# Microbial Control of Weeds

Raghavan “Charu” Charudattan

Emeritus Professor, Plant Pathology Department
University of Florida-IFAS, Gainesville, FL

**Microbial Biocontrol of Arthropods, Weeds and Plant Pathogens: Risks, Benefits and Challenges**

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# Microbial control of weeds Status

- Definitions: Classical (26)
- Bioherbicide (mycoherbicide) (11 *13*)
- My definition of bioherbicides based on epidemiology & implementation tactic or strategy
- EPA and Canadian PMRA definitions of biopesticides (by extension of bioherbicides) include a much broader types of agents, living and nonliving

# Pathogens introduced as classical biocontrol agents of weeds, 1970-2010

| | Total | Rust | Smut | Fac. Parasite |
|---|---|---|---|---|
| USA & Canada | 8 | 3 | 1 | 4 |
| Chile | 2 | 2 | | |
| Australia | 13 | 11 | | 2 |
| Argentina | 1 | 1 | | |
| French Polynesia | 1 | | | 1 |
| New Zealand | 3 | 1 | 1 | 1 |
| South Africa | 4 | 1 | 1 | 2 |

# Biocontrol of Port Jackson willow (*Acacia saligna*) by the introduced rust fungus, *Uromycladium tepperianum*

Left: Rust galls on a branch of *A. saligna*. Middle: Epidemic spread of the rust has caused *A. saligna* trees to be heavily infected and galled. Right: A “before-and-after” picture illustrating the success of this biocontrol program. Source of pictures: **Dr. Mike Morris** and Plant Protection Research Institute, South Africa and Dr. R. Charudattan, Univ. Florida.

# Pathogens for classical biocontrol Key considerations

- **Pathogen biology: Life cycle & disease cycle**
- **Host specificity – host range – nontarget risk**
- **Rust fungi: Alternate host/hosts**
- **New associations (e.g., *Puccinia psidii,* a South American rust vs. Austro-Asian Myrtaceae members)**
- **Importance of Wapshere's centrifugal-phylogenetic testing**
- **Excellent safety record of fungi used for classical biocontrol of weeds (Jane Barton, Biol. Control 2004)**

# *Uromycladium tepperianum* Some considerations

- **50 to 100 reported hosts, incl. Acacia spp., Albizzia, Falcateria, and possibly other Fabaceae trees**
- **Evidence of pathogen races & species complex**
- **Careful & detailed pathology work by Mike Morris, PPRI**
- **Matching a rust strain from A. saligna to A. saligna accessions from South Africa**
- **Two other spp. of exotic Acacias in South Africa developed a few abnormal galls**
- **LOW TECH, HIGH PAYOFF! (Mike Morris, Biol. Control 10, 1997)**

# Pathogens for classical biocontrol of invasive weeds:
## Too many weeds… not enough resources!

- About 5000 introduced plant spp. have become established in the U.S. – Simberloff et al., 1997
- In Florida alone about 850 non-indigenous plant spp.; about 60 spp. highly invasive
- At the rate of 10 SYs to develop 1 classical biocontrol pathogen, the task of developing pathogens for invasive weeds in Florida alone would be overwhelming at the current levels of funding and personnel resources
- So at the current levels of resource commitment relative to the urgency of the need to control invasive weeds, we are not at all well outfitted for classical biocontrol

# Registered microbial herbicides 1980-2010 [1]

| Country Year | Bioherbicide product | Active ingredient | Target weed(s) | Target crop or site |
|---|---|---|---|---|
| USA 1981 | DeVine | *Phytophthora palmivora* | Stranglervine (*Morrenia odorata*) | Citrus |
| USA 1982 | Collego (re-registered: Lockdown) | *Colletotrichum gloeosporioides* f.sp. *aeschynomene* | Northern jointvetch (*Aeschynomene virginica*) | Rice, soybean |
| USA 1987 | Dr BioSedge | *Puccinia canaliculata* | Yellow nutsedge (*Cyperus esculentus*) | Several row crops |
| Canada 1992 | BioMal | *Colletotrichum gloeosporioides* f.sp. *malvae* | Round-leaved mallow (*Malva pusilla*) | Wheat, lentils, flax |

# Registered Microbial Herbicides 1980-2010 [2]

| Country Year | Bioherbicide product | Active ingredient | Target weed(s) | Target crop or site |
|---|---|---|---|---|
| Nether-lands 1997 | Biochon | *Chondrostereum purpureum* | Woody weeds, e.g. black cherry (*Prunus serotina*) | Forest plantations |
| South Africa 1997 | Stumpout | *Cylindrobasidium leave* | Acacias (*Acacia* spp.) | Native vegetation, watersheds |
| Japan 1997 | Camperico | *Xanthomonas campestris* pv. *poae* | Turf grass (*Poa annua*) | Golf courses |
| South Africa 1999 | Hakatak | *Colletotrichum acutatum* | Silky hakea (*Hakea sericea*) | Native vegetation |
| USA 2002 | Woad Warrior | *Puccinia thlaspeos* | Dyers woad (*Isatis tinctoria*) | Farm, range, & waste lands, roadsides |

# Registered Microbial Herbicides 1980-2010



| Country Year | Bioherbicide product | Active ingredient | Target weed(s) | Target crop or site |
|---|---|---|---|---|
| Canada 2004 USA 2005 | Chontrol | *Chondrostereum purpureum* | Alders, aspen & other hardwoods | Rights of way, forests |
| Canada 2004 USA 2004 | Myco-Tech Paste | *Chondrostereum purpureum* | Deciduous tree species | Rights of way, forests |
| USA 2005 | Smolder | *Alternaria destruens* | Dodder (*Cuscuta* spp.) | Cranberry, plant nurseries |
| Canada 2009 | Sarritor | *Sclerotinia minor* | Dandelion (*Taraxacum* spp.) | Lawn and turf |

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North Joinvetch in trays: Left two trays treated with LockDown; right two trays are untreated.

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- Fact Sheet
- Brochure
- MSDS

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## New LockDown Biological Herbicide controls Curly Indigo (North Jointvetch weed) in rice crops.

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**LockDown is a post emergence herbicide that can easily be sprayed via aerial application. LockDown is easy to use, safe and effective. It is perfect for Clearfield rice systems and hybrid rice. LockDown is university-tested with 30 years of positive support research.**

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# Pathogens for weed control How successful?

- **Classical biocontrol pathogens: Primary and decisive role in controlling a few high-profile exotic invasive weeds:**
  ***Puccinia chondrillina*-skeletonweed in Australia**
  ***Entyloma ageratinae*-Hamakua pa-makani in Hawaii**
  ***Uromycladium tepperianum*-Port Jackson willow in South Africa**
- **Bioherbicides: Only three have achieved some measure of success in the marketplace:**
  **Collego/Lockdown**
  **Chontrol and Myco-Tech Paste**
  **Sarritor**

# The classical vs. the bioherbicide

- Two advantages of classical biocontrol:
  - Almost exclusively public funded and public policy-driven
  - Implementation is not dependant on clients/ customers to purchase & use it
- Conversely, bioherbicides require:
  - Capital outlay for industrial R&D
  - A willing registrant
  - Willing customers

# The classical vs. the bioherbicide

- As bioherbicides typically consist of native pathogens, they do not face the same regulatory burden of proof that exotic pathogens must bear
- Classical biocontrol agents must satisfactorily address the <u>sole and inflexible criterion</u> of host specificity
- The bioherbicides face a more flexible, case-by-case approach to risk analysis

# Microbial control of weeds
## Successful or disappointing?

- It has been written up that the level of success of microbial weed control (i.e., projects that produced a usable agent or product) is insignificant, i.e., too few
- My view: the 39 agents and products that have been implemented have resulted from about 100 weed-pathogen projects (39% fruition rate; 39 over four decades)
- This “rate of success” higher for classical biocontrol
- This is a high rate of return given that the number of naturally occurring pathogens suitable for development is small and finite

# Types of pathogens

- **Majority fungi:**

  **Rusts (17); coelomycetes (9; *Colletotrichum, Phoma, Phloeospora,* and *Septoria*); hyphomycetes (3; *Alternaria, Cercospora,* and *Phaeoramularia*); agaricomycetes (2; *Chondrostereum* and *Cylindrobasidium*); 1 each in ascomycetes (*Sclerotinia*), oomycetes (*Phytophthora*), and smuts (*Entyloma*)**
- **So far, only one bacterial pathogen registered as a bioherbicide**
- **A plant virus-based bioherbicide is under EPA review for possible registration**
- **In the future, more emphasis on bacteria and viruses justified**

# Types of target weeds and crops/sites

- Used in cranberries, golf greens, grain fields, natural areas (urban and rural lands, woodlands, forests), plant nurseries, orchards, timber plantations, rangelands, and waterways
- Dodder, a parasitic weed is also a bioherbicide target
- Efforts to develop bioherbicides for weeds in row crops (e.g., soybean, tomato), a major market, have failed for reasons to be explained

# Availability/suitability of support technologies

- **Existing microbial technology in private industries is adequate**
- **Likewise, formulation technology, both proprietary & published, can be adopted for different types of pathogens**
- **Preference is for application with conventional application tools, such as tractor- or aircraft-mounted sprayers, a mower with mow-and-smear capability, backpack sprayers, and hand application**
- **Need for special application equipment is a deterrent to the adoption of microbial control agents into existing weed-management programs**

# Why is microbial weed control underutilized?

# Welcome to the Three Ring Circus!

# Why underutilized?

- **Efficacy and consistency of performance play out as major constraints when bioherbicides reach the commercial field-testing stage**
- **Often this results from the fact that many pathogens do not have the capability * to control weeds that typically have <u>a variety of survival strategies</u>, including the ability to compensate for disease**

*** Virulence/aggressiveness, rate of reproduction, and/or environmental fitness**

# Efficacy-consistency dilemma
## Two possible solutions

- Basic research and technical innovations can help assure high efficacy and consistency
- However, it is not possible to undertake comprehensive studies unless the bioherbicide pathogen has reasonable economic prospects in the marketplace
- Genetic engineering can provide solutions; some workers have proposed using genetically engineered pathogens for weed control
- Presently no genetically modified pathogen has been approved for weed control

# A formidable competition

- **Strongest reason for underutilization of microbial herbicides: competition from chemical herbicides**
- **Broad-spectrum chemical herbicides serve the needs a clientele accustomed to chemical herbicides**

# Ways to position bioherbicides in the marketplace

- Targeting niche markets is one solution, e.g., bioherbicides for markets where chemical herbicides are unavailable or unacceptable
- Two examples: Collego and Sarritor
- Chontrol and Myco-Tech Paste could gain significant market shares as alternatives to chemical herbicides
- Sarritor, Chontrol, and Myco-Tech Paste all contain pathogens with broad host-ranges; so it may be possible to offer these to a broader market than a highly host-specific bioherbicide that is effective only against a single weed target

# Regulatory framework, support structures, and some issues

- APHIS-TAG (Technical Advisory Group for Biological Control Agents for Weeds) review process for the introduction and use of exotic pathogens
- EPA-FIFRA biopesticide registration process
- They are adequate, in my opinion
- The latter is registrant-friendly; the tiered testing protocol and the ability for case-by-case risk analysis provide a clear roadmap to develop registration data
- For instance, the case-by-case approach allows for broad host-range pathogens to be considered from a strain level rather than the taxon level
- Similarly, members of fungal genera that are known to produce several toxins may be registerable if the strains in question are atoxigenic or produces no mycotoxins

# Regulatory framework and support structures

- Petition to release and use exotic biocontrol pathogens in the United States must be reviewed and recommended by the TAG and approved by APHIS-PPQ
- In addition, these agents may/will require EPA registration since their use for weed control invokes a "pesticidal claim"
- Interstate movement of registered bioherbicide pathogens. Currently, the registrant should petition APHIS for a permit(s) to ship the bioherbicide pathogen across state lines
- In addition, the bioherbicide should be registered with the Departments of Agriculture in each state where it will be used

# Current regulatory process
## Threatened & endangered species

- Assessment of risks to T&E spp. is integral to both the EPA registration and TAG processes
- Testing of T&E species could be onerous
- Should focus on a case-by-case need for risk assessment
- Collecting/acquiring T&E plant material for testing can be problematic
- Microbial weed control agents could help rather than hurt the recovery and preservation of T&E species

# Support structures in place and needs

- Thank heavens for the IR-4 Biopesticide Program!
- Also for the USDA-NIFA-Small Business Innovation Research program!
- A basic & applied NIFA grants program for microbial biocontrol agents would be nice
- A program to incentivize the adoption of microbial biocontrol by users - NRCS-EQIP model is needed

# Way forward: the needs

- More intensive networking & communication among research, regulatory, industry, and user groups
- Networking is critical to clear misperceptions of pathogens
- The “pathophobia” – unfounded fear of mutability of pathogens, unpredictable genetic recombination, unpredictable nontarget attack, mycotoxins, environmental buildup, etc.
- Current regulatory oversight addresses these concerns, so we need to overcome this fear

# Research needs

- **More SYs to replace retiring scientists and to strengthen research in newer areas of pathogen biology, weed biology, fermentation, formulation, and application technologies**
- **Resources are needed to address both basic and applied sciences (see above: proposed funding initiatives)**
- **Need to move beyond the search & screen stage**
- **Search & screen is the life blood, but we need to emphasize physiological and molecular effectors of pathogenicity and plant death**

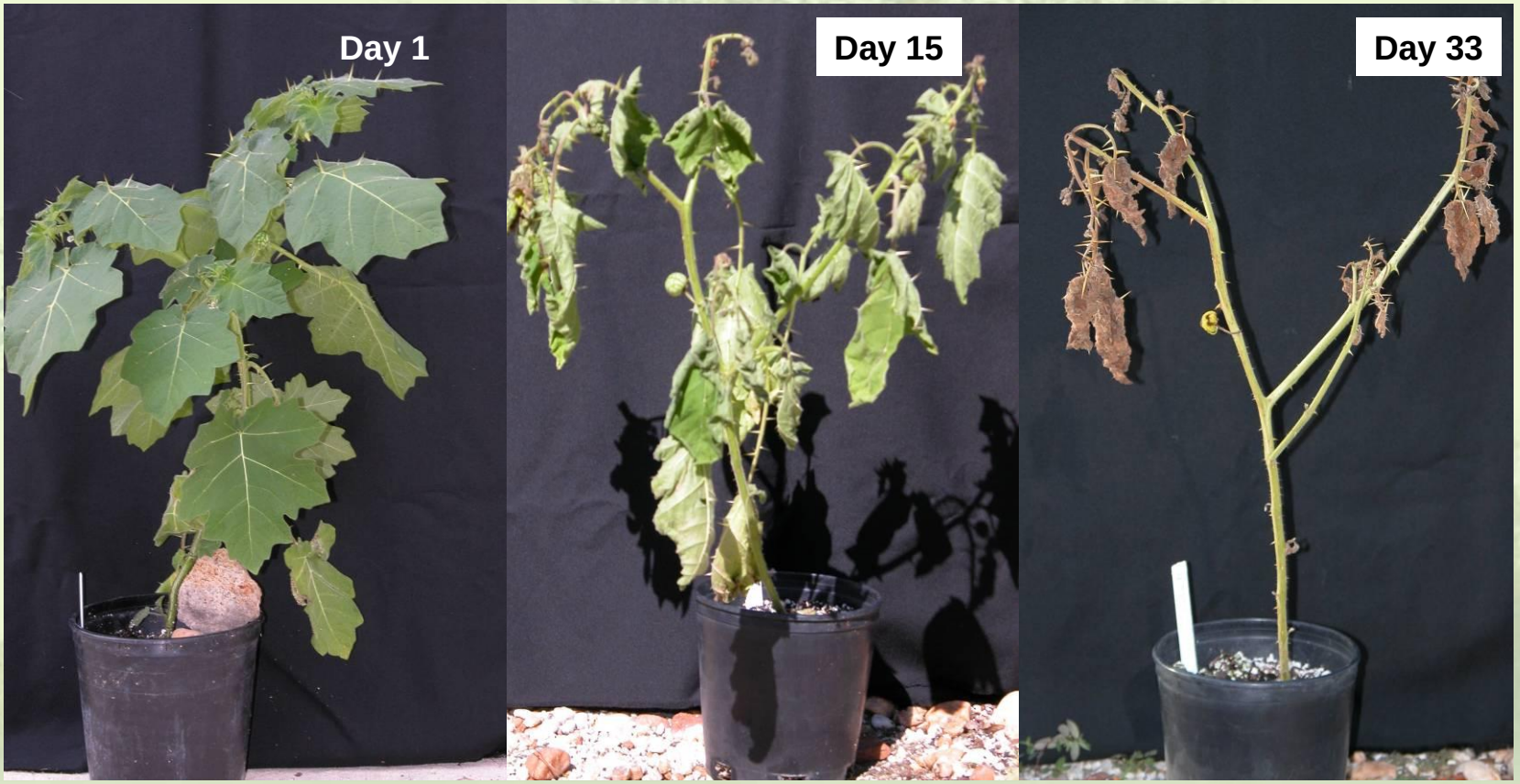
# A pathogen that is 100% effective and 100% consistent: *SolviNix* LC™

## A plant virus-based bioherbicide for tropical soda apple

# What does TMGMV do to TSA?

- Infects and kills TSA fairly quickly and consistently
- TSA dies from a lethal hypersensitive response to the virus infection -- the plant self-destructs as it responds to TMGMV infection
- About a week after inoculation, a few leaves develop dead spots or lesions
- About 3 weeks after inoculation, the plants suddenly wilt
- The wilted plants die completely in 4 to 6 weeks
- TSA plants of all ages -- from the seedling stage to full maturity -- are killed

# How does ***SolviNix*** work?



# How does ***SolviNix*** work?

**View of Site 2 - 05-22-2009**

**View of Site 2 - 07-23-2009**

# Thank you!