Ecological consequences of *Echinacea* hybridization: survival of specialist aphids and impacts on host fitness

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Abstract

Introduced *Echinacea pallida* can hybridize with native *Echinacea angustifolia*, a perennial prairie forb. Although *E. angustifolia*'s primary herbivore, the aphid *Aphis echinaceae*, cannot survive on *E. pallida*, nothing is known about its ability to feed on *Echinacea* hybrids. Its ability to do so would affect its ability to withstand the genetic swamping of its native host, which in turn has consequences for the ants that tend it and the arthropod herbivores it competes with. The impact its presence or absence has on hybrid fitness relative to native fitness could affect *Echinacea* competitive dynamics. I propose to investigate the survival of *Aphis echinaceae* on *E. angustifolia* x *pallida* hybrids to shed light on the potential ecological consequences of *Echinacea* hybridization for *Aphis echinaceae*, *Echinacea angustifolia*, and dependent organisms.

Introduction

Echinacea angustifolia, already suffering from habitat fragmentation and inbreeding depression, is also at risk of genetic swamping (Wagenius et al. 2010). The closely related but non-native *Echinacea pallida* has been introduced to western Minnesota. Although Goldsmith (2011) and Sanford-Long (2013) have already documented the ability of these species to hybridize, the ecological consequences of hybridization are unknown. The aphid *Aphis echinaceae* Lagos is of particular interest because it is believed to be an *E. angustifolia* specialist, and because its activities are closely tied to those of other species, including the ants that tend them and the competing herbivores the ants drive away. Whether *A. echinaceae* can survive on *E. angustifolia* x *pallida* hybrids may influence whether genetic swamping will affect their population, as well as the broader arthropod community. If they can survive, the relative fitness impacts they have on their native and hybrid hosts could affect the competitive dynamics of these varieties in the field. I will experimentally investigate these ecological consequences of *Echinacea* hybridization by adding and excluding *A. echinaceae* to/from *E. angustifolia* and *E. angustifolia* x *pallida* and comparing the aphid survival rates and host fitness between treatments.

Background

Focal species

Lagos and Voegtlin first described *Aphis echinaceae* (Hemiptera: Aphididae) in 2009, using specimens Helen Hangelbroek and Stuart Wagenius collected from *Echinacea angustifolia* (Lagos & Voegtlin 2009). It is the primary herbivore of *Echinacea angustifolia* (Ridley et al. 2011). Based on a field experiment in which all *A. echinaceae* added to *E. pallida* and other prairie forbs died within a week, while those transferred to other *E. angustifolia* survived, *A. echinaceae* appears to be a specialist (Hobbs and Lyons, unpublished data; Ridley et al. 2011). It is tended by ant species including *Formica obscura* and *Lasius spp.* (Ridley et al. 2011).

Echinacea angustifolia is a long-lived perennial forb native to tallgrass prairies across North America. *Echinacea pallida* is a non-native introduced for prairie plantings, either mistakenly or because its seed is cheaper and more readily available than that of *E. angustifolia* (Stuart Wagenius, personal communication). Sanford-Long showed that the two *Echinacea* species can cross, and are in fact more likely to accept pollen from each other than from their own species, perhaps due to their self-incompatibility systems. This makes invasion by swamping a realistic possibility for *E. angustifolia*, a species already suffering the effects of habitat loss, habitat fragmentation, and resulting inbreeding depression.

Study sites

My research will use three experimental plots in Douglas County, Minnesota. I will collect aphids from adult *Echinacea angustifolia* in the expt01, the site aphid monitoring and collection in past years (Hobbs and Lyons, unpublished data; Ridley et al. 2011; Muller 2013). I will conduct aphid addition and exclusion experiments in expt06 and expt07. These plots have been planted with *E. angustifolia, E. pallida*, and both types of *E. angustifolia* x *pallida* hybrids (male angustifolia x female pallida, female angustifolia x female pallida). Hegg Lake is a particularly interesting site because it is a prairie restoration that contains both *Echinacea* species, making it a possible site for hybridization.

Goals of research

Can *Aphis echinaceae* survive on *E. angustifolia* x *pallida* hybrids? If so, how does its impact on the fitness of its hybrid hosts compare to its impact on the fitness of native hosts?

Research plan

Objectives

1. Compare the survival rate of aphids added to both *E. angustifolia, E. pallida,* and their hybrids.
2. Compare the leaf senescence of aphid-supplemented *E. angustifolia, E. pallida,* and their hybrids relative to plants from which aphids have been excluded.

Methods & procedures

The experiment will consist of eight treatments representing each combination of two aphid conditions (excluded and added) and four host plant pedigrees (*E. angustifolia* x *E. angustifolia*, *E. angustifolia* x *E. pallida*, *E. pallida* x *E. angustifolia*, and *E. pallida* x *E. pallida*, where the first species listed is that of the maternal plant and the second species is that of the paternal plant). I will remove aphids from the exclusion treatments. I will collect aphids in expt01 and transfer them to the addition treatments. Both study plots (expt06 and expt07) will contain both addition and exclusion treatments. Each week I will count and remove aphids from exclusion treatments, count aphids in addition treatments, and record leaf senescence.

Aphid transfer protocol (based on that of Katherine Muller, 2011)

Materials:

Datasheets, 1 clipboard, 1 pen
1 fine paintbrush

5 wide-mouthed vials with caps
1 blue ice pack
1 portable cooler

Procedure:

1. Collection
    a. Preparation
        i. Pack paintbrush, vials, and blue ice pack into cooler; carry cooler. Carry clipboard with pen and datasheets.
        ii. Select collection site from list of plants on which team members have seen aphids.
    b. Hold an open vial under the leaf with aphids.
    c. Gently agitate aphids with paintbrush until they remove their stylets and start scurrying.
    d. Brush aphids into the vial.
    e. Record relevant data.
2. Storage
    a. Place vials in refrigerator overnight.
3. Addition
    a. Preparation
        i. Pack paintbrush and vials with aphids into cooler; carry cooler Carry clipboard with pen and datasheets.
        ii. Select addition site from randomly ordered list of target plants.
    b. Take out and open one vial. Hold the vial with its mouth over the cap and at an angle slightly below horizontal. Tap slightly so 2-5 aphids fall onto the cap, using paintbrush to move aphids if necessary.
    c. Use the paintbrush to transfer two of the aphids to the largest leaf on the plant.

I will also search for *Aphis* on *E. pallida* growing in a restored prairie near expt07 to check Hobbs' and Lyons' experimentally informed predictions that *Aphis* will not be found on *E. pallida.*

Projected outcomes

I expect aphid survival on hybrids to be lower than on *E. angustifolia*, possibly as low as zero. Since we do not know what phenotypical difference accounts for the failure of *Aphis* on *E. pallida*, nor do we completely understand the phenotypes of the hybrids, we cannot say whether hybrids will support aphids or not. However, it is likely that the hybrids either share some traits with their *E. pallida* parents or have traits intermediate between *pallida* and *angustifolia*, either of which is likely to be a disadvantage to *Aphis.* I expect these lower rates of herbivory to result in lower rates of leaf senescence in hybrids.

Significance

Intellectual merit

We will learn more about the feeding requirements of *Aphis echinaceae*, a newly discovered and little understood species. This will help us assess the conservation risks for this species: is its persistence dependent solely on *E. angustifolia*, or can it make use of hybrid hosts? That is, how likely is genetic swamping to perturb it and the arthropod community it interacts with? The aphid-hybrid relationship is also important to understanding the competitive dynamics of hybrid and native *Echinacea*. If, for example, it is that case that there is less aphid herbivory on hybrids and they have higher fitness because of it, we can expect hybrids to have a competitive advantage over natives. Addressing this possibility is critical to assessing the severity of the emerging threat of genetic swamping to already threatened native *Echinacea* populations.

Broader impacts

I will produce a written report and a poster. This project will provide me with valuable experience in field ecology research. Among the new skills I will learn are insect experimentation techniques, use of R software, and poster design and presentation. I will also continue to develop my scientific writing skills.

Timeline for the proposed research

Fourth week of June:	Visit study sites, finalize data sheets, test and refine procedures.
First week of July:	Administer addition and exclusion treatments.
July-second week of August:	Maintain exclusion treatments, collect data on aphid survival and leaf senescence. Learn to use R. Begin writing report.
Third week of August:	Analyze results, finish report, make poster.

Data management plan

Echinacea Project resources

I will need maps of expt01, expt06, and expt07, and pedigrees of the *Echinacea* at the latter two sites.

Data to be collected

Aphid collection: plant row, plant position, number of mature aphids collected, number of nymphs collected.
Aphid exclusion: plant row, plant position, date, number of aphids found and removed, number of leaves senesced.
Aphid addition: plant row, plant position, date, number of mature aphids present (first day: added), number of aphid nymphs present, number of leaves senesced.

For datasheets, go to Dropbox>Echinacea Project>CMS Aphid Hybrid Project and see CMS_DatasheetAphidCollection_2Jul2010, CMS_DatasheetAphidExclusion_2Jul2010, and CMS_DatasheetAphidAddition_2Jul2010.

Data management and analysis

Collect data on paper datasheets. Analyze with R.

Storage and dissemination of results

I will post the products of my research to the Field Log for storage and dissemination, present my results to the Cole Student Naturalists at Carleton College in September 2014, and pursue opportunities to present to a wider audience at an undergraduate research conference.

Environmental impacts

This project requires the disturbance, collection, and transfer of aphids. Some will die in the process, but the population will likely be only negligibly affected.

References

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