P. Stephen Baenziger

- B. A. from Harvard University
- M.S. and Ph.D. from Purdue University
- Employment
  - USDA-ARS: 1976-1983
  - Monsanto: 1983-1986 (continue to own stock)
  - University of Nebraska: 1986 to present

The opinions given in this talk represent my views and not those of any institution, organization, or committee upon which I serve.
Small Grains Improvement Team

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Cropping Systems:
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Small Grains Improvement Team

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Barley:
My graduate students
Topics:

• The need for plant breeding and crop management.
• The phases of plant breeding.
• Who will be the 21st century plant breeders?
• Critical needs for future plant breeding and understanding how to use your resources (competitive advantages).
The need for plant breeding and crop management:

- The demands on our food system will increase:
  - Increasing population
  - Increasing prosperity
  - To meet environmental needs
Increasing Prosperity:

- 800,000,000 people undernourished—will change with income growth.
- For each 1% increase in real income, the demand for wheat will increase 0.5%.
- Increased wheat utilization is due 2/3 to population and 1/3 to income growth.
- Greater demand for meat—Already 35% of world grain supplies are used for livestock production
Having the Tools vs. Having the Will:
Meeting Environmental Needs:

- Agriculture is often viewed as an enemy of the environment--relies on pesticides, fertilizer, irrigation. Yet intensive agriculture preserves land from being used for farming.
- Agriculture is the largest and most flexible managed ecosystem. It will be asked to remediate the detrimental effects of human activities.
- Future agriculture will rely more on genetics and less on chemical inputs.
Revolutions in Agriculture

- Fertilizer
- Pesticides (herbicides, insecticides, fungicides)
- Irrigation
- Genetics
  - Hybrids (better in diploids than polyploids)
  - Semi-dwarf cultivars for intensive management

Which of these revolutions will be available in the future?
\[ P = G + E + GxE \]
\[ P = G + E + M + GxM + GxE + GxMxE \]

- **Environment**: Weather, tillage, pesticides, irrigation, fertilizer, and prior history. It has both a fixed and a random component.

- **Genotype**: What Plant breeders are modify.

- **Genotype x environment Interaction**: How the genotypes respond to different environments.

How will the next production gains be obtained? Have we reached the upper genetic limit (can genetic Improvement continue)?
Phases of Plant Breeding:

- Introduction of genetic variation
- Genetic segregation and selection (may or may not be accompanied by inbreeding)
- Evaluation and release

Plant breeders will change their programs to do something which they could not previously do or to do something they could previously do in a better way. Everything must be tempered by finding your competitive advantage, your niche—which will differ.
Traditional Plant Breeding

- Introduce Variation
- Segregation and Selection
- Evaluation and Release
Introducing Variation:
Introduce Variation

Segregation and Selection

Evaluation and Release

Transgenes

Wide hybrids (embryo rescue)

Mutations

Allied Sciences

Traditional Plant Breeding

Introduce Variation

Segregation and Selection

Evaluation and Release
Crop Transformation:

• Fundamental question is does a plant breeder have enough genetic diversity (variation) within those species and genera that can be hybridized with the crop of interest?

• According to James (2006), 100 million hectares were planted to transgenic crops of which 54.6 million hectares were in the US. On a global basis, 57% of soybeans, 25% of maize, 13% of cotton, 5% of canola, and 0% of wheat and 0% of rice are transgenic.

• Are wheat and rice destined to become “orphaned” crops due to limited technology?

http://www.isaaa.org/resources/publications/briefs/35/executivesummary/default.html
Variation Through Mutations:


Imidazolinone-tolerance and wild type susceptibility in wheat. Sodium azide mutagenesis.
Introduce Variation

Segregation and Selection

Evaluation and Release

Better assays
Marker assisted Selection
Doubled haploidy

Traditional Plant Breeding

Allied Sciences
Segregation and Selection:

- Nothing is more efficient than visual selection when it can be used.
- With the size of modern breeding programs, nothing is more necessary than visual selection.
- There is a hierarchy of assays where you use the easier, less expensive assays first, so fewer lines have to be evaluated with expensive assays.
Marker Assisted Selection:

- Best use of technology: on-site or cooperative
- Recommendation:
  - Small local effort for specific projects, especially for training.
  - Centralized labs for the large jobs. Needed for skilled personnel, and for higher quality and modern equipment. Also, the equipment is becoming so fast that a few machines have enormous capacity. Also, it is difficult for many individual programs to have the latest equipment.
Fusarium head blight:

- The disease assay is difficult and time consuming, usually done on flowering wheat plants.
- There are major resistance genes, but they often have to be pyramided to give useful levels of resistance.
- Natural infections are not uniform—maturity dependent.
- The major genes are tagged with molecular markers.
Fusarium head blight: Breeding Strategy

- Cross HRS/SRW//HRW
- Two doses of hard texture
- Two doses of winter growth habit
- Can fix the FHB QTL or at least allow it to be more frequent in the 3 way cross.
- Need to remove the spring growth habit lines that are soft or low protein. Can be done in the F$_2$ or F$_3$ generation using selection.
Stem Rust:

- The disease assay is simple and quick, usually done on seedlings.
- There are major resistance genes, and are effective when used singly. Races change slowly or quickly (e.g. Ug99).
- Natural and artificial infections can be induced in the field.
- Many major genes are tagged with molecular markers.
Stem Rust: Breeding Strategy

• Resistance is a critical trait. Excellent germplasm is available.

• Cross Resistant by Resistant or R/S//R and select in the F₅ and thereafter seedling stage.

• Use race differentials or molecular markers to identify pyramided gene combinations.
Understanding Grain Yield

- Complex trait controlled by many genes.
- Can be difficult to identify differences, especially in relatively low yielding environments. Average grain yield for wheat in Nebraska is 2.5 t/ha.
- Very large environmental effects.
- Need very effective tools.
Effect of Wichita Chromosome(s) on Yield in Cheyenne Background

Deviations from Cheyenne’s Mean (%)
Effect of Cheyenne Chromosome $s$ on Yield in Wichita Background

Deviations from Wichita’s Mean (%)
Segregation of RFLP probe *BCD907*, in the RICLs-3A population of Wheat

Cheyenne

Wichita

CNN(W13A)

Recombinant Chromosome Lines (for chromosome 3A)

← = Polymorphic band
Grain Yield

$R^2 = 28.1\%$ A.E. = +66 kg ha$^{-1}$

WI genotype adds 132 kg ha$^{-1}$
QTL Regions

Region 1

Region 2

Region 3

Region 4

Region 5

GYLD
KPSM

Xbcd907
Xbarc357
Xbam055
Xbam61
Xcd395

Xbarc86
Xcal305
Xcal330
Xcmw601
Xbcd1380

Xbcd155
Xbcd341
Xbcd22
Xbcd372
Xbcd361
Xgwmi155
Change in Magnitude

XBARC67-GYLD

Environmental Index

Grain Yield (Mg ha\(^{-1}\))

- CNN allele
- WI allele

Linear (WI allele)
Linear (CNN allele)
Crossover Interaction

**XCDO549 - PHT**

- CNN allele
- WI allele

**Environmental Index**

- Plant Height (cm)

**Graph Details:**
- Linear (WI allele)
- Linear (CNN allele)
KPSM vs. GYLD at Xbarc67

\( y = 0.0002x + 1.095 \)

\( R^2 = 0.632 \)

\( R = 0.83^{**} \)
Selection Techniques:

- The importance of selection seems to becoming less researched and less understood.
- Natural Selection and selection nurseries
- Cropping systems and optical sorting.

- The question is one of opportunity costs- What technologies are we giving up for those we are accepting? Also, one technology is not right for everyone.
Optical Kernel Sorting:

- Vacuum wheel for picking up single kernels
- NIR spectrum collected here
- Bin for unsorted kernels
- 4-way kernel sorter
- Sorting bins
Segregation and Selection:
Evaluation and Release:

- **Cropping systems**: Crops have to be evaluated in the manner to which they are to be grown.
- **Biometry**: Statistical approaches to identify differences. More efficient designs allow better evaluation (nearest neighbors, alpha lattices, etc.)
- **Modeling**: Will allow the trial data from a limited number of tests to be extrapolated to other environments.
Mean annual water balances were derived from the Newell Simulation Model (Van Wambeke et al., 1992) using 1981 to 1980 normals for precipitation and temperature from a population of 125 weather stations (Swenson and Holz, 1982). The annual water balances represent the cumulative differences between monthly precipitation and potential evapotranspiration. The water balance surface was constructed from a terrain regression applied to the USGS 3 arc-second digital elevation models (DEMs) 1:250000 with a final resolution of 200 m.
The effect of drought: Field Variation
The effect of snow cover: Field Variation
Hybrid Crops: Wheat

Hybrid wheat is grown in India, South Africa, and Australia.

Seed costs and the lower levels of heterosis are major limitations to hybrid wheat adoption.

Though considerable effort has been made on CHA, CMS systems appear to be the most efficacious and reliable. Restoration has been a problem.
All testing is done at $\frac{1}{2}$ the pureline seeding rate. This cuts the seed costs in half.
Hybrid Crops: Wheat

- CMS Female
- Multiple Ovary
- Experimental hybrids
- Hybrid production field
Critical Needs for 21st Century Plant Breeding: Fearless Predictions
Critical Needs for 21st Century Plant Breeding

- Have we reached our upper genetic limit? Have we reliable cropping systems to allow breeders to select for higher yield?
- Can we better identify the world’s agroecological zones to foster germplasm exchange among similar zones?
- Need a global consensus on the appropriate use of technology.
- Need public-private partnerships to benefit all in plant breeding. The public sector need to re-evaluate how it deploys its resources so as not to duplicate the private sector research and to address the great problems affecting our crop productivity (e.g. hybrid wheat or non-hybrid maize).
... a good past is positively dangerous if it makes us content with the present and unprepared for the future.

Charles Eliot
Thank You