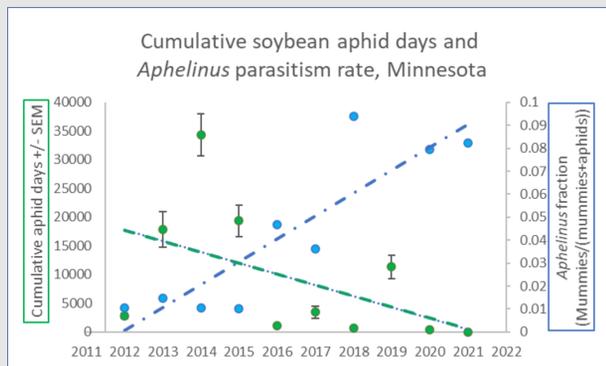


Parasitism of soybean aphid by *Aphelinus certus* in Minnesota, 2011 to 2021

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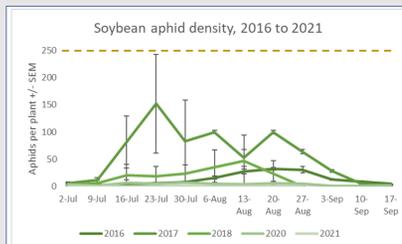
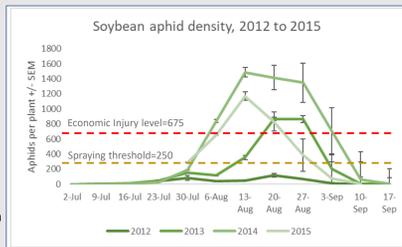
Soybean aphid and *Aphelinus* parasitism



Cumulative aphid days per plant from experiments using repeated sampling in Minnesota soybean fields untreated with insecticides. **Parasitism rate** was calculated for each year from total mummies and total aphids counted. Both regression lines have slopes significantly different from zero, **Aphids** $F_{(1,8)}=7.4$, $p=0.026$, **Parasitism** $F_{(1,7)}=25$, $p=0.002$. We were unable to find a significant relation between parasitism and the cumulative aphid days of the following year.

Aphid population numbers on soybean

Earliest date: June 6th, 2016
Median early date: June 11th
Median 250 aphids: August 6th
=Spraying threshold
Median 675 aphids: August 13th
=Economic injury level
Note the lower numbers after 2015.



Aphelinus appears by the beginning of July, hyperparasitoids in July.



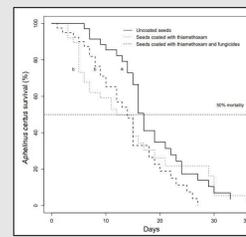
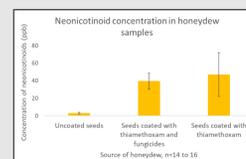
Aphelinus certus is the dominant parasitoid of soybean aphid in North America. On the soybean leaf we find aphids and black "mummies" which are the aphid exoskeleton, hardened as the pupal case for *Aphelinus*.

Soybean aphid was first detected in North America in the year 2000, and rapidly became the most costly pest of soybean, prompting extensive insecticide use. The parasitoid *Aphelinus certus* was first detected in Connecticut in 2004 and by 2011 it was found in Minnesota; since establishment this parasitoid has been widespread including in neighboring states even at low aphid densities. Minnesota has shown higher aphid densities than other states in the region, which makes this an excellent place to study the dynamics of aphid biological control. Even in Minnesota the aphid has not regularly exceeded the spray threshold in the past 6 years, and we explore whether this can be attributed to the parasitoid.

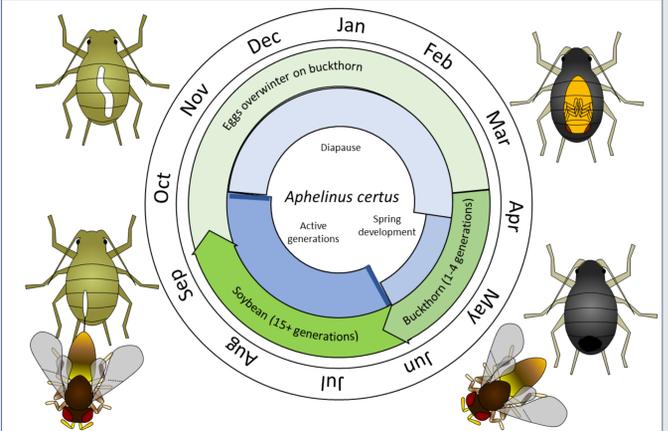
Honeydew as a newly described route of insecticide exposure to beneficial insects.

Aphid honeydew provides an important ecosystem service: sugar. Honeydew also carries neonicotinoids from seed treatments to insects that eat it. Neonicotinoid seed treatments are commonly applied to soybeans, and we found treated honeydew decreased survival of a predatory midge as well as *A. certus*. Honeydew was collected 30 to 43 days after planting. Since 2020, two neonicotinoids are routinely tested in Minnesota surface water as "pesticides of concern," but this does not include thiamethoxam.

Calvo-Agudo, M., Dregni, J., González-Cabrera, J., Dicke, M., Heimpel, G.E., Tena, A. 2021. Neonicotinoids from coated seeds toxic for honeydew-feeding biological control agents. Environmental Pollution 289, 117813.



Aphelinus overwintering and benefits of no-till



Annual lifecycle of soybean aphid and *A. certus* with aphid host plants buckthorn (fall – spring) and soybean (summer), and images of *A. certus* June emergence from the black mummy, summer oviposition for several generations, larval growth within the aphid, and winter diapause as prepupa in the mummy.

Overwintering: where and when does *A. certus* first encounter soybean aphid in the spring?

A. certus emerges from diapause in June.

The earliest: June 6th in 2016

Median earliest: July 3rd

Soybean plants are generally well into their vegetative growth by the time *A. certus* emerges, so the parasitoid does not need to find the aphid on its winter host, buckthorn, but can reliably find the aphid in soybean fields.

11.24°C = *A. certus* lower development threshold
261 +/- 8 degree days for development, diapausing *A. certus*

Southern Minnesota degree days (monthly avg 1895 -2021):

May 135 +/- 6 degree days

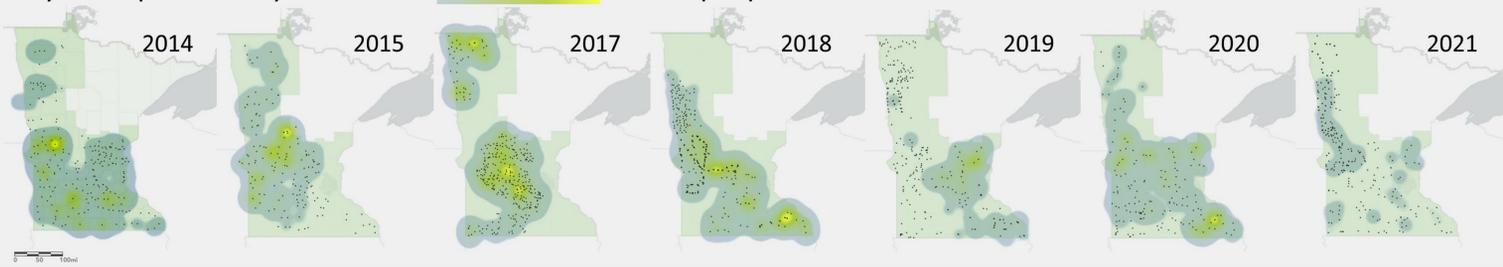
June 286 +/- 4 degree days

Tillage reduces *A. certus* overwintering survival by 99%.

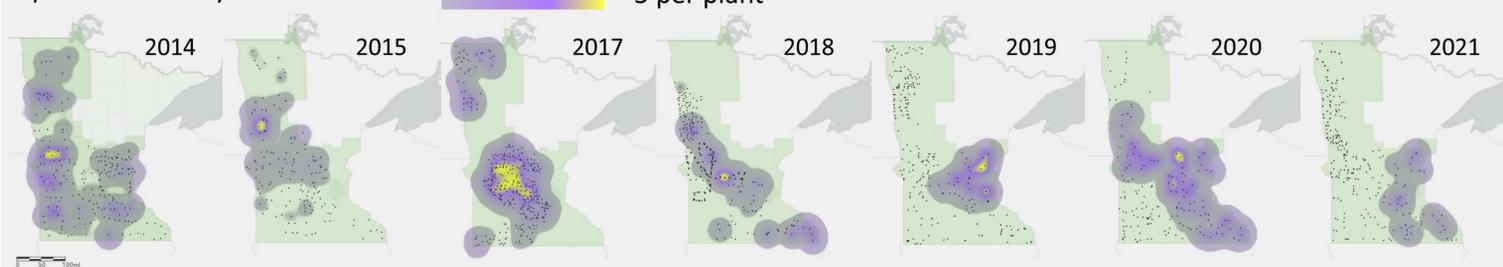
In a field test we had *A. certus* mummies emerge at the surface of the soil or beneath 4 cm loose soil.

4cm of soil reduced the numbers recaptured by 99%.

Soybean aphid density



Aphelinus density

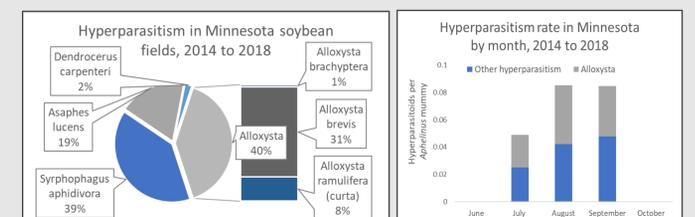


We coordinated sampling across the major soybean growing counties of Minnesota (green). Each sample point was one field on one date between mid July and early September; in each field 15 to 31 plants at least 10m apart were sampled for aphids and parasitoid mummies. We generated heat maps with ArcGIS, using the default area of influence.

Despite cold dry winters, drought, and low aphid numbers, *A. certus* maintains a presence.

Aphids were widespread, even in years of very low densities. With a recent immigrant like *A. certus* we watch for local extirpation due to factors such as local aphid extirpation, extreme weather, or misaligned timing of spring emergence. However we find even after years of low aphid numbers, *A. certus* maintained a presence. Note the patch in east central Minnesota, in counties dominated by wetlands and woods: since 2019 the aphid and the parasitoid populations remained relatively high in these counties compared with the prairie counties of western Minnesota.

Hyperparasitoids may reduce *Aphelinus* biological control



Adult hyperparasitoids emerged from field-collected parasitoid mummies, graphed by species and across the months of the summer soybean growing season, including 7 hyperparasitoids collected in the last 4 days of September when *A. certus* is beginning diapause. We showed that *Alloxysta brevis* is thelytokous, with almost no males.

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