Bioenergy Research at BNL: Increasing Productivity Using Biological Interactions

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So who am I?

- Education
- Work
- And beyond
What Type of Research Do I Do?
Phytoremediation

A solar driven, plant based system that is used to contain, sequester, remove, or degrade organic and inorganic contaminants in air, soils, sediments, surface water, and groundwater.
Monitoring
Biofuels

• What are Biofuels?
• Where do we get them from?
  • Sugars
  • Starch
  • Vegetable Oil
  • Animal fat
  • Wood
  • Charcoal
  • Dried excrement
• In order for the fuel to be considered a “biofuel” it must contain at least 80% renewable material
At the Most Basic

- Burning plant material for heating and cooking
Biofuels for Transportation
Biofuels for Transportation

• Nicolaus August Otto (1879)
  • Invented the internal combustion engine

• Rudolf Diesel (1898)
  • Invented the diesel engine

• Henry Ford (1903–1923)
  • Founded the Ford Motor Company
• "The fuel of the future is going to come from fruit like that sumach out by the road, or from apples, weeds, sawdust -- almost anything," Henry Ford said. "There is fuel in every bit of vegetable matter that can be fermented. There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the fields for a hundred years."
Biofuels: What happened to Them?

- Texas and Pennsylvania and the Roaring 20's
Why do we need them now?

• 1973 to Present
$\text{CO}_2$ and the Atmosphere

RECENT MONTHLY MEAN $\text{CO}_2$ AT MAUNA LOA

PARTS PER MILLION

YEAR

2004 2005 2006 2007 2008 2009

390

385

380

375

370
“Enough” biomass for biofuel?

- 50B gallons of EtOH would require approximately 1B dry tons of biomass per year (DOE-USDA “Billion ton study”).
- Corn based biofuel economy has major consequences:
  - Price of corn has doubled
  - Farmers are planting more corn for ethanol
- Increase alternative feedstock production without competition for food production or endangering our natural heritage:
  - More than one use per crop
  - Growth of lignocellulosic biomass on marginal soils.

Determining which plant species can be grown to produce both high biomass for energy production as well as oil for biodiesel.
Biosolid Comparison of Seed Mass per Plant

Seed mass per plant

<table>
<thead>
<tr>
<th>Species</th>
<th>Avg. Seed Mass in Grams</th>
</tr>
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<tbody>
<tr>
<td>Helianthus annus</td>
<td>50</td>
</tr>
<tr>
<td>Brassica juncea</td>
<td>5</td>
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<tr>
<td>Glycine max</td>
<td>50</td>
</tr>
<tr>
<td>Ricinus cominus</td>
<td>50</td>
</tr>
</tbody>
</table>
Biomass per plant

Species

- Helianthus annus
- Brassica juncea
- Glycine max
- Ricinus comminus

Mass in Grams

0 200 400 600 800 1000 1200 1400
Poplar trees for biomass production and cleaning the environment

Poplar is one of the trees of choice for biomass production and phytoremediation of contaminated groundwater

• Impressive production of biomass on many soil types
Endophytes

• What are endophytes?

Previous work with endophytes showed improved phytoremediation
Improved poplar biomass production

• Can bacteria be used to improve biomass production of poplar on marginal soils?
  – Selection of bacterial strains
  – Greenhouse studies
  – Field experiments

Distribution of cultivable root bacteria isolated from poplar

Brookhaven Science Associates
Beneficial effects of bacteria on their host plant

• Short term effects - improved plant establishment on marginal soils
  – Accelerated root development
  – Faster initial growth

• Long term effects - improved plant growth, health and survival, leading to economically sustainable feedstock production
  – Counteracting environmental stress
  – Protection against pathogens
Change in Growth

[Bar chart showing growth changes for different samples over various dates: 28-Jun, 8-Jul, 18-Jul, and 30-Jul. Each sample is represented by bars of different colors and heights.]

Samples include CONTROL, BU72, CH34, W619, STEN MALT, M. populi BJ001, ENTERO, and SERR 568.
Production of plant growth promoting compounds

- Auxins influence root morphology, inhibit root elongation, increasing lateral root production and inducing adventitious roots
- Auxins include indole-3-acetic acid, phenylacetic acid, indole-3-butyric acid, acetoin
So how do they do that?

- Prior colorimetric methods showed low levels of IAA production (most common auxin).
- But what of others?
Growing conditions

- Grow bacteria in presence of plant extracts
  - Look for production of other plant-growth related compounds
- Grow bacteria in presence of plant sugars
  - Simpler to quantify reaction
Compounds of interest

- Diacetyl
- Acetoin
- 2,3-butanediol
Enterobacter sp. 638 alone
Enterobacter sp. 638 grown with poplar extract
How else do they affect the plant?
Protein levels

Week

June 24 | July 10 | July 22

Protein (mg g\(^{-1}\) FW)

0 10 20 30 40 50
Poplars and more poplars
Hardwoods
And still more
Where do we go from here?

- Genetic analysis of bacteria and plants
- Physiological responses of plants
Other areas

- PET imaging
- NSLS
- Field site
  - On BNL
  - SUNY-Environmental Science and Forestry at Syracuse
- Energy garden
• Develop collaborations with local/state schools and Universities to train students
  – Dowling College
  – Stony Brook Southampton
  – Syracuse University
  – SUNY-Environmental Science and Forestry at Syracuse
  – City University of New York
  – Sachem Central School District at Holbrook
Field Site

• Grow a variety of plants on site with different growing conditions
  – Soil amendments
  – Endophytes

• Determine which plants/conditions are of optimal productivity here on Long Island

• Develop strategy for full-scale production of biofuel at BNL
**POPLAR**

Poplar hybrids

Poplars are native to North America. Their leaves are broad and oval, and they thrive in moist, sandy soils.

*The perfect poplar for biofuel doesn’t exist, but scientists at the Department of Energy think they’re close to creating one.*

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**CASTOR BEAN**

*Ask your grandparents about castor oil, and she’ll tell you that it used to be a common household medicine.*

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**POWER PLANTS**

*Farming Energy*

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**Plants in the Garden**

1. Castor bean
2. Barley
3. Mustard
4. Jatropha
5. Sugarcane
6. Corn
7. Sunflower
8. African oil palm
9. Soybean
10. Switchgrass
11. Poplar
12. Sorghum
13. Algae
14. Alfalfa
15. Sugar beet
16. Cuphea
17. Miscanthus
18. Camelina
19. Lesquerella
20. Peanuts
21. Canola
Remember to Thank a Plant today!