Advances in Phenotyping

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GK12 INSIGHT
Plant Breeding – It’s a numbers game

Bulk populations
- 300,000 plants

Small plot yield test
- 3,000 plots

Prelim yield trial
- 300

Advanced yield trial
- 30-40

Kansas Interstate Nursery
- 10-12

New Variety
- 1
Increasing selection intensity = more to chose from
The need for phenotypes:

1. more efficient selection (breeding)
2. understanding the parts (genetics)
G2P: connecting genotype to phenotype

Canopy Temperature (°C)

Yield (g m\(^{-2}\))

\(r = -0.71\)
Trending: Phenotyping vs Genotyping

![Graph showing the comparison between Phenotyping and Genotyping costs from 2001 to 2012. The x-axis represents the years from 2001 to 2012, while the y-axis shows the cost in dollars per megabyte (Mb). The graph includes three lines:

- Blue line for minimum wage ($).
- Green line for farmland cost ($/acre x1000).
- Red line for DNA sequencing cost ($/Mb).

The graph indicates that the minimum wage has remained relatively stable, while the farmland cost has increased. The DNA sequencing cost has decreased significantly over the years.](image-url)
Field-based high throughput phenotyping

Defining “field-based high throughput”

✓ Fully- (or mostly) automated data collection
✓ <1 second per plot (3h for 10,000 plots)
✓ Data analysis must be “pipelined”
✓ High-resolution ≠ high-throughput
✓ Field conditions targeting production systems
✓ Automated data processing
A multi-disciplinary approach
Phenotyping vehicle

+ Carry lots of equipment
+ flexible deployment
+ easy to operate

- Can not assay whole field simultaneously
- Not completely automated
Precision Ag meets Plant Genetics
“Geo-referenced proximal sensing”

Physiologically define proximal measurements

RTK-GPS (cm level accuracy)

Sensors
- GreenSeeker = NDVI
- IRT = canopy temperature
- SONAR = plant height
HTP: Platform configuration

LabView program
✓ 10 Hz sampling
✓ Real-time feedback
✓ Flat file output
HTP: Multiple sensor orientation

![Diagram showing data points and orientation with NDVI values from 0.1 to 0.9, labeled as Right GPS and Left GPS.]
NDVI – raw data

NDVI - 2012.05.10

Longitude (DD.dddd)

Latitude (DD.dddd)
Assigning data to field entries

Raw data

Define plot boundaries

Trim data
Assign to plots

NDVI - 2012.05.10

Latitude
3907.74
3907.72
3907.70

Longitude
-9636.82
-9636.80
-9636.78
-9636.76
-9636.74
HTP: Plant Height

SONAR MEASUREMENT - PLANT HEIGHT

Latitude (DD.ddddd)

Sonar (cm)

Single pass down one column

Centimeter level precision in plant height measurements
NDVI: Multi-temporal measurements

Rapid assessment enables repeated measurements over time
NDVI: Multi-temporal measurements

Advanced Yield Nursery

Identify dynamic differences among genotypes

DATE

5/3/12 5/10/12 5/15/12 5/21/12
Phenotyper: Increased accuracy

Plant Height w/ SONAR

- 40 varieties
- 3 reps
- 1.3m x 3m plots
PheMU
Phenotyping Mobile Unit

Phenocorn
Phenocorn:

☑️ Global Deployment
☑️ Low(er) cost

Bipedal Mobile Unit
GPS
IRT
GreenSeeker

GPS
IRT

Latitude
Longitude

NDVI

0.2
0.4
0.6
0.8

2723.83
2723.84
2723.85
2723.86
2723.87

10955.56 10955.56 10955.56 10955.56

GreenSeeker

Bipedal Mobile Unit
HTP platforms of all shapes and sizes...
HTP: Imaging
HTP: small Unmanned Aerial Systems (sUAS)

IRIS+ Quadrotor with custom KSU Gimbal Cannon S100 NDVI camera

+ Not too expensive
+ flexible deployment
+ Image whole field

- Need trained pilot
- FAA restrictions?
- Limited payload (<1kg)
- Crashes
UAS: mission planner

Flight planning and field survey of wheat field nursery (Oct 2014)
HTP: sUAS platform and 3D modeling

- Ortho mosaic from multiple images
HTP via UAV

3DR IRIS+ | NDVI converted Cannon S100

NDVI image - BISA, Ludhiana, INDIA, Jan 2015

NDVI map - BISA, Jabalapur
HTP: The future is here...

Implementation of existing technology
✓ Commercial and existing sensors
✓ Imaging
✓ Low-cost, modular ‘nodes’
Interactive data collection and analysis
If we knew what it was we were doing, it would not be called research, would it?

- Albert Einstein