Biological Control with Plant Pathogens

Yandoc-Ables, Rosskopf, and Charudattan. 2006. Plant Pathogens at Work:
Progress and Possibilities for Weed Biocontrol. Part 1: Classical vs. Bioherbicidal Approach.
http://www.apsnet.org/online/feature/weed1/.

Yandoc-Ables, Rosskopf, and Charudattan. 2006. Plant Pathogens at Work:
Progress and Possibilities for Weed Biocontrol. Part 1: Improving weed control efficacy.
http://www.apsnet.org/online/feature/weed2/.

Weed biocontrol with plant pathogens has been studied using two basic approaches: the inoculative and the inundative or bioherbicide approaches.

Inoculative or Classical Approach

The use of a pathogen imported from a foreign location to control a native or naturalized weed.

- Introduced weeds can be easy targets for control by the introduction of coevolved pathogens from which they have been physically separated for a period of time.
- The introduced pathogen is released or inoculated into small weed infestations relative to the total infestation (i.e., inoculated into the population as opposed to inundation of the population).
- If conditions are favorable, the pathogen multiplies on the weed host and spreads, causing a high level of disease (an epiphytotic) that may kill or severely limit the growth and reproduction of the weed.
  - The weed population may then begin to decline.
  - Disease spread is typically gradual and several months or years may pass before a significant level of weed control is seen.

Caveats:

- Not possible to predict the success of an introduced pathogen
- Undesirable release cannot be completely reversed.
- Careful evaluation of efficacy and safety must precede a pathogen’s introduction.
- However, excellent safety record for worldwide pathogen introductions - no undesirable effects.

The overall success rate of classical weed biocontrol projects using imported pathogens has been estimated at 57%.
Success for insect-based weed biocontrol projects, at around 30-35%.
Integration of pathogens and insects in future weed control projects is suggested.

Work in this area began in the late 1960s.
Since the early 1970s, 7 pathogens have been imported into the United States:

- Mainland: *Puccinia chondrillina*, *P. carduorum*, *P. jaceae*
- Hawaii: *Entyloma ageratinae* (also described as *E. compositarum*), *Colletotrichum gloeosporioides* f.sp. *clidemiae*, *Septoria passiflorae*, and a *Septoria* sp. on lantana.

***Entyloma ageratinae* - a foliar smut fungus**

- Imported from Jamaica to control Hamakua pamakani or spreading mist flower (*Ageratina riparia*) in Hawaiian forests and rangelands
- Originally misnamed as *Cercosporella* sp.
- Subsequently described as *Entyloma ageratinae* and *E. compositarum*
- Introduced into Hawaii in 1974.
    - In cool, high-rainfall sites in Oahu, Hawaii, and Maui: 2-3 months of release - devastating epiphytotics occurred in dense stands of *A. ripari*; weed populations were reduced by 80% in a 9-month period.
    - At sites with adequate moisture: similar reductions in weed populations were recorded 3 to 4 years after the pathogen was released.
    - At sites with low temperatures and low rainfall: greater than 50% reduction in the weed population in 8 years after the pathogen's release.
    - More than 50,000 ha (123,550 acres) of pasture land is estimated to have been rehabilitated.
    - No evidence of host resistance or mutant stains of the pathogen.

***Puccinia carduorum*: a rust fungus**

- Imported from Turkey and released into the northeastern United States (Virginia and Maryland) in 1987 to control musk thistle, *Carduus thoermeri*.
- Spread widely from its original introduction to the western states of Wyoming and California
- Reduces musk thistle density by accelerating senescence of infected plants and reducing seed production by 20 to 57%.
- Effects of the fungus on insect biocontrol agents of this weed are negligible.

Inundative or Bioherbicide Approach

When fungal - mycoherbicide

- Indigenous plant pathogens are isolated from weeds and are cultured to produce large numbers of infective propagules (such as spores).
- Infective propagules are applied at rates that will cause high levels of infection, leading to suppression of the target weed before economic losses are incurred
- Annual applications are required since the pathogen does not generally survive in sufficient numbers between growing seasons and does not produce the level of inoculum needed to initiate a new epiphytotic on new weed infestations.

DeVine:

- *Phytophthora palmivora*
- Kills strangler or milkweed vine (*Morrenia odorata*) in citrus.

Collego:

- *Colletotrichum gloeosporioides* f. sp. *aeschynomene*
- Controls northern jointvetch (*Aeschynomene virginica*) in rice and soybeans.

Smolder:

- *Alternaria destruens* strain 059.
- Control of dodder in agricultural fields, dry bogs, and ornamental nurseries.

Table

Of the 15 or so bioherbicides that have been registered few are commercially available:

- Due to the lack of continued commercial backing.
- High cost of mass production.
- Introduction of newer herbicidal chemistries.
- Resistant weed biotypes (e.g., Dr. BioSedge).
- Limited markets.
- One bioherbicide agent, *C. gloeosporioides* f.sp. *aeschynomene* (previously Collego), has been re-registered as of March 2006 under the commercial name LockDown for use in rice in Arkansas, Lousianna and Mississippi.

Tobacco Mild Green Mosaic Tobamovirus.
Trade name SolviNix™; target weed: *Solanum viarum* – Tropical Soda Apple
Solanaceae family, native to South America

Use areas: cattle ranches and natural areas: A non-chemical option for beef and milk producers and for natural-resource managers.

The TSA plant dies as the result of an overreaction to the virus infection.
It is a case of a self-destructive, systemic, hypersensitive response from the plant.

Risks?

TMGMV naturally infects about 25 different plants in the Solanaceae and causes a mild mosaic disease.
The lethal response to the virus occurs only in three genera in Solanaceae: *Nicotiana, Capsicum,* and *Physalis.*
There is risk to *some* pepper and tobacco cultivars that may be killed if directly sprayed with TMGMV.
Several other cultivars are immune or resistant to TMGMV

Tomato is immune to the virus.
About 98% of 250 plants in families other than Solanaceae that were tested are immune or resistant to the virus

Three most effective methods: abrade-&-spray, wiper application, and high-pressure spray

BioProdex, Inc. has developed a commercial production process for TMGMV.
Currently Solvinix is undergoing commercial trials under an Experimental Use Permit, with Florida Department of Agriculture approval.

Inundative approach

Expected to kills susceptible weeds quickly in a few days.
Applicable to annual cropping systems – weed suppression needed early in the growing season to stave off competition.

Investigating systems that enhance the efficacy of these agents.

1. **Formulations with water-retaining additives to reduce dew dependence.**
    - The requirement for long periods of dew or moisture is a major hurdle in the development of foliar fungal pathogens into bioherbicides, mainly because humidity and dew period duration can significantly limit disease initiation and disease progress.
    - Use of formulations that minimize the influence of humidity is one approach to overcoming this restraint.
        - Invert emulsions – an ordinary emulsion small droplets of oil is suspended in water. Invert emulsion – a suspension of small droplets of water in an oil.
        - Metamucil – contains finely chopped psyllium seed husks that expand and become mucilaginous when wet.

2. **Broadening the spectrum of bioherbicides.**

- Where several species of problematic weeds occur and a broad-spectrum weed control is required.
- This has been often cited as a major limitation to the bioherbicide approach in cropping systems.
- Two approaches to broaden the host range of bioherbicides have been explored
    a. via formulation,
    b. combining pathogens.

Formulation with fruit pectin and plant filtrates allowed *Alternaria crassa*, a biocontrol agent specific to jimsonweed (*Datura stramonium*), to infect hemp sesbania, showy crotalaria, and eastern black nightshade, which were resistant to the fungus when applied without the fruit pectin and plant extracts.

Formulation with an invert emulsion, suppressed the selectivity of *A. crassa* and *A. cassiae* and resulted in the successful infection of eight other plant species other than their target hosts. In addition, *C. gloeosporiodes*, isolated from coffee senna (*Senna occidentalis*), controls sicklepod (*S. obtusifolia*) when formulated as invert emulsion or corn oil/Silwet L-77 emulsion.

Mixtures of inoculum:

- Mixtures of 3 host-specific pathogens:
    - *Alternaria cassiae* (specific to sicklepod), *Phomopsis amaranthicola* (specific to pigweeds), and *Colletotrichum dematium* f. sp. *crotalariae* (specific to showy crotalaria
    - Simultaneous and efficacious control of pigweed, sicklepod and showy crotalaria.
- Excellent control of 7 weedy grass species (southern sandbur, large crabgrass, crowfootgrass, guineagrass, Texas panicum, yellow foxtail, and johnsongrass) was also

achieved when conidia of three host-specific pathogens (*D. gigantea*, *E. rostratum*, and *E. longirostratum*) were applied together.

3. Enhancing bioherbicidal efficacy through delivery or application systems.

- Use high volumes of bioherbicides
    a. To ensure complete coverage of infection courts
    b. To provide sufficient moisture needed for spore germination for maximum infection.
- Factors affecting number of lesions produced or the infection density:
    a. spray droplet size, droplet retention and distribution, inoculum concentration and spray application volume
- Solvinix - novel application methods have been effective and could easily be implemented by ranchers. These include low pressure application (20 psi) of the virus combined with plant abrasion using either a section of chain-link fence or carpet, and high pressure application (400 psi) directly to plants.
- Solid-based formulations, have been tested for pre-emergence bioherbicides that are meant to attack weeds at or below the soil surface.
    a. Pesta (wheat-gluten matrix) for *C. truncatum*, *A. crassa*, and *F. lateritium* and *Fusarium oxysporum* f.sp. *orthoceras*
    b. Cornmeal-sand for *F. solani* f. sp. *cucurbitae*, a bioherbicide for Texas gourd
    c. Formulation with solid substrates allows for improved shelf life and also acts as a buffer when extreme conditions in the field occur.
    d. Bioherbicidal efficacy of *Trichoderma virens* enhanced by applying it with composted chicken manure.

4. Enhancing biocontrol efficacy through selection and use of amino acid excreting strains.

- Improved efficacy of *Fusarium oxysporum* f.sp. *cannabis* Cs95, a potential biocontrol agent for *Cannabis sativa*. Valine-excreting mutants caused greater control (70 to 90%) of *C. sativa*, as compared to 25% control by the wild type. The mutants also caused severe wilting within a shorter period (2 to 3 weeks) after application, as compared to the wild type, which caused severe wilt and death after 6-8 weeks. Test plants inoculated with the valine-excreting mutants also caused leaf distortion, loss of stem apical dominance and stunted growth. The mutants failed to infect or cause damage to other plant species tested, indicating no change in the host-range.

5. Combination of biocontrol agents with herbicides and other chemical agents that predispose weeds to infection.

- One of the many factors that can influence the level of weed suppression through biological means is the ability of a target weed to resist infection and colonization by the biological control agent.
- Herbicides can be used to suppress host plant defenses vs the pathogen.