Discovery & Development of Natural Products for Controlling Weeds
Pam Marrone, CEO & Founder
Fewer New Chemicals – Higher Cost

Source: Ag Chem New Compound Review (Vol 25) 2007

Increasing resistance to glyphosate; few new herbicidal modes of action since RR crops

(Source: CropLife)
Herbicides from Microorganisms

Basta - Glufosinate ammonium

- Phosphinothricin (a breakdown product of bialaphos) discovered from *Streptomyces viridochromogenes* and *S. hygroscopicus*
- Inhibits the activity of the glutamine synthetase enzyme, which causes ammonia build-up in the cell.
Herbicides from Microorganisms

Methoxyhygromycin

- Produced by *Streptomyces* sp. 8E-12 (Korea)
- Bleaches and kills plants
- Has some selectivity to cucumber, rice, wheat and soybean
Herbicides from Plants
Leptospermone

- From the *bottlebrush tree Callistemon citrinus*
- Developed into Callisto® herbicide (mesotrione) by Syngenta
- Mesotrione inhibits an essential plant enzyme, HPPD (p-hydroxyphenyl pyruvate dioxygenase) that is found primarily in the cytoplasm of the chloroplasts
What We Do

We discover, develop, and market effective and environmentally responsible natural products (biopesticides) that fill unmet needs for weed, pest & plant disease management.

• Products that improve yields and quality in conventional ag compared to chemical-only systems
• Products that lower the cost and increase yields in organic farming
• Products for water treatment and water bodies
Company Overview

- Founded April 2006 by industry expert, serial entrepreneur Pam Marrone in Davis, California
- 54 employees; 12 PhD, 7 MS, 4 MBA, 30 BS, 1 AS
- Selling GreenMatch® Bioherbicide and Regalia® Biofungicide
- Products in advanced development:
  - Zequanox™ Invasive mussel product - launch early 2011
  - Two bioinsecticides and two bioherbicides waiting EPA approval – launch 2011/12
- 7 U.S., 10 international patents filed
- $23.5 million of invested equity capital
Microorganisms Isolated From Unique Habitats and Geographies

Samples from Areas of high biodiversity are cultured on specific media.

Individual fungal, bacterial, and actinomycete colonies picked from primary plate.

Fermentation broths are used for bioassays.

Purity is confirmed on separate plates.
Biological Efficacy Testing

Nematode Screening

Seedling assay

Herbicide Screening

In vivo screen

Weed screen includes high throughput enzyme assays for systemic mode of action

Plant Disease & Insect testing - miniaturized, automated assays vs. pest or plant pathogen

Seed Treatment & Nutrient Efficiency screens

Algaecide screening
Natural Product & Analytical Chemistry

- Characterize/identify pesticidal compounds produced by the microbes or plants
- Eliminate strains with harmful compounds
- Develop analytical assays based on bioactive chemistry for QC
Fermentation and Formulation

- Optimize processes
- Scale up - pilot & manufacturing
- Field trials
- Registration

Develop user-friendly formulations (wettable powder, WDG, liquid suspension, RTUs) & packaging
Strategy: develop multiple products in parallel to create substantial revenues and high growth

Product Pipeline

Market Entry Date

May 09
Jul 09
Nov 10
Feb 11
Sep 11
Nov 11
Jun 12
Oct 12
Feb 13

Haven™ Anti-transpirant

GreenMatch™ Organic Burndown Herbicide
Regalia™
ZEQUANOX™

MBI 203 Insecticide
MBI 005 Herbicide
MBI 206 Insecticide
MBI 010 Herbicide
MBI 302 Nematicide
Active Ingredient: d-limonene ................... 55%
Inert Ingredients: ..................................... 45%
Total: ..................................................... 100%

• An effective burndown for organic only – price of raw materials too high for conventional
• Good first entry into the market to understand what organic growers want for weed control compared to hand weeding, tractor cultivation, flaming and landscape fabric, etc.
• Will be replaced by other MBI products
Before and After - Examples

Before Treated

After Treated with GreenMatch
Bindweed – Camarillo, CA
14 Days After Treated

Before Treated

After Treated with GreenMatch
14 DAT, 14% dil. 60 GPA
Bindweed – Yakima, WA
7 and 14 Days After Treated

After Treated with GreenMatch
7 DAT, 14% dil. 60 GPA

After Treated with GreenMatch
14 DAT, 14% dil. 60 GPA
Irrigation Channel – Gonzales, CA
14 Days After Treated

Before Treated

After Treated with GreenMatch
55F, 17% dil @ 65 GPA
MBI 005 – Selective Bioherbicide

*Identified as active vs. sedges in rice by Dupont*

- Broad spectrum control of broadleaf weeds and sedges
- **Uses:** Rice, corn, wheat, sugarcane, sorghum, turf
- **Active ingredient:** Thaxtomin *from* *Streptomyces* *spp.*
- **Regulatory status:** Pending at the EPA

Aquatic sedge control
MBI 005 Efficacy on Rice Weeds - Sedge and Sprangletop (greenhouse)

<table>
<thead>
<tr>
<th>Rate of MBI-005 (arbitrary units)</th>
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<tr>
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<tr>
<td>5 days</td>
</tr>
<tr>
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</tr>
<tr>
<td>1</td>
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<td>2</td>
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<tr>
<td>4</td>
</tr>
<tr>
<td>8</td>
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</tbody>
</table>
MBI 005 Tank Mix with Clincher® CA

Greenhouse Test - Rice

Effect on the most common rice weeds in the Northern Central Valley in California was evaluated 8 days after treatment

<table>
<thead>
<tr>
<th>MBI-005 @ increasing dose, with Clincher®</th>
<th>Redstem</th>
<th>Waterplantain</th>
<th>Sedge</th>
<th>Sprangletop</th>
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<tr>
<td>8</td>
<td>100</td>
<td>85</td>
<td>100</td>
<td>100</td>
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</tbody>
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Clincher® CA is a product of Dow AgroSciences
MBI 005 Good Dandelion Control

Dandelion Test
Pre-treatment (17 days old)

UTC
MBI-005 1.0 mg/mL
MBI-005 0.5 mg/mL
Roundup 1 fl oz/gal

10DAT

24DAT
Sarmentine as a Herbicide

- Methanol extract of dry long pepper (*Piper longum* L.) fruits showed herbicidal activity in our screen.
- Used in Chinese medicine and as an anti-oxidant and solubilizer of hydrophobic compounds in cosmetics.
- At 5 mg/mL has good activity against most grass and broadleaf weeds.
- Mode of action looks similar to pelargonic acid.
- MBI filed a patent application for use of sarmentine to control plant pests.
Control of different plant species when treated with 5.0 mg/mL Sarmentine

<table>
<thead>
<tr>
<th>Plant name</th>
<th>Control</th>
<th>Plant name</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigweed</td>
<td>80-100%</td>
<td>Lambsquarters</td>
<td>80-100%</td>
</tr>
<tr>
<td>(<em>Amaranthus retroflexus</em>, L.)</td>
<td></td>
<td>(<em>Chenopodium album</em> L.)</td>
<td></td>
</tr>
<tr>
<td>Barnyard grass</td>
<td>80-100%</td>
<td>Bluegrass</td>
<td>80-100%</td>
</tr>
<tr>
<td>(<em>Echinochloa crus-galli</em> L.)</td>
<td></td>
<td>(<em>Poa annua</em> L.)</td>
<td></td>
</tr>
<tr>
<td>Bindweed</td>
<td>80-100%</td>
<td>Wild mustard</td>
<td>80-100%</td>
</tr>
<tr>
<td>(<em>Convolvulus arvensis</em>, L.)</td>
<td></td>
<td>(<em>Brassica kaber</em> L.)</td>
<td></td>
</tr>
<tr>
<td>Crabgrass</td>
<td>80-100%</td>
<td>Black nightshade</td>
<td>80-100%</td>
</tr>
<tr>
<td>(<em>Digitaria sanguinalis</em> L.)</td>
<td></td>
<td>(<em>Solanum nigrum</em> L.)</td>
<td></td>
</tr>
<tr>
<td>Horse weed</td>
<td>&lt; 20%</td>
<td>Curly dock</td>
<td>80-100%</td>
</tr>
<tr>
<td>(<em>Conyza Canadensis</em> L.)</td>
<td></td>
<td>(<em>Rumex crispus</em> L.)</td>
<td></td>
</tr>
<tr>
<td>Sprangletop</td>
<td>80-100%</td>
<td>Wheat (PR 1404)</td>
<td>80-100%</td>
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<tr>
<td>(<em>Leptochloa fascicularis</em> Lam.)</td>
<td></td>
<td>(<em>Triticum aestivum</em> L.)</td>
<td></td>
</tr>
<tr>
<td>Dandelion</td>
<td>80-100%</td>
<td>Rice (M 104)</td>
<td>0%</td>
</tr>
<tr>
<td>(<em>Taraxacum officinale</em> F.)</td>
<td></td>
<td>(<em>Oryza saliva</em> L)</td>
<td></td>
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MBI 010 - Our “Organic Roundup®”

SYSTEMIC HERBICIDE
(e.g. glyphosate=Roundup®)

MOVEMENT IN PLANTS

Water movement in plant

Long term control of weeds – roots are killed after spraying the leaves

- New species of bacteria discovered from our screen
- Two novel systemic compounds produced by the bacteria
- Broad spectrum weed control
- Not the same mode of action as glyphosate
- Fermentation and formulation are critical for activity
**Phoma macrostoma**

**Bioherbicide**

- Karen L. Bailey, Agriculture and Agri-Food Canada (AAFC)
- Discovered from diseased sow thistle
- Licensed to Scott’s for turf
- Control of: dandelion (68%), field bindweed (60%), annual sow thistle (97%), and wild mustard (82%).
- Some reduction in perennial sow thistle, smart weed, Canada thistle, false cleavers, hemp nettle, and Brassica (25-50%).
- No effect on stinkweed, lambs quarters, and wild oat.
- Best on emerging seedlings; less effective on well established weeds using a single application
*Pseudomonas fluorescens* Strain BRG 100

Control of green foxtail & wild oats

"Pesto" formulation

Sue Boyetchko & Russell Hynes, AAFC
Pseudomonas fluorescens
Strain BRG 100

Pre-emergence annual grass control in wheat
Bioherbicides – an Emerging New Category for Biopesticides

• There is a need for new modes of action for weed control
• Efficacy can equal chemicals
• Can be combined with chemical pesticides for better weed control
• In some cases, costs can compete with chemical products
• Microbial strain selection, characterization of associated herbicidal compounds, and formulation are keys to efficacy
Thanks to Dr. Marja Koivunen, VP of Research and all the scientists at MBI for the work in this presentation