ARTÍCULO DE OPINIÓN

ENTOMOLOGICAL DISCOVERIES IN THE DOMESTICATION OF NATIVE PRAIRIE PLANTS

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Certain native grasses and one dicot are currently being investigated at South Dakota State University for their value and potential as biomass feedstock for the production of cellulose-derived ethanol. The expectation is that these plants will be grown on croplands that are least productive for maize, soybean, or wheat, and are typically highly erodible, are conservation lands, or are otherwise not optimum for most crops. Not surprisingly, each of these native plants have insects associated with them, but the involved and their relationships to their host plants are poorly understood and their dynamics are only now being investigated as the plants are brought into monocultural agronomic production.

This presentation will review several species of insects that are now regarded as significant pests of native plants being investigated as biomass feedstock crops. The discovery of these insects and the nature of their relationships with their host plants provide superior examples and models that illustrate the need and value of in-depth life cycle investigations, and also illustrate that new species and life styles continue to be discoverable by simply looking closer at native and agroecosystem biodiversity.

Our research team involves four principal investigators and four additional collaborators. I am the senior P.I. (principal investigator) entomologist and project leader, with a joint appointment in the departments of Plant Sciences (PS) and Natural Resource Management (NRM). My co-PI's are Dr. Susan Rupp (Dept. NRM), a wildlife specialist studying small mammals and birds; Dr. Arvid Boe (Dept. PS), a native plants agronomist and breeder; and Dr. Vance Owens (Dept. PS), a forages and biomass production agronomist.

Three species of grass (Poaceae) are the focus of our studies, namely Switchgrass (*Panicum virgatum*), Prairie cordgrass (*Spartina pectinata*), and Big bluestem (*Andropogon gerardii*). The dicot is Cup plant (*Silphium perfoliatum*), a large statured species of the Asteraceae. The grasses are intended to form the foundation of each agroecosystem community with specific proportions tailored for the field site and condition as each species has differing tolerances to soil conditions and moisture demands. Cup plant is intended as a complementary and compatible species that will grow with the grasses, provides considerable additive biomass, and can be grown and harvested in concert with the grasses. The Cup plant also adds to the agroecosystem as a species highly attractive to a wide diversity of pollinators. Other native species will also be planted in fields to provide biodiversity, though they would be negligible for significant additional biomass. Each plant species being studied has several insect species identified as potentially significant pests in agronomic plantings, some of which remain undetermined and at least one (Switchgrass midge) was discovered as an undescribed species. Here, I will focus on some of the insects associated with *Panicum virgatum* and *Silphium perfoliatum*.

Four basic entomological goals define our studies on these insect-plant relationships: 1) Complete our understanding of the life stages of each potential pest species, to include elucidating their taxonomy; describing as needed each life stage, characterize each life stage periodicity, duration, and microhabitats; acertain their dynamic relationship to their host phenology; and assess the identity and activity of cellulases in the larval guts of each species. 2) Estimate population development rates, density, and abundance. 3) Determine the presence, identity, and phenology of parasites and predators. 4) Quantify plant development and biomass changes resulting from insect feeding in the different life stages. All studies are being conducted at two research farm and two native community sites in eastern South Dakota that are within the natural range of the host plants in the Tallgrass Prairie Biome. These sites are the Oak Lake Field Station, Aurora Research Farm, Felt Research Farm, and Aurora Prairie, all within 25 miles distance of Brookings, South Dakota.

Switchgass, *Panicum virgatum*

Switchgrass is a native, medium to tall (≤ ca. 2 m), warm-season, bunch grass found throughout most of North America except the far western provinces and states of Canada and the United States. This is a perennial species that occurs in a diversity of habitats with mesic soils, including prairies, meadows, and ruderal sites, and is co-dominant with *Sorghastrum nutans*, *Schizachyrium scoparium*, and *Andropogon gerardii*. Switchgrass provides high value food and cover for wildlife, imported game birds, and is used extensively for erosion prevention and conservation plantings, and it has a massive root system that sequesters high quantities of carbon. Due to its native status and high biomass productivity it is highly ranked as a potential crop for biomass feedstock and ethanol production.

Three insects, two moths and one fly, have shown themselves as significant pests of Switchgrass. None of these species were associated with Switchgrass prior to recent studies. The Switchgrass moth, *Blastobasis repartella* (Dietz) first had its biology summarized by (Adamski et al. 2010). The Switchgrass midge, *Chilophaga virgati* Gagné, was described (Boe and Gagné 2011) from specimens discovered during this study. Meanwhile, the so-called Top-node borer (Lepidoptera: Crambidae), remains unidentified at the genus and species levels.

Blastobasis repartella was first collected by two specimens in 1906 at Denver, Colorado, using an electric light, which at that time what was a novel technique for collecting insects, and was then described it in 1910. The types found their way to the U.S. National Museum of Natural History, but as a small (< 10 mm long) grey-white moth the species remained essentially unknown until 2008 when I reared and collected specimens from Switchgrass grown near Brookings, South Dakota. Now, the species is known from seven States. The adult is active in July and August, the female lays eggs at the base of the tiller, and the larvae overwinter and feed in the proaxis of the rhizome. In early spring the larvae extend feeding into the basal internodes of new tillers and kill them before reaching the third leaf stage. Pupation occurs in the tiller in late June and early July. We did rear a parasitoid from the moth pupa, the wasp *Bassus difficilis* Muesebeck (Hymenoptera: Braconidae).

The impact of this moth on Switchgrass is highly variable, but typically significant. In wild plant populations the immature stages are nearly impossible to find and effects on the plant extremely difficult to assess. However, in agronomic conditions this insect can be very abundant at times resulting in upwards of 40% of tillers being damaged per plant and a 5-10% range of infestation being typical, giving an arithmetic estimate of 750,000 larvae/ha. All occupied tillers die prematurely, giving a loss of biomass and seed production.

During investigation on the Switchgrass moth, it was found that inflorescences of Switchgrass were not developing normally and prematurely died. Based on previous experience with a gall midge (Diptera: Cecidomyiidae) in *Andopogon gerardii*, team member Dr. Arvid Boe suspected a midge in Switchgrass. Larvae of a midge were found at the base of each senescing inflorescence from July through August where they feed in the intercalary meristem area at the base of the peduncle. Through rearing it was found that a new species of gall midge was responsible, and as noted earlier this was described as *Chilophaga virgati.* The larvae remain in the damaged tiller until autumn when they start to drop from the tiller and burrow into the soil for a winter-long dormancy. They remain as larvae into mid-spring and then pupate when the host plants begin their seasonal growth. Though we do not yet know where the eggs are deposited, they must be laid when the host tillers are growing actively in June.

Plants infested by *C. virgati* lose biomass upwards of 35% below production of uninfested tillers. Since the damage prevents normal inflorescence development then there is also a 100% loss of seed production from infested tillers. There is a tolerance differential by cultivar ranging from 7.2-21.8%, suggesting that resistance breeding may be possible.

The third insect in Switchgrass is another moth of the Family Crambidae. Thus far we have several instars of the larva, which bore through the terminal two internodes of nearly mature tillers. Unfortunately, we have yet to successfully rear this species, so we do not yet have a confirmed identification. It appears that the larva of this species drops from the plant at maturity in late August and probably pupates in soil at the base of plants. We expect that the insect over-winters either as a dormant mature larva or as a pupa, with the adult emerging in late spring.

Cup plant, *Silphium perfoliatum*

Cup plant is a native, warm-season, medium to tall (≤ 2.5 m) flowering plant found throughout most of eastern boreal North America east of the Rocky Mountains. This is a perennial species that occurs mostly in lowland habitats with strongly mesic soils, including streamsides, wetland margins, and vernal wet meadows. Cup plant provides high value food for wildlife, including a wide diversity of pollinators, and is used extensively for conservation plantings. This plant has a massive root system that sequesters high quantities of carbon. Due to its native status and high biomass productivity it is highly ranked as a potential crop to interplant with grasses for biomass feedstock and ethanol production. Relatively few insects feed on Cup plant, but those that do have some most interesting life cycles.

Eucosma giganteana (Lepidoptera: Torticidae) is the largest tortricid moth in North America and is associated only with *Silphium* spp. (Asteraceae). The adults are active from early July through mid-August and are mimics of bird feces that are abundant on the host plant leaves. Eggs are laid primarily in early and mid July when the stems are bolting and the first instar larvae commence feeding on the developing disc and ray flowers. Second and third instar larvae burrow into the buds and feed internally on all floral parts, including the hypanthium and ovaries, and ultimately kill the buds. By late August and early September the larvae leave the dead inflorescences and move through the soil and along emergent stems to the crown area where they begin feeding and enter the rhizome. Mature larvae overwinter in the, excavating large chambers in the vascular and parenchymal tissues that become infected with fungi and bacteria. At some point in spring the larvae leave the rhizome and pupate, probably in the surrounding soil. Pupal exuviae attributed to this species can be found partially emergent from the soil at the plant base in late June.

Wild populations of *S. perfoliatum* have relatively low incidences of infestation, with typically <10% of buds infested and killed by early instar larvae. In contrast, agronomic populations suffer considerable loss with 95-100% of floral and seed crops annually. Multiple years of infestation have the plants losing vigor within 3 years resulting in 50-70% loss of biomass in addition to the floral damage.

Uroleucon cf. *ambrosiae* is a curious aphid that is similar to *Uroleucon* populations on *Ambrosia* spp. Populations of *U*. cf. *ambrosiae* on *S. perfoliatum* can become large and dense, being found on leaves, peduncles, stems, and floral parts. This aphid is inconstant on Cup plant, geographically and temporally, and has short-lived colonies that develop and crash within 4-6 weeks, but still attract large numbers of predators and parasitoids, including lacewings (Neuroptera: Chrysopidae, *Chrysoperla plorabunda*), ladybeetles (Coleoptera: Coccinellidae, *Hippodamia convergens*), flower flies (Diptera: Syrphidae), and a parasitoid wasp (Hymenoptera: Braconidae, *Acanthocaudus* n.sp.). To date, we have not found any evidence of virus transmission or discernable damage from feeding, other than slight chlorosis at sites of denser colonies. The *Acanthocaudus* n.sp. parasitoid helps illustrate a common modern malady when working with alternative crops. The type locality of this new wasp was part of an agronomy research farm on the South Dakota State University campus, but was destroyed to construct an access road for a business development.

Summary

A curious historical trend in the United States and many other countries is to extensively use non-native plants for crops, particularly as food or fuel plants. In the search for ecological appropriate and environmental adaptable plants for biomass production in the Upper Midwest and northern Great Plains native plants are being studied. This shift in plant as crops brings a wealth of native species associates that are often poorly known or even undescribed species. The examples given here of insect associates of switchgrass and cup plant demonstrate this trend and illustrate that these insects also possess unusual life histories that are biologically intriguing. These examples plainly demonstrate the wealth of investigatory potential in biology using relatively low-cost technology and high value field techniques and curiosity. As a side benefit, rational agronomic protocols can be developed early in the cropping evolution of plants when the natural history of the plants and their insect associates are properly elucidated.

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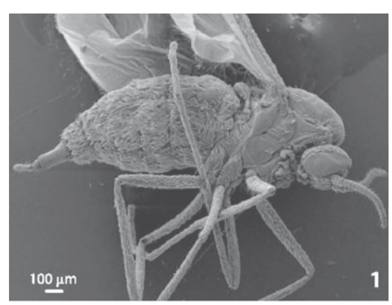
Panicum virgatum

Blastobasis repartella, adult

Blastobasis repartella, larva in proaxis

Chilophaga virgati, larvae in stem



Chilophaga virgati, adult

Silphium perfoliatum, inflorescence

Eucosma giganteana, mature larva

Silphium perfoliatum, root mass

Uroleucon cf.*ambrosiae*

Eucosma giganteana, adult

Acanthocaudus n.sp.