10A.2 SOYBEAN APHIDS ALOFT: SPREAD OF AN EXOTIC PEST THROUGH THE UPPER MIDWEST

Robert C. Venette* and David W. Ragsdale
Department of Entomology, University of Minnesota, St. Paul MN 55108

1. INTRODUCTION

Soybean aphid (*Aphis glycines* Matsumura) occurs in most soybean (*Glycine max* L.) producing areas of eastern Asia where it is believed to be native. Its range extends from Indonesia to northern China. The primary, overwintering host for the aphid is buckthorn (*Rhamnus* spp.) and its dominant summer host is soybean. In Asia, soybean aphid is a significant pest of soybean where it damages plants both directly and indirectly. Direct damage comes from the consumption of photosynthates and the inhibition of photosynthesis. Feeding by soybean aphid on young plants (2-leaf stage) was reported to reduce yields by 2.7-51.8% depending on pest density. Aphids also excrete excess sugar as honeydew, which supports the growth of saprophytic fungi (i.e., sooty mold). In addition, soybean aphid is a vector of several viruses, including soybean mosaic virus, which raises concerns about seed quality and certification.

Soybean aphid was first detected in Wisconsin, Michigan, Indiana, Illinois, Missouri, Iowa, and Ohio, West Virginia, and Minnesota during the 2000 growing season. In 2001, distribution of the aphid expanded to include Virginia, Pennsylvania, New York, and North and South Dakota. During the 2001 growing season, the agronomic and economic impacts of soybean aphid were documented carefully under North American growing conditions. Maximum yield benefits from the application of insecticide ranged from 180 kg/ha in Minnesota to 260 kg/ha in Michigan. Yield losses between 22 and 80 kg/ha were common throughout the Upper Midwest. In 2002, spread continued to the west with new infestations reported primarily in Nebraska. To date, approximately 280 counties nationwide have reported infestations of the aphid.

Significant spread of the aphid is associated with key stages of its life cycle. In the spring, the first opportunity for significant dispersal occurs as fundatrigeniae leave buckthorn to colonize soybean fields. Fundatrigeniae primarily produce apterous offsping, which are relatively sessile. In response to overcrowding, changes in photoperiod, or changes in plant quality, apterous adults will produce alate offspring, which when fully developed will be capable of significant flight. Alate parents bare apterous young, and aphids will cycle between winged and non-winged forms throughout the growing season, typically producing one to two periods of rapid population movement (Quimo and Calilung 1993). The final dispersal event begins sometime in summer/fall when sexual forms return to buckthorn and prepare to produce eggs to overwinter.

Effective rates of spread also depend on the ability of soybean aphid to overwinter in newly infested areas. The broad geographic distribution of soybean aphid in its native range suggests this insect has the ability to survive a wide range of temperature and moisture conditions. However, the biology of soybean aphid in northern China, with a climate relatively similar to central North America, remains poorly characterized.

The objectives of this study were to estimate seasonal rates of spread of soybean aphid in Minnesota and to develop a preliminary model of the overwintering potential of this insect based on winter temperature.

2. MATERIALS AND METHODS

Spread. In 2001, fields of soybean were inspected for the presence of soybean aphid. Surveys were conducted by the Plant Pest Survey and Biological Control Program (Ag. Development Division, Minnesota Department of Agriculture) and the Dept. of Entomology, University of Minnesota. Soybean fields were surveyed following a standardized protocol developed by the University of Minnesota. Soybean fields were arbitrarily selected throughout the state. Latitude and longitude of each field were noted with a GPS unit. From each field, 30 whole plants were selected at random and inspected for soybean aphid, aphid predators, and aphid pathogens. Additional details about the survey are available at: http://www.soybeans.umn.edu/crop/insects/aphid/aphid_scouting.htm.

Between 12 June and 21 August, 1,707 fields (or approximately 51,210 plants) were inspected for soybean aphid.

All data were entered into a geographic information system (ArcView 3.2, ESRA, Redlands, CA) for analysis. Data were displayed using an Albers-Equal-Area projection. The kernel-home range and minimum-convex-polygon functions within the ArcView extension, Animal Movement 2.0 (Hooge and Eichenlaub 1997), were used to estimate the area infested by soybean aphid on a weekly basis. The distances from each new find to the first find were averaged on a weekly basis to estimate the radius of an ≈50° arc, from which area calculations were made.

**Corresponding author address:* Robert C. Venette, Univ. of Minnesota, Dept. of Entomology, St. Paul, MN 55113; e-mail:venet001@umn.edu

Spread rates were estimated through linear regression. The square root of the area infested was analyzed as a function of time (wks from first detection). PROC REG (SAS 1995) was used for statistical analysis.

Overwintering. Minnesota Department of Agriculture also provided results of surveys conducted from August and September of 2000. These records were compared with early-season records from 2001. Colonization of early-vegetative (V1 growth stage) soybean provided evidence of winter survival, at least in localized areas. Overwintering was considered unsuccessful in areas where the aphid was observed in 2000, but not detected in the spring of 2001.

Weather records were obtained from the Midwestern Climate Information System (MICIS). Weather stations were selected in areas where overwintering was judged successful of unsuccessful. At each location, the cumulative number of cooling degree days (CDD) below a threshold of 9.5°C were calculated from daily minimum and maximum temperatures using the modified sine method of Allen (1976). CDD were calculated between 1 Oct 2000 and 31 May 2001. Missing temperatures were estimated by linear interpolation. Weather stations with more than nine consecutive days of missing weather data were excluded from the analysis. Logistic regression (PROC LOGISTIC; SAS 1995) was used to determine the probability of successful overwintering based on the number of cumulative cooling degree days.

To validate the model, weather records from 1 Oct 2001 to 31 May 2002 were obtained for 56 weather stations throughout Minnesota. CDD were calculated as before, and a probability of successful overwintering was estimated. Interpolation between weather stations was conducted using Inverse Distance Weighting. Predictions were compared with results from early season field surveys conducted in June and early July 2002.

3. Results and Discussion

Spread. Soybean aphids were first detected on 12 June in Houston Co., MM. During the 2001 growing season, we estimate that soybean aphid spread at and average rate of 40.6 to 60.2 km/wk in Minnesota. This rate was not constant throughout the year. Rather, from 12 June to approximately 3 July, the area affected by soybean aphid increased at a moderate rate. From 3 July to 24 July, the area increased very slowly, and from 24 July to 14 August, the range occupied by soybean aphid increased very rapidly. We believe these three phases correspond with three distinct changes in aphid populations. In late June, alate (winged) soybean aphids dispersed from their overwintering host and began to colonize soybean. During this time, aphid movement between soybean fields was probably limited. In early July, populations within fields continued to grow through the production of apterous (wingless) offspring with little to no movement of aphids between soybean fields. In late July and early August, as aphids became increasingly crowded on plants, alate aphids were produced and began to fly . A sample collected on 25 July indicated that approximately 80% of the aphids on a plant were alatoid nymphs that would be capable of flight in 2 - 3 days.

A suction trap network (the Aphid Alert), maintained by the University of Minnesota, collected alate soybean aphids. Soybean aphids were not captured early in the growing season, but were collected from 23 Aug to 3 Sept 2001. This period coincided perfectly with the second peak in aphid movement predicted from field observations.

By the end of the 2001 season, soybean aphid had spread throughout Minnesota and into North and South Dakota and southern Manitoba. Buckthorn, particularly *Rhamnus cathartica*, is common throughout the area presenting the possibility of widespread overwintering.

Overwintering. Early-season field surveys confirmed the presence of soybean aphid in most of the state, suggesting that the aphid had survived the winter in these areas. No signs of successful overwintering were evident for northwestern Minnesota. Observed patterns matched our predictions of overwintering very well. For example, in Roseasu (northern MN) nearly 3,100 CDD were accumulated which translated to an overwintering probability of 0.03. No aphids were observed in this area in the spring. Conversely, in Little Falls (central MN) only 2,200 CDD were accumulated. This translated to an overwintering probability of nearly 1.0. A series of sentinel plants placed near buckthorn stands in early June provided independent confirmation of the presence, and likely overwintering, of soybean aphid in the southern half of the state (I. MacRae, personal communication).

The winter of 2001-2002 was warmer than average. Nevertheless, soybean aphid was not able to survive the winter in all areas of the state. Under more typical conditions, soybean aphid may only withstand winters in more limited areas. Long-term weather records suggest the northern third of the state has winter temperatures that are too cold for soybean aphid.

Soybean aphid may be able to compensate for limited overwintering potential in the north by spreading rapidly from the south during the next growing season.

4. References

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