IOWA STATE UNIVERSITY

Plant Sciences Institute UPDATE

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Crop Protection Initiative takes new direction

This year Iowa suffered extensive outbreaks of soybean aphids, *Aphis glycines*. Millions of acres of farmland were sprayed to control the pest, because if left untreated, aphids can reduce soybean yields by up to 40 percent.

Originating from Asia, these aphids first appeared in the Midwest in 2000, and every few years since, troublesome outbreaks have occurred.

To develop new tools for managing soybean aphids, the Plant Sciences Institute has launched a new project in the Crop Protection Research Initiative. Funding from the institute and the Iowa Soybean Association is making it possible to attack the problem from two different angles.

Gustavo MacIntosh, assistant professor in the Department of Biochemistry, Biophysics and Molecular Biology, will use microarrays—gene chips containing copies of soybean genes—to compare the gene expression patterns of resistant and susceptible aphid infested soybean plants.

"This will give us a very good idea of the signaling and metabolic networks that function in this response," said MacIntosh.

Additionally, MacIntosh's lab will study the differences in chemical makeup of

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A research initiative before its time

Ernest W. Lindstrom created the first genetics department at Iowa State. He headed the department for 26 years.

The prosperity of Iowa agriculture owes much to the development of hybrid corn. The robustness of hybrids is attributed to the phenomenon called hybrid vigor or heterosis. Scientists have been trying to figure out the molecular mechanism for hybrid vigor for the better part of a century.

In the mid-1930s, as hybrid corn was becoming a feature in the Iowa landscape, Professor Ernest W. Lindstrom was conducting genetic experiments hoping to reveal the mechanisms responsible for heterosis.

Lindstrom came to Iowa State to create and lead a new genetics department. His interest centered on testing the hypothesis that dominant gene action explains why hybrids are larger than their inbred parents. He started by debunking an existing theory: that heterosis was nothing more than an initial advantage in embryo size and not due to greater growth efficiency.

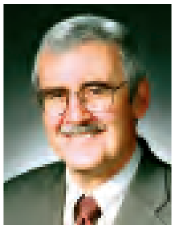
In a paper entitled "Genetic experiments on hybrid vigor in maize" in *The American Naturalist* (1935), Lindstrom presents experimental results in which the so-called initial growth advantage of hybrids was reduced by cutting them back above the growing point. When the hybrids grew back much bigger than their untouched parents, it was clear proof that the plants had an inherent growth advantage. This was one of some 50 papers published by Lindstrom throughout his career.

Lindstrom served as the genetics department head for 26 years. For his in-depth knowledge of genetics research, he was recruited away from Iowa twice. In 1927, the Rockefeller Foundation invited him to Paris to assist the International Education Board in selecting researchers worthy of funding. It is said that this task made him realize how much

CONTINUED ON PAGE 2

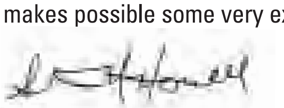
Massively parallel science

The Plant Sciences Institute helped to usher in a whole generation of genomic-related technologies to the Iowa State University campus. But advances in technology never end, so it is important that we stay ahead in this rapidly evolving area. DNA sequencing is an example of the rapid pace of technology. The sequence of the human genome was completed in 2003 by a public consortium costing more than $500 million. Since that time, newer sequencing technologies have appeared that would reduce the costs for sequencing a whole human genome to $100,000. New sequencing technologies are "massively parallel sequencing platforms" that allow for millions of pieces of DNA to be sequenced all at once, producing as much as one terabyte (1 trillion bytes) of raw data every three days.



What is the use of that much information? One important application is "metagenomics," the analysis of DNA of whole populations of organisms, not just from a single organism. A metagenomics analysis can be conducted on a sample of soil containing hundreds of different microbes. Other uses might be surveys of all genes expressed in a given plant or animal. For example, from "deep" sequencing analysis of RNAs obtained from a single plant tissue, one could determine all the genes that are expressed in that tissue. Such an approach has been undertaken in a project led by Patrick Schnable, professor in the Departments of Agronomy and Genetics, Development and Cell Biology and director of the Center for Plant Genomics, in which they used a massively parallel sequencing platform to characterize RNAs isolated by laser microdissection from the shoot apical meristems of corn plants (Emrich et al. 2007, *Genome Research* 17: 69-73).

So while the rapid pace of technological development presents challenges, it also makes possible some very exciting science.



Stephen Howell
Director

Closing a gap

"Even with 15 years worth of genomic research, a gap still remains between research discoveries and their application to crop improvement," says Bill Beavis, George F. Sprague Endowed Chair and professor in the Department of Agronomy.

"When plant breeders and agronomists have a problem in the field, they do not use the results of genomics to address the problem," says Beavis, a leading expert in bioinformatics who joined Iowa State in August, and who aims to put genomic information into the hands of those who will use it.

Beavis envisions diagnostic kits that provide growers, breeders and agronomists real-time decision support—biomarkers that might show disease or chemical drift, for example. They'll grind up a leaf, do a chemical test and get a read on patterns on the spot. A handheld portable device will send data to a database for a diagnostic match, and the database will return information in a decision support format.

"For example, sometimes plants are sick but they don't show symptoms, yet they're spreading the disease to their neighbors," Beavis said.

The uses for diagnostic kits will be broad. For instance, a breeder may obtain DNA-based information on plant characteristics that are not observable every year.

Beavis received his Ph.D. in plant breeding at Iowa State. He gained extensive experience in the application of statistical genetic methods during 12 years at Pioneer Hi-Bred International, Inc. (1986-1998).

For the past 10 years, Beavis served as chief scientific officer at the National Center for Genome Resources, in Santa Fe, New Mexico, where he was the principal investigator for a variety of bioinformatics projects, including the Arabidopsis Information Resource (TAIR) and the Legume Information System (LIS). There he also identified a set of biomarkers that can be used in a handheld diagnostic kit by clinicians—a simple blood test with 45 markers that predict sepsis in patients.

Beavis is credited with recognizing the statistical anomaly whereby the genetic effects of quantitative trait loci (QTL) are overestimated when searching genomes for genes associated with desired phenotypic traits—"the Beavis Effect."

A research initiative before its time/CONTINUED

he missed his own research. In 1944, Lindstrom spent a year establishing a genetics department at the National University of Medellin, Columbia, South America.

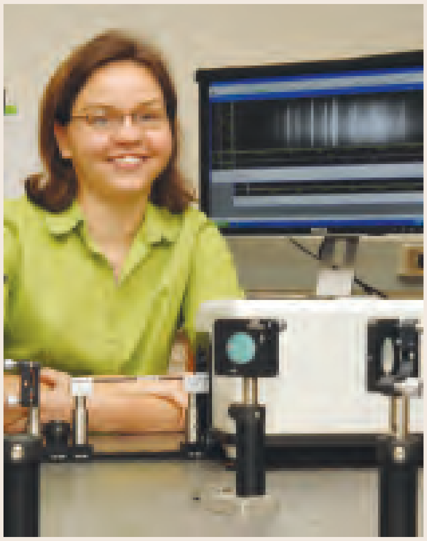
Lindstrom was highly sought after on campus. He conducted an extremely popular genetics seminar, served up a wealth of sound counsel to many commercial corn breeders and developed Lindstrom Long Ear (LLE)—the source of ear length advancements in the modern inbred corn lines developed by Raymond F. Baker.

Seventy-five years later, Iowa State plant scientists are carrying forward the work of Lindstrom—continuing the effort to understand the molecular mechanisms responsible for heterosis.

Modern technological advances have made new approaches possible. As part of the Plant Sciences Institute's Genomics Research Initiative, Patrick Schnable, initiative leader, and Dan Nettleton, professor in the Department of Statistics, have used microarrays or DNA chip technology to study the expression of thousands of genes in an F1 hybrid as compared to its inbred parents.

In 1937, Lindstrom became vice dean of the Graduate School while still maintaining his faculty responsibilities. In 1943, Iowa State President Charles Edwin Friley appointed Lindstrom to lead a committee for planning a maize museum. The museum never materialized, though records show a site on U.S. Highway 30 had been selected. But in many ways, Iowa agriculture is a living museum to corn.

Getting a rapid read on plants



A new tool being developed at Iowa State will allow scientists to swiftly assess qualities in plants being selected and grown for eventual conversion to biofuels.

Emily Smith, assistant professor in the Department of Chemistry, is developing the tool with the help of funding jointly provided by Ames Laboratory and the Plant Sciences Institute.

Smith is using Raman imaging, a spectroscopy technique coupled to an optical microscope, to look at plant microstructure—individual plant cells or tissues. The tool can be used to determine how much lignin, cellulose and hemicellulose are present—important factors in determining when a plant can most efficiently be converted to fuel. Lower lignin content may be a desired trait for biofuel feedstocks.

"The ultimate goal is to provide information that can be used by people who are genetically modifying or engineering plants that are going to be suited for high ethanol conversion efficiencies," Smith said.

Plant scientists are engineering plants to reduce the synthesis of lignins or to alter the types of lignins made. The Raman imaging tool could quickly illuminate their degree of success.

Smith also hopes to collaborate with scientists in the Department of Agronomy to study the correlation of different growing conditions with plant composition.

The new method offers several advantages over other techniques, says Smith. Analysis with the Raman tool is quick and requires only small samples to be taken over time. This minimizes damage to the plant. Additionally, the method uses an intact piece of plant leaf allowing a view of whole plant cells, whereas many other techniques require extraction and grinding of the plant material.

Smith added that there are other applications, too. She envisions a handheld device used by farmers in the field to help determine optimum harvest times. That reality may be a few years down the road. For now, Smith hopes to team up with collaborators on campus who specifically grow crops for ethanol conversion.

"This research touches on potentially important issues in the bioeconomy," said Ames Lab interim director Alan Goldman. "I regard this as an excellent, excellent first collaboration between Ames Lab and the Plant Sciences Institute to help develop the potential of young scientists at Iowa State."

Crop Protection Initiative/CONTINUED

Gustavo MacIntosh, assistant professor in the Department of Biochemistry, Biophysics and Molecular Biology, is studying soybean plant responses to aphid infestation.

resistant and susceptible soybean plant cells. This "metabolomic" information will be meshed with the gene expression data to glean a full view of the plant's defense mechanisms.

"With microarray analyses we know the players, but we don't know the game," said MacIntosh. "With metabolomics we know the game—we know exactly what is changing in the plant at the level of metabolites and what has an effect on the aphids."

MacIntosh's preliminary research suggests that soybean plants respond differently to predation from aphids as opposed to other insects and that stress plays an important role in modulating these responses.

It is the hope that MacIntosh's research will help breeders or genetic engineers to develop more resistant soybean plants.

Allen Miller, director of CPRES and professor in the Departments of Plant Pathology and Biochemistry, Biophysics and Molecular Biology, is working with Bryony Bonning, CPRES affiliate and professor in the Department of Entomology, to develop the equivalent of a Bt toxin for aphids. They are attempting to coax viruses from a variety of aphid species to control soybean aphids.

Miller and Bonning are also developing a virus-based tool called virus induced gene silencing (VIGS) to characterize aphid gene expression. Using a virus to introduce an aphid gene of interest, the host will see it as an "alien gene" and destroy that gene and its own in the process.

"We can use VIGS to knock out genes in aphids of interest and see how that affects their ability to infest plants," said Miller.

Additionally, Bonning's lab is sampling aphids across Iowa in search of new soybean aphid viruses. The high soybean aphid populations in 2007 should favor the presence of viruses.

"The Crop Protection Research Initiative fills an important niche between basic and applied research. This is basic research, but it's on crops specific to Iowa, an interesting combination," said Miller.

Recent research grants

The following 14 new grants totaling $3.9 million were awarded recently to plant science researchers at Iowa State.

Iowa Botanical Supplements Research Center
National Institutes of Health—$1,473,354
(D. Birt, food science and human nutrition)

PLEXdb: Plant Expression Database
National Science Foundation—$367,834
(J. Dickerson, electrical and computer engineering)

Coarse Grained Models of Proteins
National Institutes of Health—$248,600
(R. Jernigan, biochemistry, biophysics and molecular biology)

Collaborative Research: Molecular Genetic and Metabolic Analyses to Characterize Terpenoid Indole Alkaloid Pathways
National Science Foundation—$174,624
(J. Shanks, chemical and biological engineering)

CYP701A: A Family of Multifunctional Cytochromes P450 in Terpenoid Biosynthesis
National Science Foundation—$164,925
(R. Peters, biochemistry, biophysics and molecular biology)

Osmoprotection of *Pseudomonas syringae* During Its Association with Plants: Role of the BetT OpuC Transporters
National Science Foundation—$130,000
(G. Beattie, plant pathology)

Flaxseed Lignans for Heart Health
Archer Daniels Midland—$126,000
(S. Hendrich, food science and human nutrition)

Making Improvements to the PCAP Genome Assembly Program
U.S. Department of Health and Human Services—$102,487
(X. Huang, computer science)

Biobased Pressure Sensitive Adhesives
Avery Dennison—$74,473
(R. Larock, chemistry)

Transformation of Maize Inbred Line B104
Dow Agrosciences, LLC—$34,686
(K. Wang, agronomy)

IGERT: Computational Molecular Biology Training Group
National Science Foundation—$592,776
(D. Voytas, genetics, development and cell biology)

Computational Investigation of Cellulase and Xylanase Mechanisms
USDA, CSREES—$307,057
(P. Reilly, chemical and biological engineering)

International Biofuels Scenarios Analysis
Environmental Protection Agency—$95,000
(B. Babcock, economics)

Department of Agriculture Cochran Seed Training on Seed Programs
USDA, FAS—$19,441
(J. Cortes, Seed Science Center)

Plant Sciences Institute UPDATE

The Plant Sciences Institute Update is published four times each year by the Plant Sciences Institute at Iowa State University, 1060 Roy J. Carver Co-Laboratory, Ames, Iowa 50011-3650; phone 515 294-5255.

The Plant Sciences Institute at Iowa State University is dedicated to becoming one of the world's leading plant science research institutes. More than 200 faculty from the College of Agriculture and Life Sciences, the College of Liberal Arts and Sciences, the College of Human Sciences, and the College of Engineering conduct research in nine centers of the institute. They seek fundamental knowledge about plant systems to help feed the growing world population, strengthen human health and nutrition, improve crop quality and yield, foster environmental sustainability and expand the uses of plants for biobased products and bioenergy. The Plant Sciences Institute supports the training of students for exciting career opportunities and promotes new technologies to aid in the economic development of agriculture and industry throughout the state. The institute is supported through public and private funding.

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