions, cropping system and the level of infestation. The speed with which spores can be spread by winds and storms, combined with the speed of infestation within a specific field, requires monitoring and scouting to be done at a greater distance from a

farmer's production fields than for other production pests. Furthermore, scouting for soybean rust requires frequent examination of about 50-70 leaves per 50 acres. Regional disparities in the incidence and level of infestation within and between years also create additional uncertainty about the soybean price.

The situation just describes shows how costly it is to manage soybean rust on a specific farm. Indeed, some plant pathologists even suggest that fungicides could be applied prophylactically in order to prevent the infestation of soybean by soybean rust. While the situation is similar, the treatment decision model for soybean aphid needs to be adjusted to reflect the greater uncertainty of infestation, increased cost of monitoring conditions farther from the specific production area, regional differences in impact, and the larger potential for price impacts due to soybean rust infestations.

Table 1. Estimated net value of treatment when aphid colonization occurs on July 1				
Threshold	3	100	250	500
Results with: 2 day double, untreated yield = 6.6 bu/ac				
Number of treatments	4	4	2	1
Treated yield (bu/ac)	49.9	46.3	35	28
Net value of treatment (\$/ac)	220	198	151	118
Results with: 3 day double, untreated yield = 33.5 bu/ac				
Number of treatments	2	2	2	2
Treated yield (bu/ac)	49.7	48.7	46.8	43.8
Net value of treatment (\$/ac)	76.8	71.02	59.77	41.54
Results with: 4 day double, untreated yield = 36.9 bu/ac				
Number of treatments	1	1	1	1
Treated yield (bu/ac)	49.4	48.8	47.9	47.5
Net value of treatment (\$/ac)	65	61	56	54

Table 2. Estimated net value of treatment when aphid colonization occurs on July 14				
Threshold	3	100	250	500
Results with: 2 day double, untreated yield = 37.5 bu/ac				
Number of treatments	3	2	2	2
Treated yield (bu/ac)	49.9	45.5	42.1	40.5
Net value of treatment (\$/ac)	44	28	7	-2
Results with: 3 day double, untreated yield = 40.4 bu/ac				
Number of treatments	1	1	1	1
Treated yield (bu/ac)	49.2	49.0	48.7	48.2
Net value of treatment (\$/ac)	42.69	41.57	39.80	37.88
Results with: 4 day double, untreated yield = 46.8 bu/ac				
Number of treatments	1	1	1	1
Treated yield (bu/ac)	49.9	49.7	49.5	49.0
Net value of treatment (\$/ac)	9	7	6	3

Table 3. Estimated net value of treatment when aphid colonization occurs on July 28				
Threshold	3	100	250	500
Results with: 2 day double, untreated yield = 40.6 bu/ac				
Number of treatments	1	1	1	1
Treated yield (bu/ac)	48.8	48.5	47.9	47.0
Net value of treatment (\$/ac)	39	38	34	29
Results with: 3 day double, untreated yield = 48.4 bu/ac				
Number of treatments	1	1	1	1
Treated yield (bu/ac)	50.0	49.8	49.5	49.0
Net value of treatment (\$/ac)	-0.75	-1.88	-3.64	-6.56
Results with: 4 day double, untreated yield = 49.7 bu/ac				
Number of treatments	1	1	1	1
Treated yield (bu/ac)	50.0	49.8	49.7	49.7
Net value of treatment (\$/ac)	-8	-10	-10	-10

## References

- DiFonzo C., and R. Hines. 2002. Soybean aphid in Michigan: update from the 2001 season. MSU Ext. Bull. E-2748. Michigan State University, E. Lansing MI.
- Hall, D.C., and R.B. Norgaard. 1973. On the timing and applications of pesticides. *Am. J. of Agric Econ.*, 55:198-201.
- Hueth, D., and U. Regev. 1974. Optimal agricultural pest management with increasing pest resistance. *Am. J. of Agric Econ.*, 56:543-552..
- Landis, D., M. Brewer and G. Heimpel. 2003. Soybean aphid and parasitoids 2003: A survey of NCR-125 cooperating states. In 2003 Michigan state report to NCR-125. <http://www.cips.msu.edu/ncr125/StateRpts2003MI.htm>
- Smith, G.S., and D. Pike eds. 2002. Soybean strategic pest management plan. Nov. 7-8, 2002 St Louis, MO. <http://pestdata.ncsu.edu/pmsp/pdf/RCSoybeanPMSP.pdf>