Harnessing the New Sciences In Support of Agriculture in the Developing World

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Universities and their Role in U.S. Agriculture
Some History

"It was the deepest article of faith that the university would not only generate new knowledge but would also apply that knowledge to real-life problems. This is what is distinctive in the land-grant concept"

----Harold Enarson, former President of Ohio State University

How do we connect what happens here……..

With what happens here……?

The typical African farmer is a woman who farms about one hectare of land with little or no access to improved seeds, fertilizer, herbicides, pesticides, irrigation

What We're Up Against

Maize Yields in Sub-Saharan Africa

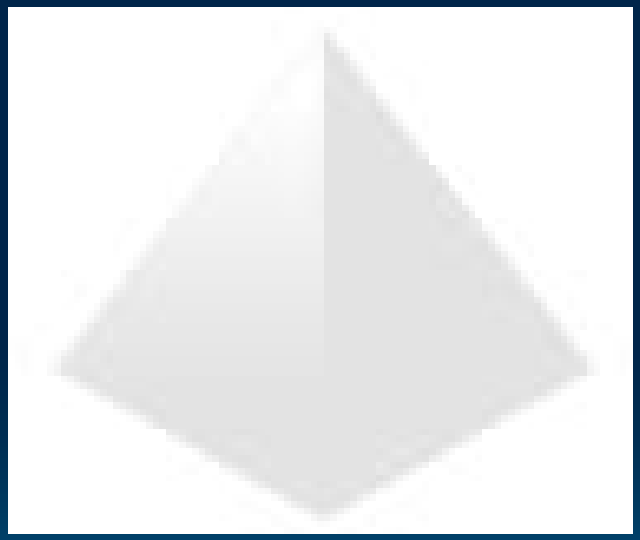
Typical small farmer yield	1.2 MT/ha
Max yield for a large commercial farm in Zimbabwe	10.0 MT/ha

High Inputs Low inputs

Key Elements that Synergize to Enhance Agricultural Productivity at the Farm Level

Improved seed

Fertilizer,
Good soil quality



Adequate Water

Good agronomic practices
Access to strong markets provide incentives

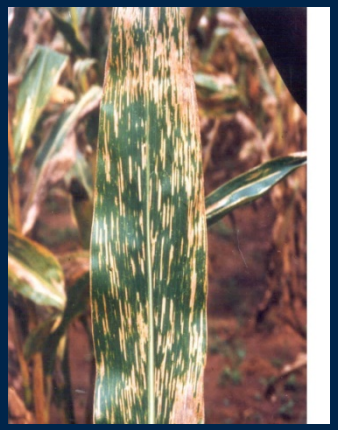
Fungal Diseases

Wheat and Soybean Rusts
(*Puccinia, Phakospora*)

Potato Blight
(*Phytophthora*)

Black Sigatoka in Banana
(the ascomycete *Mycosphaerella*)

Grey leaf spot in maize
(*Cercospora*)



Geminiviruses are a Threat Worldwide

Two cases where emergence of DNA satellites have broken resistance to geminiviruses

Cotton Leaf Curl Virus
(Pakistan)

Cassava Mosaic Virus
(sub-Saharan Africa)

Can fundamental research on small RNAs help solve this problem?
Do satellites encode suppressors of silencing?
Do they integrate into genome? Mode of action?
How to deal with this phenomenon at a practical level?

Improve Bananas in Uganda

(Collaboration beween Rahan Meristem, Israel and Ugandan national banana program)

Control parasitic nematodes through plant-mediated RNAi
(bananas express RNAi construct against nematode collagen synthase)

Might it also work for fungi? For parasitic plants? For sucking insects?

Control ripening through expression of anti-apoptosis gene on fruit-specific promoter—delays ripening by several weeks in Cavendish bananas

Control Flowering Time in Cassava and Mango

Helps breeders do crosses

Produce fruit in “off-season”

Need more promoters that are inducible by cheap chemicals or other simple manipulations

More robust transformation of tropical fruit trees

"Make breeders happy while also addressing a key regulatory issue"

Develop robust technologies for targeted gene replacement/insertion

- The ultimate in precision breeding---replace a single "bad" allele with a better one
- Identify optimal sites for gene insertion that provide high expression and stability---for all crops important to developing world
- Offers a serious and safe alternative to event-specific regulation---- very important for vegetatively-propagated crops like banana and cassava
- Exploit new findings on homologous recombination
  - Zinc finger nucleases
  - Triplex-forming oligonucleotides conjugated to DNA-cleaving orthophenantholine

A Story about Rice, Silicon, Arsenic and Cell Walls

Rice Straw Has Higher Content of Silicon (and relatively less lignin) than other major cereals

	SiO_2 (g/kg)	Lignin (g/kg)
Rice straw	~130	50
Barley straw	~20	110
Oat straw	~30	140
Wheat straw	~30	85-140

(taken from Van Soest, 2006. Animal Feed Sci and Technol 130: 137-1717)

Which can be good…….

- May play a role in disease resistance (especially rusts?)
- Can strengthen stems/leaves and decrease lodging
- 27X less ATPs used to deposit compared with lignin
  ---important for a C3 cereal?

WT Low Silicon

Or bad……..

- Can affect health of animals—creates urinary siliceous calculi
- Often correlates with poor digestibility of straw and also adversely affects pulping properties—loss of potential substrate for biofuel
- Rice residues are usually burned---no other good use and returning them to the soil contributes to stem rot.
- Burning creates big environmental effects (e.g. California, the Punjab, China)—not just air pollution but also health affects—amorphous silicon fibers

And maybe even worse…….

“Arsenic poisoning affects millions of people worldwide. Human arsenic intake from rice consumption can be substantial because rice is particularly efficient in assimilating arsenic from paddy soils,”

Recent paper by Ma et al (2008) PNAS 105: 9931

“Arsenite transport in rice roots therefore shares the same highly efficient pathway as silicon, which explains why rice is efficient in arsenic accumulation.”

Strategy for Improved Rice Straw

- Two transporters (LS1/LS2) of silicic acid from soil to root xylem also transport arsenite
- Work with single or double mutants of Ls1/Ls2; these mutants will be low in silicon and will also not transport arsenite
- Will probably need to address two issues:
  - Lowered disease resistance
  - Poor stem strength

Approaches to Wall Modification

- Enhance lignin content---could enhance both strength and disease resistance; note that rice is relatively low in lignin compared to other cereals
- Up-regulate cellulose synthesis—some problems with this, but possible
- Over-express transcription factors that regulate onset of secondary wall synthesis (myb, NAC)
- Select for silicon transporter that does not also transport arsenite---but won’t stop the burning of rice straw

Universities and their Relevance to the Developing World

Challenges!!!

- Faculty are already over-committed
- Few opportunities to identify and meet with potential partners in developing world
- Few opportunities to learn about constraints to developing world agriculture and to consider how new innovations might be relevant
- Almost no incentives to get involved!!!

Time, Opportunities, Incentives

- Competitively-funded summer study tours of Africa, Asia and Centers of the CGIAR
- More Fulbright-type opportunities relevant to international agriculture
- “Howard Hughes” Scholars for International Agriculture
  - Generous funding of basic research to selected outstanding plant scientists
  - Relief from excessive teaching and committee work
  - Scholars devote 30% of time/funds to relevant translational research
    - Learn of constraints; identify opportunities to apply innovations through targeted research projects
    - Establish long-term partners
    - Train students/post-docs
    - Sabbaticals in partner countries
    - Scholars collectively advise donors on new opportunities
- Tenure and promotion committees reward efforts at translational research
- More programs to fund exploratory translational research

Medical researchers have increasing opportunities to collaborate with clinicians

JOURNAL OF TRANSLATIONAL MEDICINE

JOURNAL OF TR ANSLATIONAL PLANT BIOLOGY??????
(ASPB?? PLoS??)

What about a Global Online Land-Grant Institution?

"…….there are many parallels between the environment in which the U.S. land grants were established in the nineteenth and twentieth centuries and the current environment in much of the modern developing and developed world. …….social unrest, post-war reconstruction, profound economic and social stratification…….the need for developing civil infrastructure, agricultural capacity, education, health, and human service systems to support economic and social capacity to scaffold the civil society".

- Ken Udas, Penn State University

Exploit the huge amount of digital teaching tools and lectures/lab protocols already available

Success Requires Integration with Downstream Efforts

The Innovation Pipeline for Crop Improvement

Capacity building opportunities at every site in the pipeline!!!!

Universities, ARIs
Gene/trait discovery
New innovations

NARS
Deep capacity to adapt crops to local germplasm; listen to farmers

Modern, finished varieties

Feedback

Market forces

Farmers

New traits
In good germplasm

Feedback

CGIAR Research Centers
Closely connected to centers of innovation
New traits from exotic germplasm

Germplasm

Traits

The Private Sector
Key traits and modern breeding

One final thought……..

We all know that success in research, as in life, requires a lot of patience