Lessons learned from six years of kudzu research

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My Story

From 2006 to 2010 I studied biological control of kudzu at the University of Delaware under the guidance of Professor Judy Hough-Goldstein. But kudzu has always been a part of my life. As a boy, I swung on kudzu vines suspended from a tree near our house in Westchester County, NY. Back then we only knew it as “the vine,” and my dad started his battle against kudzu in 1974.

Where did it come from?

Kudzu is native to Asia, and was intentionally introduced to New York in 1855, but most notably in 1876 at the Centennial Exposition in Philadelphia.

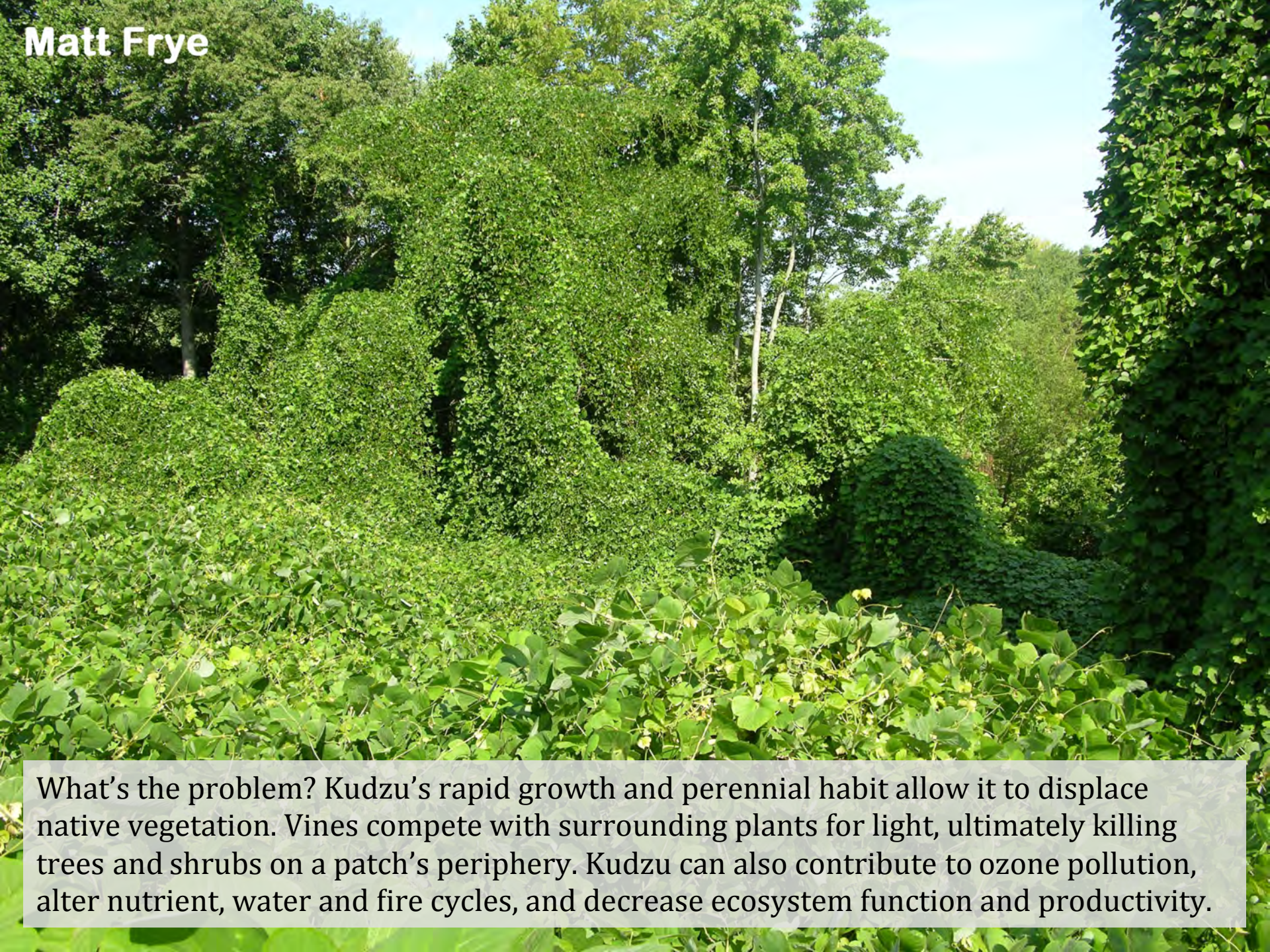
Anhui Province, China (Photograph by K.O. Britton)

Where do we find it?

Kudzu was planted extensively as a forage crop and a soil stabilizer throughout the Southeastern US. Today, the most severe infestations of kudzu can be found in Mississippi, Alabama and Georgia.

Where do we find it?

In the Northeast, we typically find kudzu where it was planted. This includes steep slopes and along rights-of-way such as railroad tracks and power lines.



What's the problem? Kudzu's rapid growth and perennial habit allow it to displace native vegetation. Vines compete with surrounding plants for light, ultimately killing trees and shrubs on a patch's periphery. Kudzu can also contribute to ozone pollution, alter nutrient, water and fire cycles, and decrease ecosystem function and productivity.

In addition to negative environmental impacts, kudzu is responsible for economic damage when vines must be removed from power lines, railroad tracks and roads.

How does is spread? Limited dispersal of kudzu might occur from seeds. Purple flowers are produced in the summer on raceme-like panicles of established plants. Flowers can be found on aerial and trailing (along the ground) vines, and yield fuzzy green seedpods with variable numbers of seeds per pod.

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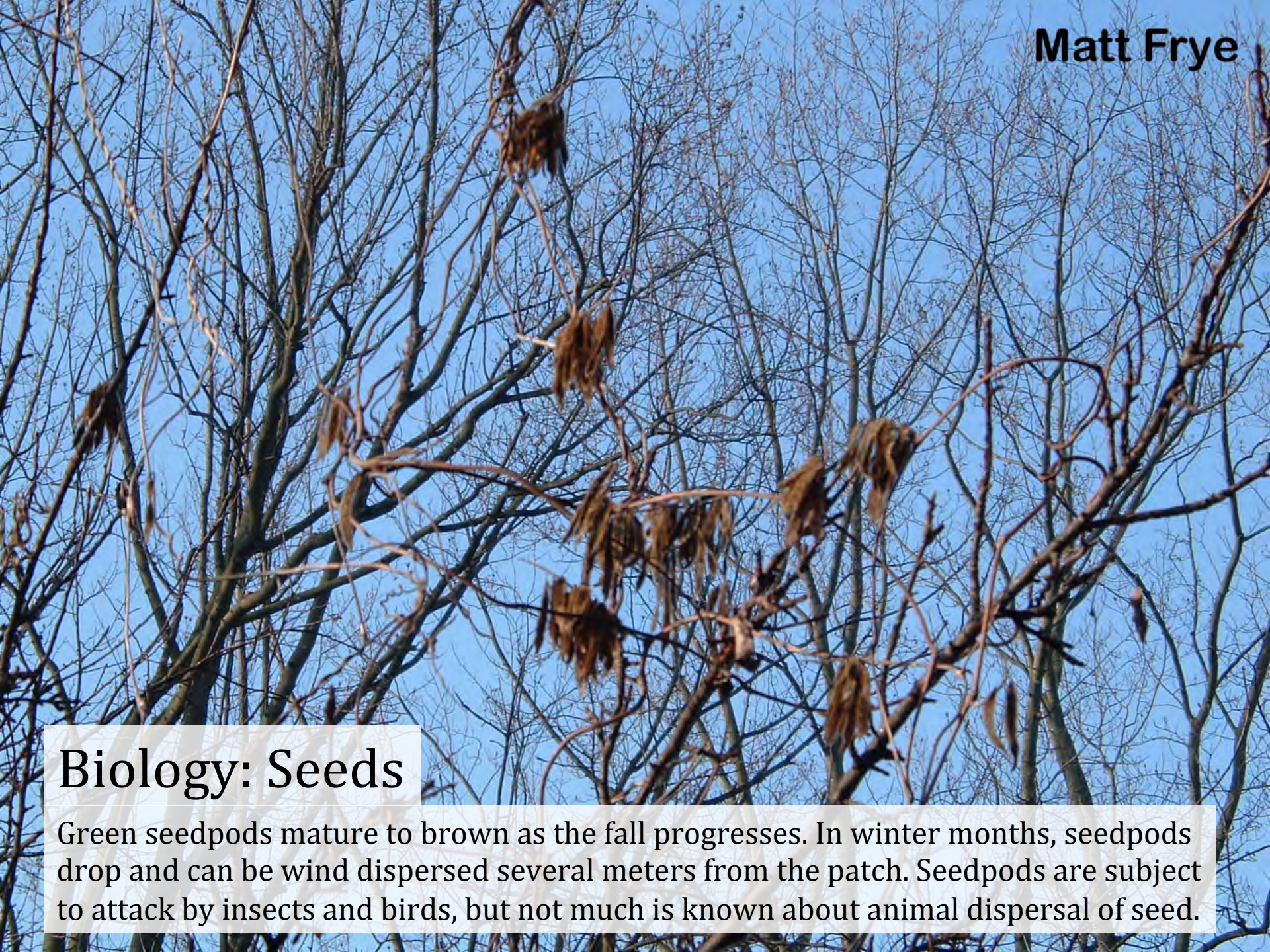

Biology: Seeds

Green seedpods mature to brown as the fall progresses. In winter months, seedpods drop and can be wind dispersed several meters from the patch. Seedpods are subject to attack by insects and birds, but not much is known about animal dispersal of seed.

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Biology: Seeds

For a review on insect frugivores, see Thornton, 2004.

Biology: Seed Dormancy

Kudzu seeds have a thick seed-coat that prevents water absorption and ultimately leads to low germination rates under natural conditions. However, several methods of breaking coat-imposed seed dormancy have been investigated, including cold stratification, boiling, and soaking seeds in ethyl alcohol or sulfuric acid (Susko et al. 2001). In my experiments, I cut off one end of the seed-coat to break dormancy and found higher germination rates for seeds from Delaware than New York. One potential explanation for this observation is the known genetic variation among kudzu populations based on its history of multiple introductions (Pappert et al. 2000).

Biology: Seedling Growth

Despite poor seed set and naturally low germination rates in the field, kudzu plants in North America produce viable seed. Shown here are kudzu seedlings grown from hand scarified seeds in a greenhouse.

Biology: Seedling Growth

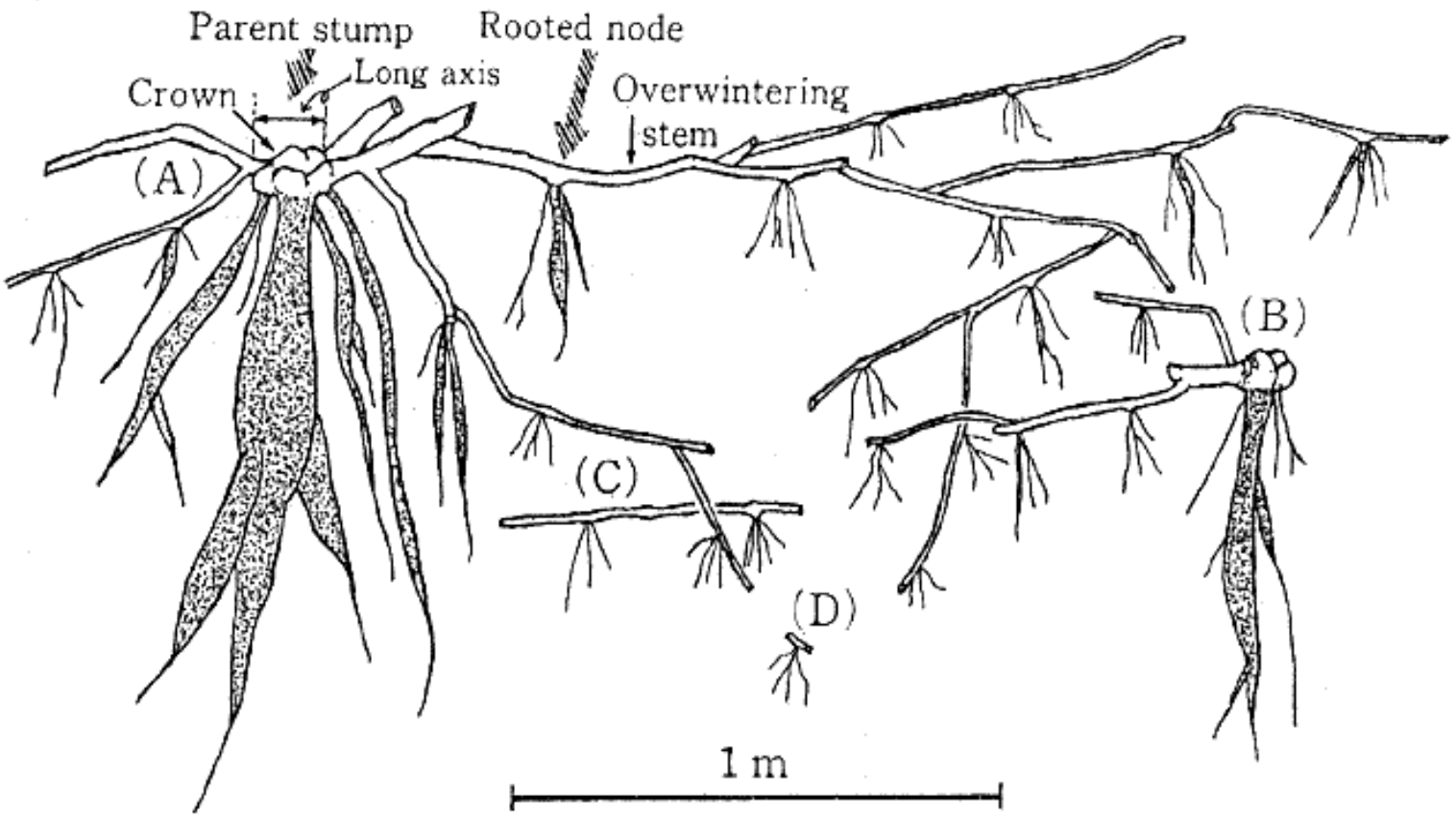
One explanation for poor seedling survival in the field is low light availability. Kudzu's large leaves and resulting dense canopy shade out other plants (including kudzu seedlings). In greenhouse experiments, we found that kudzu seedlings were able to grow in 0% direct light, but only one of 53 seedlings survived to the end of the experiment. Kudzu seedlings grown in the shade were etiolated and often produced only cotyledons (no true leaves). In nature, these plants are unlikely to survive without exposure to sunlight.

Biology: Seedling Growth

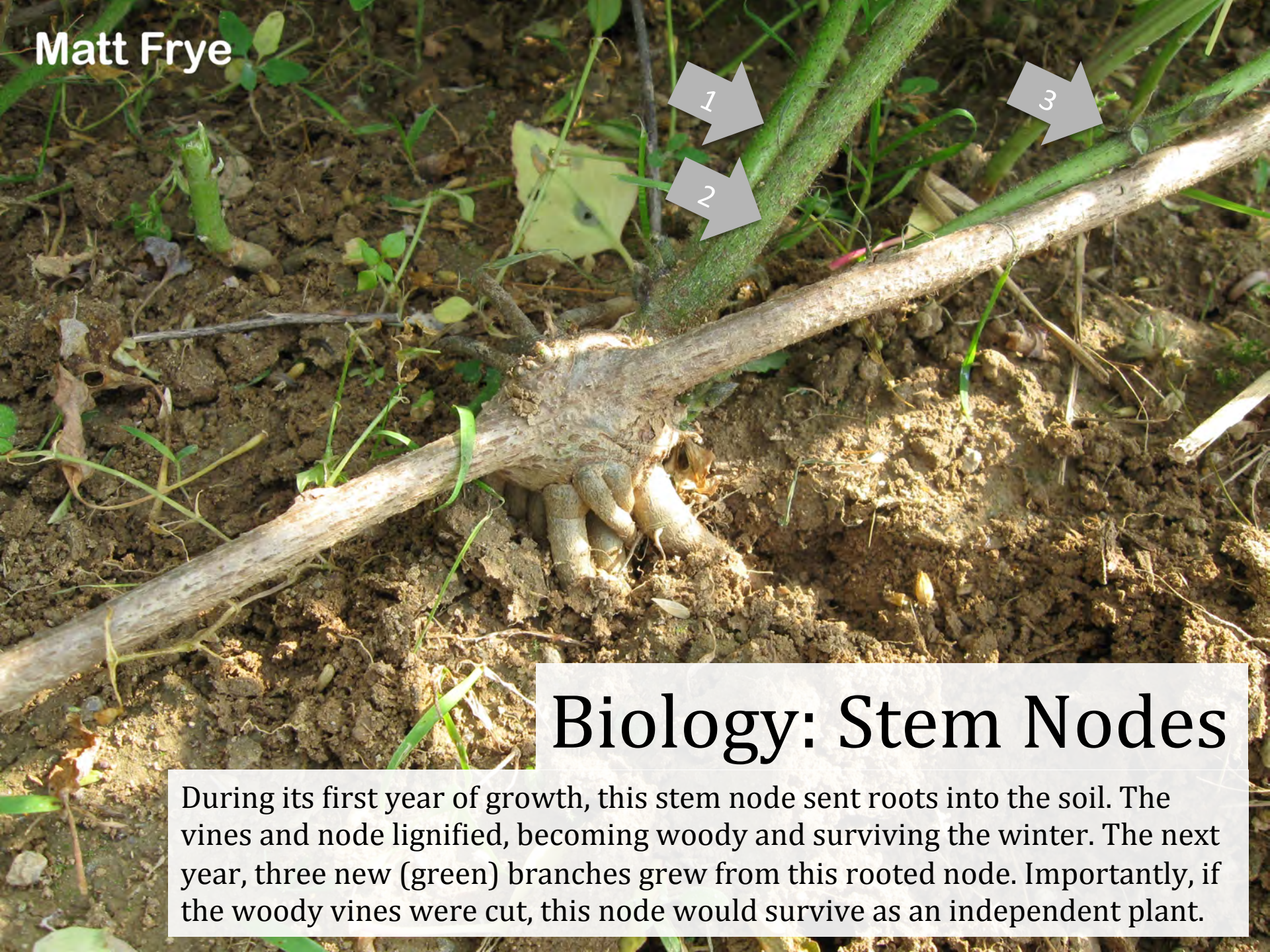
In my six years studying kudzu, I observed only a few seedlings in nature. These were located where the canopy and soil had been disturbed (my field sites) and along a roadside where high heat and salinity could have contributed to weakening the seed coat.

How does it spread?

Therefore, the primary mechanism of kudzu dispersal in the US is human introduction (intentional or otherwise) and subsequent vegetative reproduction. Stem nodes (where leaves attach) in contact with the soil can form adventitious roots. Over time, these rooted nodes can become independent plants.



Tsugawa & Kayama. 1985. J. Japan Grassl Sci 31: 167-176



Biology: Stem Nodes

During its first year of growth, this stem node sent roots into the soil. The vines and node lignified, becoming woody and surviving the winter. The next year, three new (green) branches grew from this rooted node. Importantly, if the woody vines were cut, this node would survive as an independent plant.

Biology: Root Crown

Root nodes can become root crowns when vine connections between nodes are severed. Root crowns represent the interface between aboveground plant parts (meristematic tissue that was formerly a stem node) and belowground roots (differentiated tissue that **cannot** regenerate a plant). Both root crowns and stem nodes are easily identified in the spring when new stems/shoots emerge from these structures.

Biology: Roots

In the fall, kudzu plants allocate resources to roots, which are tuberous, starchy storage organs located in the soil below the root crown. Kudzu roots are considered differentiated tissue, meaning that they cannot regenerate a whole plant.

Biology: Roots

To understand the biology of root crowns, I harvested several from a kudzu patch in Dover, DE and grew them in pots.

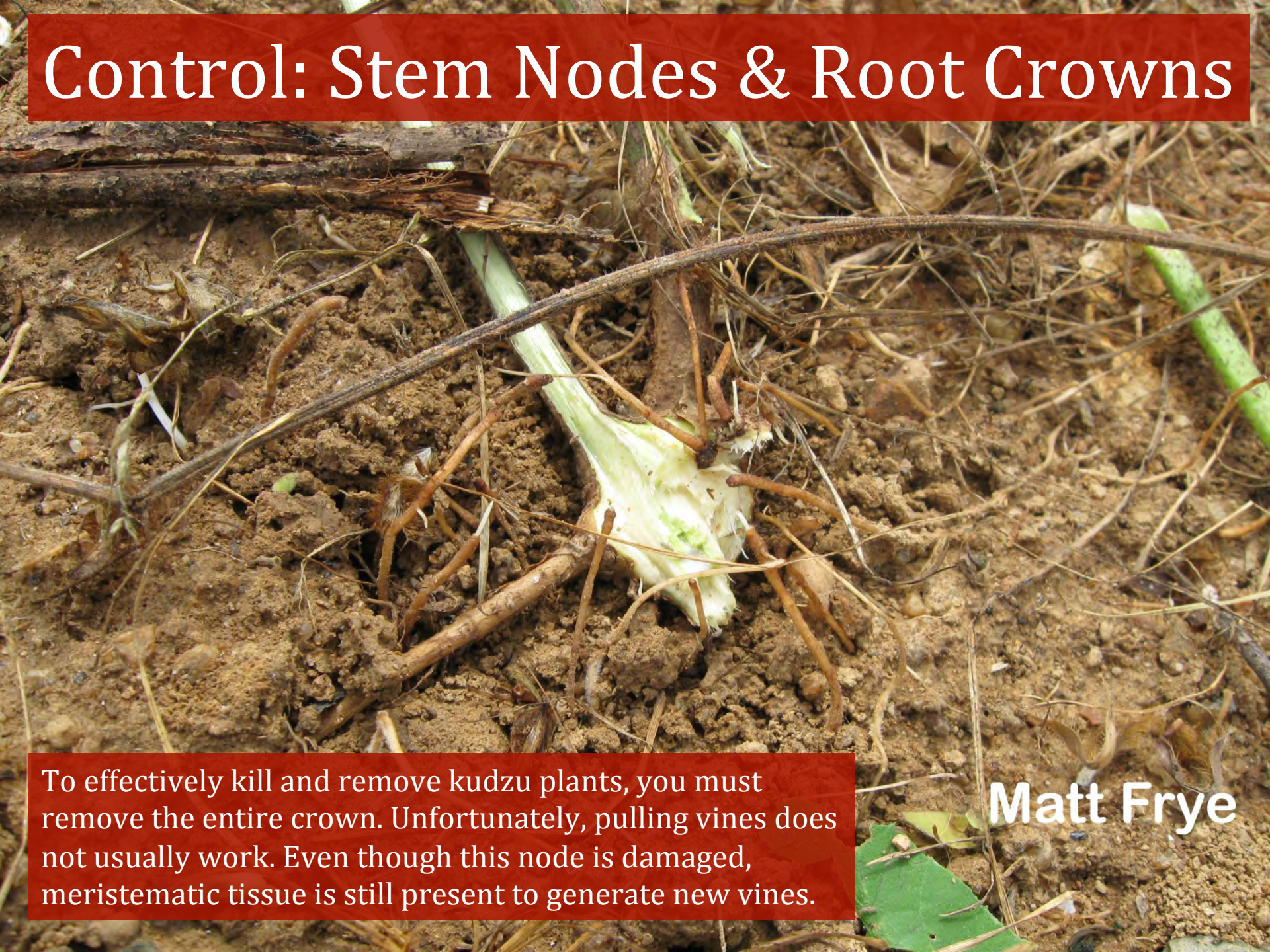
Biology: Roots

As in the field, new vines grew from the root crowns and stem nodes. This has important implications for monitoring and control strategies targeting kudzu.

Control

Because new growth appears on root crowns and stem nodes, kudzu eradication efforts should identify these structures in the spring before vines become a tangled mess (and they will).

Control: Stem Nodes & Root Crowns



To effectively kill and remove kudzu plants, you must remove the entire crown. Unfortunately, pulling vines does not usually work. Even though this node is damaged, meristematic tissue is still present to generate new vines.

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Control: Stem Nodes & Root Crowns

Instead, use loppers, hand clippers or a hand saw to **cut below the crown**.
Remove the crown, kill the plant.

Image courtesy of "Knock Out Kudzu" (KOkudzu.com)
The Coalition to Control Kudzu Without Chemicals

You might ask, does this work, or is there no stopping kudzu?

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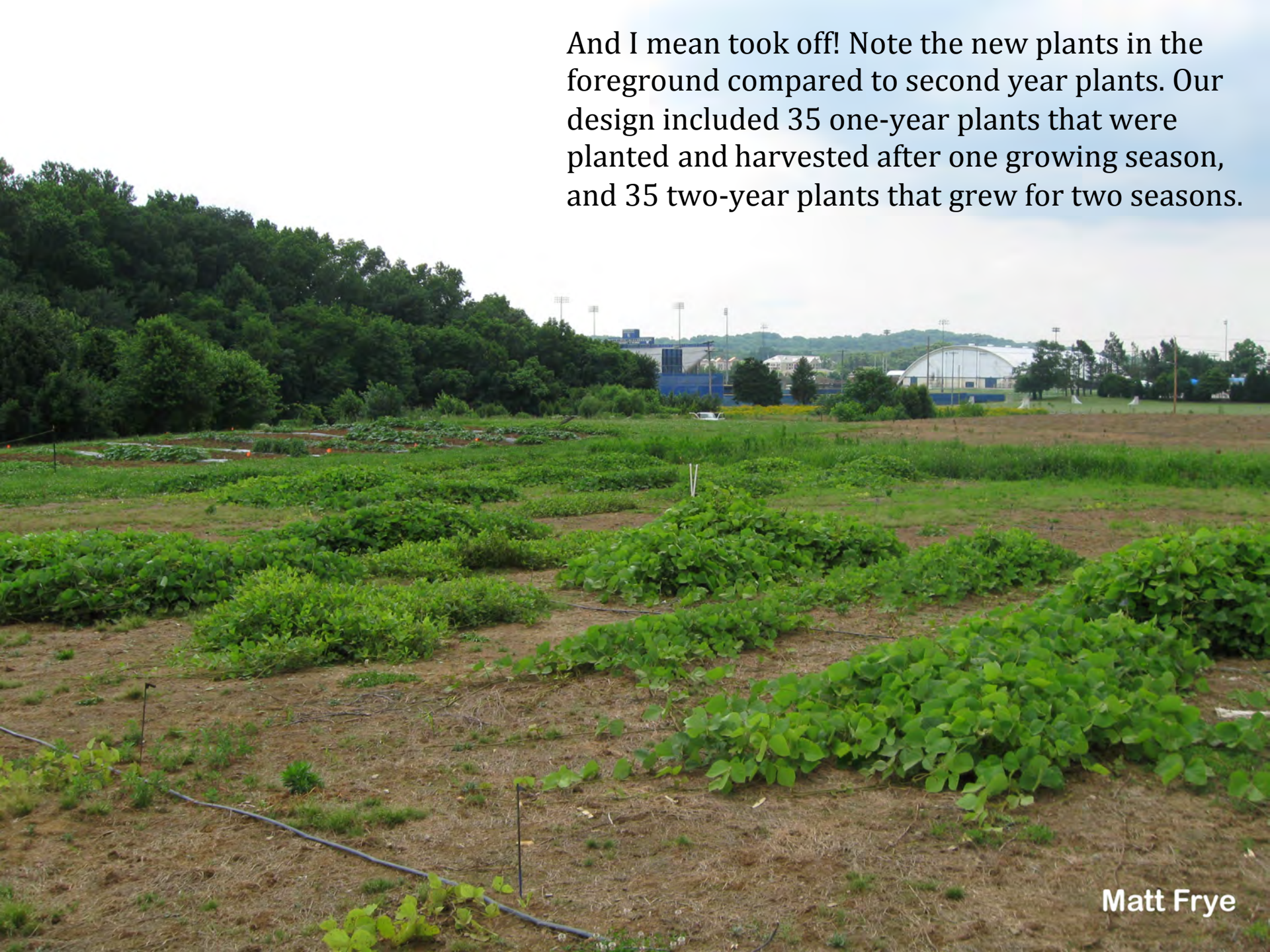
It works! Let me show you.
As part of my research, I grew 105 kudzu plants from hand scarified seed in the greenhouse.

In early summer, potted plants were transplanted to an agricultural field at the University of Delaware Farm. Even though he battled “the vine” every summer since 1974 on his own property, my dad was willing to help plant kudzu at UD.


If you think killing invasive species is difficult, try growing them! We not only drip irrigated the plants, but also inoculated them with *Rhizobium* to help them get started.
Matt Frye

In this agricultural setting, plants were relatively free from natural herbivory and light competition. Plants were subject to one of four different treatments: leaf cutting (either 50 or 75% removal) and shoot clipping (removal of 50 or 75% of all shoot tips). Treatments were designed to mimic damage by potential biological control agents from China. Once the plants got going, they really took off growing.


And I mean took off! Note the new plants in the foreground compared to second year plants. Our design included 35 one-year plants that were planted and harvested after one growing season, and 35 two-year plants that grew for two seasons.
Matt Frye


You can imagine with kudzu's reputation that the farm staff was not thrilled to let 35 plants overwinter in one of their fields…
Matt Frye

For scale, you can see that one plant is (much) larger than one kudzu researcher.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At the end of each season, aboveground biomass was harvested by clipping vines from the root crown. Each bag below represents one plant.

After taking measurements and recording data, plant material was dried in a greenhouse and weighed.


Drying plants in the greenhouse was sufficient to kill them. Plant material was discarded on a compost pile and no new kudzu plants regenerated from this discarded material.
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Although plants can be killed by removing only the root crown, for this study we were interested in the weight of roots produced after one and two years growth on the farm.

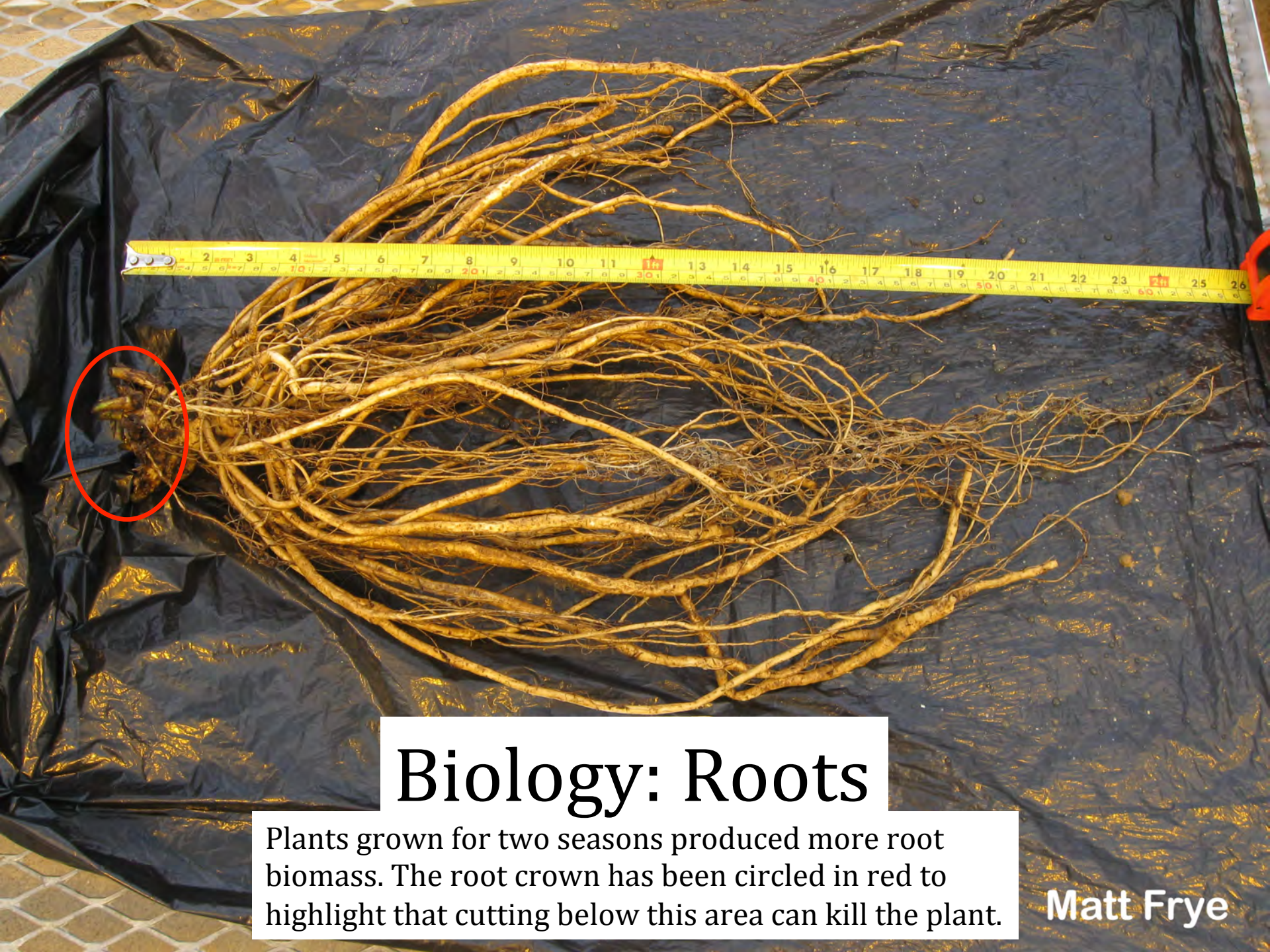
A one-meter diameter hole was dug around the root crown and all root material was harvested and brought to the laboratory.

Biology: Root Nodules

Because plants were inoculated with nitrogen-fixing *Rhizobium*, we were not surprised to find root nodules, even on adventitious roots from stem nodes.

Biology: Roots

In the laboratory, harvested root material was washed clean, measured and weighed after drying. This image represents root material from a plant grown for one season.



Biology: Roots

Plants grown for two seasons produced more root biomass. The root crown has been circled in red to highlight that cutting below this area can kill the plant.

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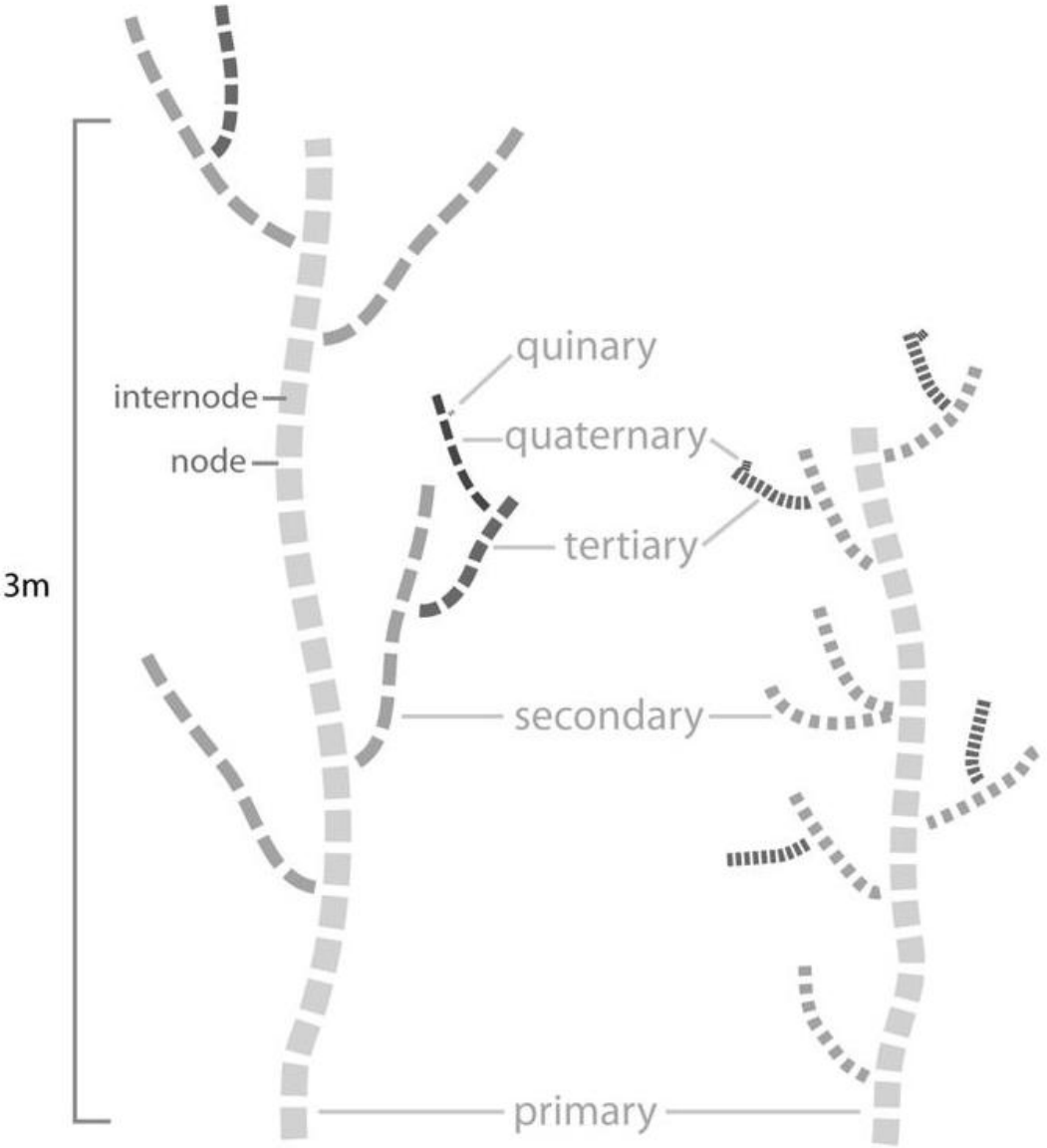
Some Results

In our experiments we observed that heavy defoliation could suppress kudzu growth. Damaged plants produced less above- and belowground biomass and shorter vines, making kudzu less able to compete with other plants in natural areas. Repeated defoliation as a way of controlling kudzu has been attempted by mowing (cutting) and grazing by goats.



Control 75% Leaf Cutting

Frye & Hough-Goldstein 2013

Can it be stopped? YES!

Both on the University of Delaware Farm, where 35 plants were grown for two years and allowed to root at nodes, and at my parents home (with the help of fellow kudzu researcher Heather Coiner, PhD), kudzu has been eradicated by removing root crowns. Importantly, areas where kudzu has been eliminated and soil has been disturbed are subject to invasion by other aggressive or alien species. Integrated weed management practices that combine physical removal, judicious herbicide applications and revegetation techniques can be used to restore native plant communities (Lake et al. 2013) .

A note about plant age

Unlike trees, kudzu vines do not add a layer of xylem and phloem each year. Therefore, several authors have concluded that growth "rings" cannot reliably be used to determine the age of kudzu vines.

A note on kudzu biological control

In addition to research on the growth of kudzu in response to damage treatments, the Hough-Goldstein Lab also investigated two potential biological control agents from China (Frye et al. 2007). Despite voracious appetites for kudzu stems (*O. trifidus*) and leaves (*G. tredecimmaculata*), both insects were able to reproduce on soybean in quarantine trials and were subsequently **rejected** as potential biological control agents.

Ornatalcides (Mesalcidodes) trifidus
(Coleoptera: Curculionidae)

Gonioctena tredecimmaculata
(Coleoptera: Chrysomelidae)

New Bug in Town

In October 2009, a new structure-invading bug was reported in large numbers from Northeast Georgia. Insect specimens were sent to the University of Georgia Diagnostics Laboratory and were identified as the kudzu bug, *Megacopta cribraria* (Fabricus) (Hemiptera: Plataspidae). Native to Asia, the kudzu bug is an invasive insect that is rapidly expanding it's range (see www.kudzubug.org for current distribution). This insect is a nuisance pest that invades structures in the fall, has the potential to feed on several important legumes, and is known to reduce soybean yield. Kudzu is a reservoir and breeding host of this insect, but feeding by bugs can reduce kudzu biomass.

For more on the kudzu bug, see: Eger et al. 2010, Suiter et al. 2010, Zhang et al. 2012, Ruberson et al. 2013, Seiter et al. 2013

Like other overwintering pests, kudzu bugs invade structures in the fall. Homeowners can keep kudzu bugs out by sealing cracks and crevices around windows, doors, utility chases, vents and fascia; replace damaged screens and remove window air conditioning units in the fall.

Photo by Dan Suiter, University of Georgia, Bugwood.ord

Thoughts on Range Expansion and Conclusions

Kudzu is a rather well known example of an invasive species, particularly in the Southeastern United States. Some old (Sasek & Strain 1988) and some new (Hickman & Lerdau 2013) literature about kudzu suggest that global climate change will affect the distribution of this plant, including a northward spread. However, it is the *opinion* of this kudzu researcher that such an expansion will not be realized. While relatively little is known about kudzu seed dispersal, we do know that germination rates are low under natural conditions (Susko et al. 2001). Anecdotally, most kudzu patches observed today were planted at one time, and, kudzu has not spread beyond those existing patches except by climbing vines. Therefore, we consider kudzu to be primarily human dispersed and consider it to be a suitable target for mechanical control. Although labor intensive, removal of root crowns is sufficient to eliminate plants. Using an integrated pest management approach that combines several control tactics can lead to restoration of native ecosystems.

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University of Delaware Biological Control of Invasive Plants Research:
http://ag.udel.edu/enwc/research/biocontrol/index.htm