Current Technology for Predicting In-Season Nitrogen Needs

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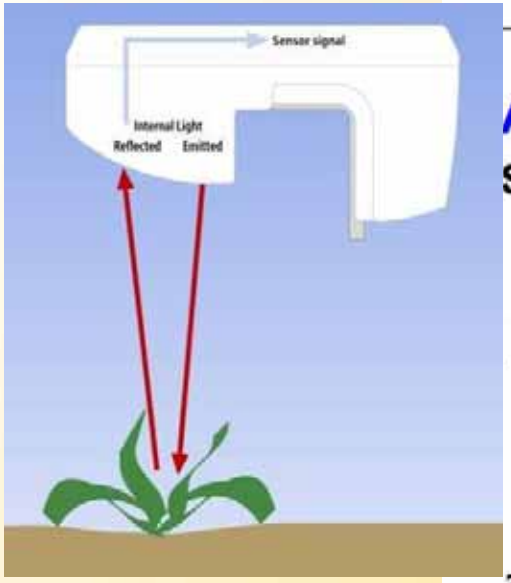
Sensor Based N Management

- In theory, offers a relatively simple method to manage N without having to physically take a sample
- Sensors have been in place for about 20 years
  - Earliest was SPAD Chlorophyll meter (~1995)
- Satellite imagery has been around for longer
  - Offers some advantages but also some major limitations
    - Limitations: return rate, minimum amounts of data to purchase, limited control on when the picture will be taken

Active or Passive Sensing

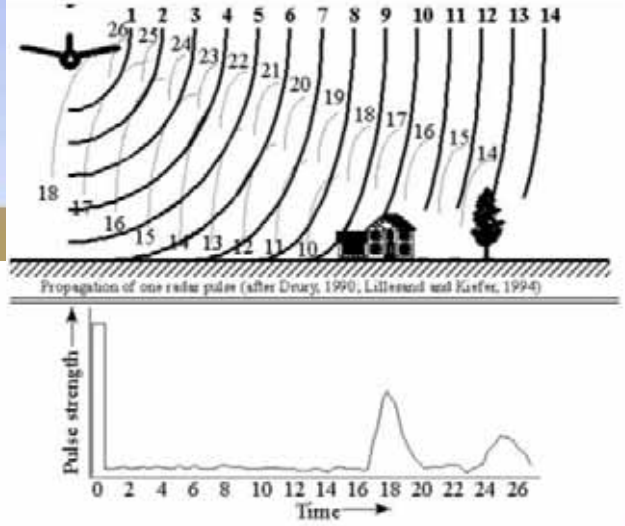


Active Sensors emit their own light source

Remote Sensing Fundamentals

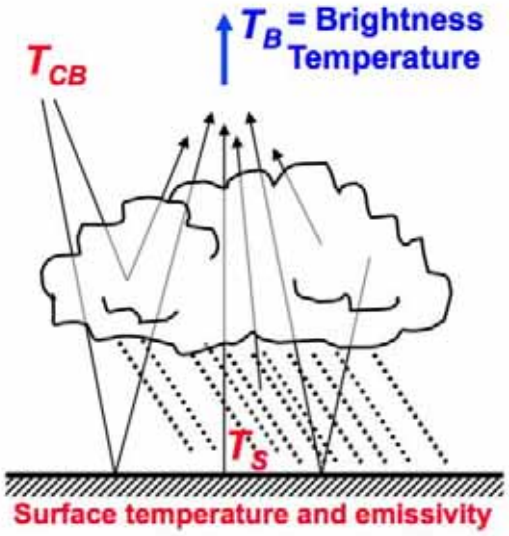
Active Remote Sensing

Source: Instrument pulse,
Needs power to operate



Passive Remote Sensing

Sources: surface emission,
cosmic background,
rain emission



Sensing Tools Currently Being Used by our research group

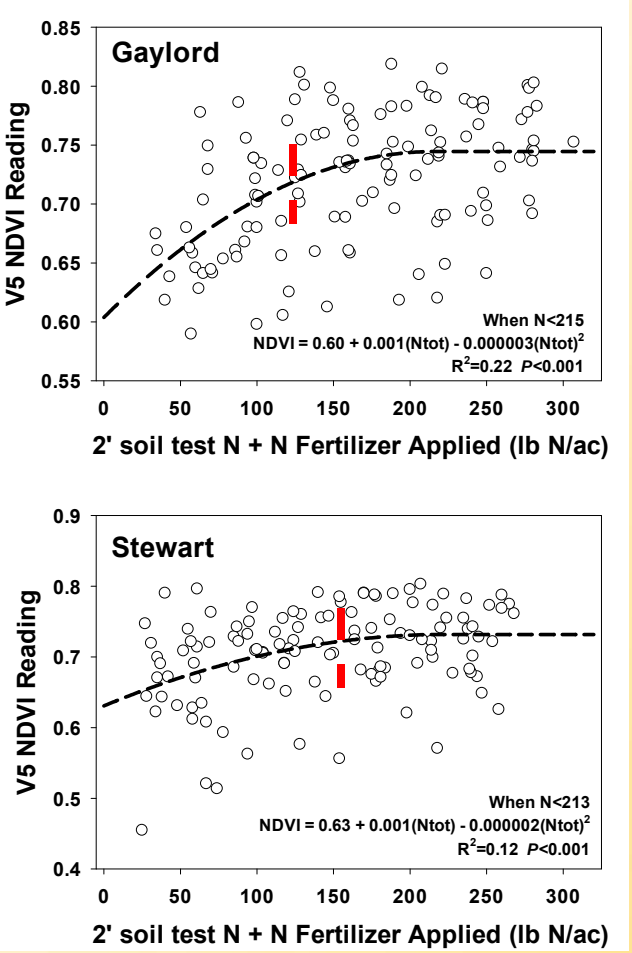
Sensing Wavelengths

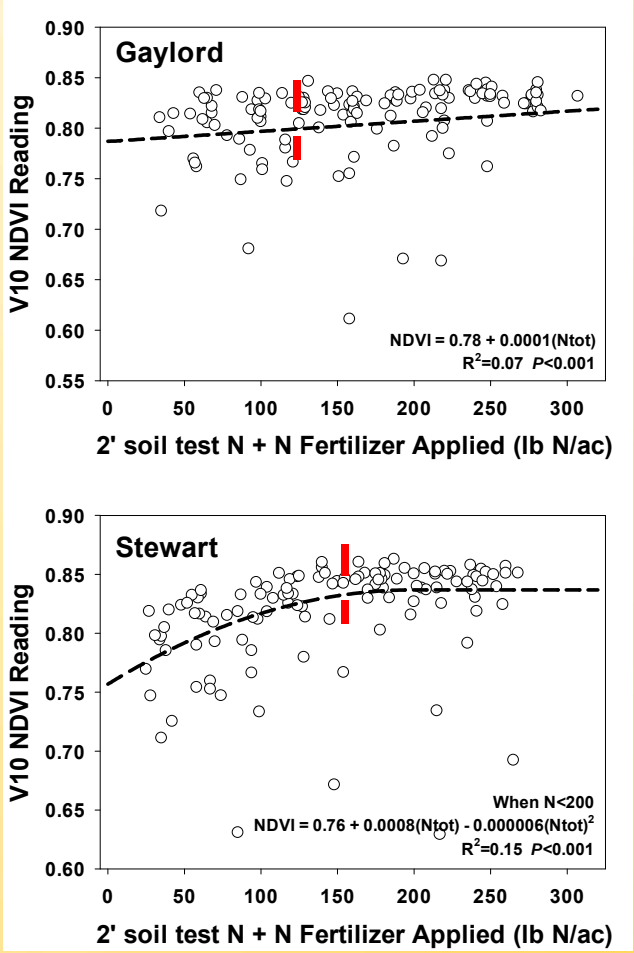
- Greenseeker model 505 - Active
  - Wavelengths: 656nm (red), 774 (NIR)
- Crop Circle 470 - Active
  - 670 (red), 780 (NIR), 730 (Red Edge)
- SPAD Chlorophyll meter - Active
  - Wavelengths: 650 (red), 940 (NIR)
- Tetracam Mini-MCA - Passive
  - Wavelengths: 490 (Blue), 550 (Green), 680 (Red), 720 (Red Edge), 800 & 900 (NIR)

NDVI

- Normalized Difference Vegetative Index
  - No units associated with the value
  - Arbitrary number based on conditions within the field
- Index utilized by many types of sensors
  - Satellite imagery can produce NDVI as well
- Ratio of reflectance values in the Red and NIR bands
  - (NIR-Red)/(NIR+Red)

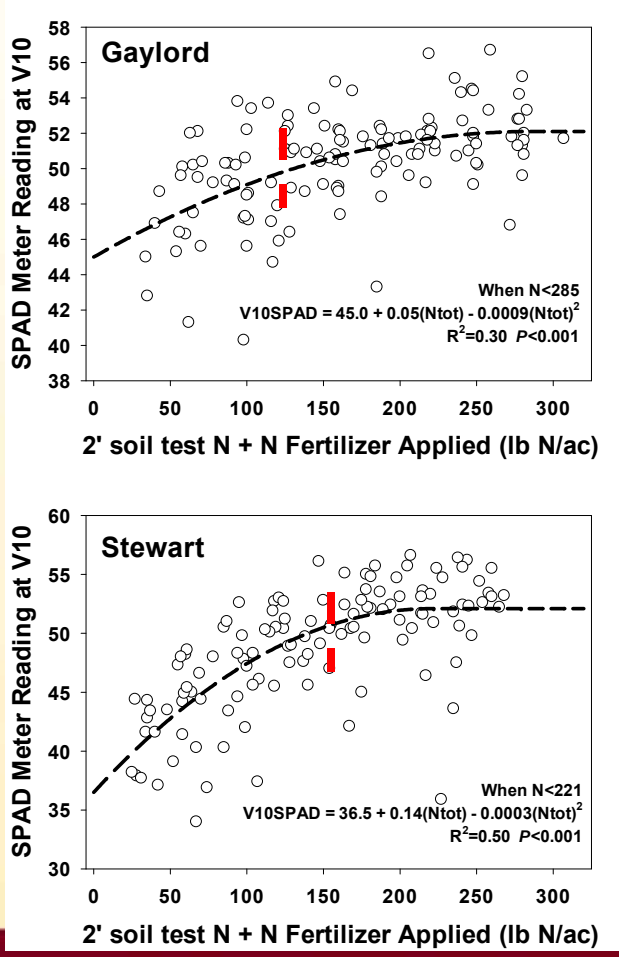
Applied N vs. NDVI – 2012

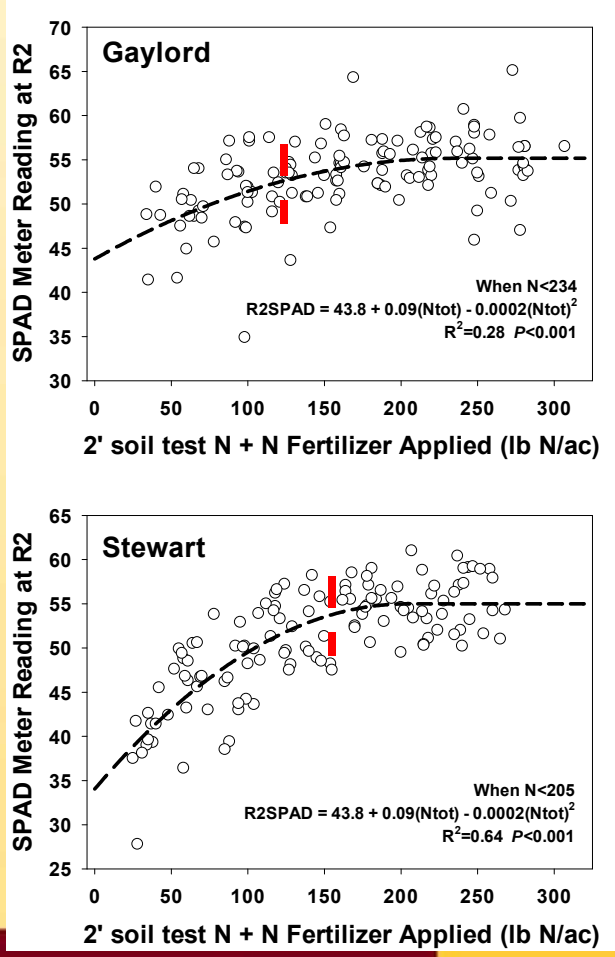




- Poor Relationship with total available N
- Relationship looks better at Stewart for the V10 sampling but R^2 is still low
- Explains very little of the total variability in available N
- Did not show any better relationship to yield

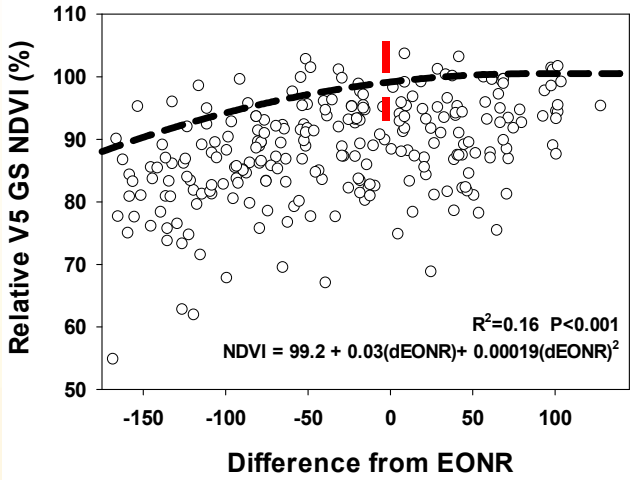
SPAD Meter vs. Applied N

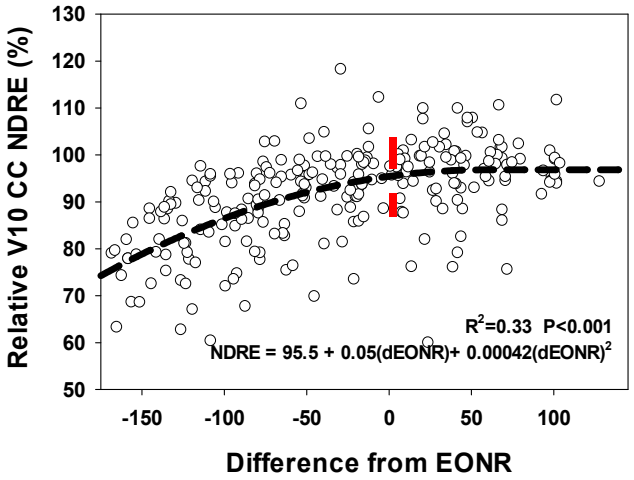


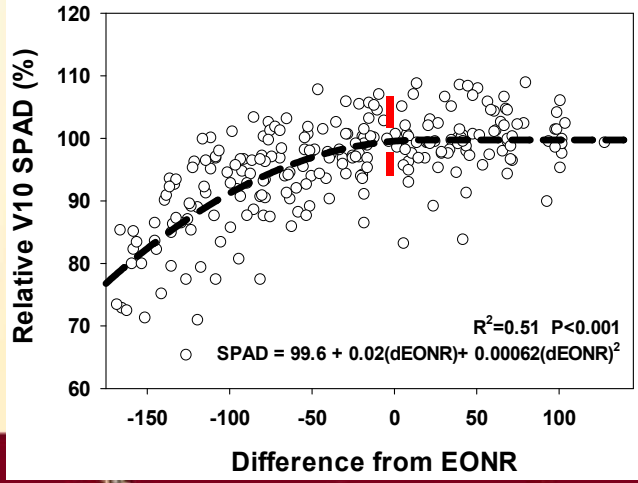


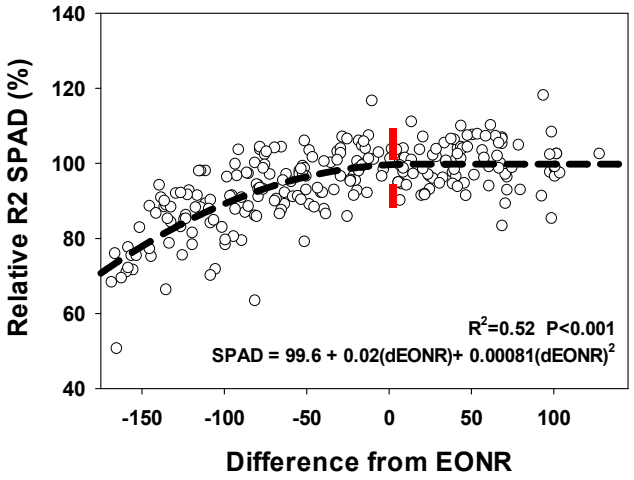
- Better correlation with total available N
- Samples were taken later in the season during and after peak N uptake
- Relationship generally better at R2 when it is too late to make corrections
- Good correlation between R2 SPAD and corn grain yield

Comparisons with EONR









Difference from EONR =Site N applied – EONR 0.10 price ratio

N includes 2' soil N and applied N

Two Field locations
--2012
--Stewart, MN
--Gaylord, MN

Corn following Soybean

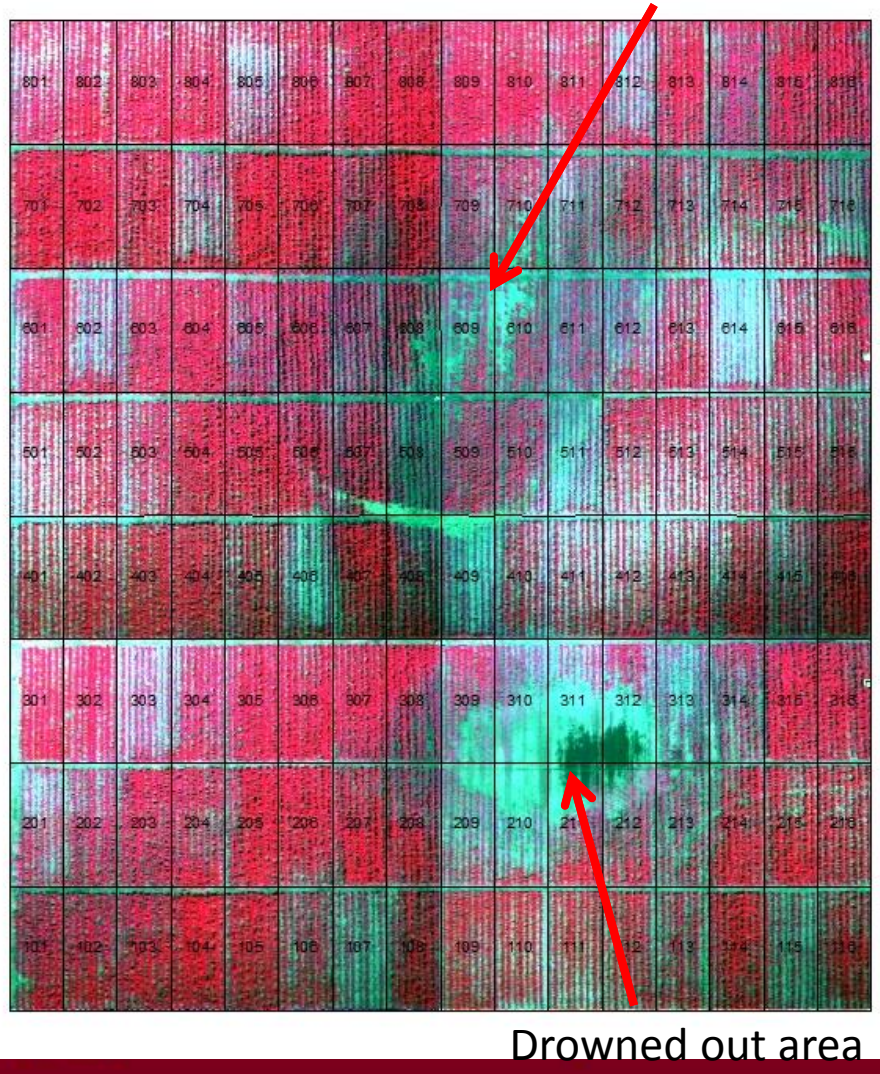
NDVI and NDRE overestimated N need ~ +50 lb N/ac

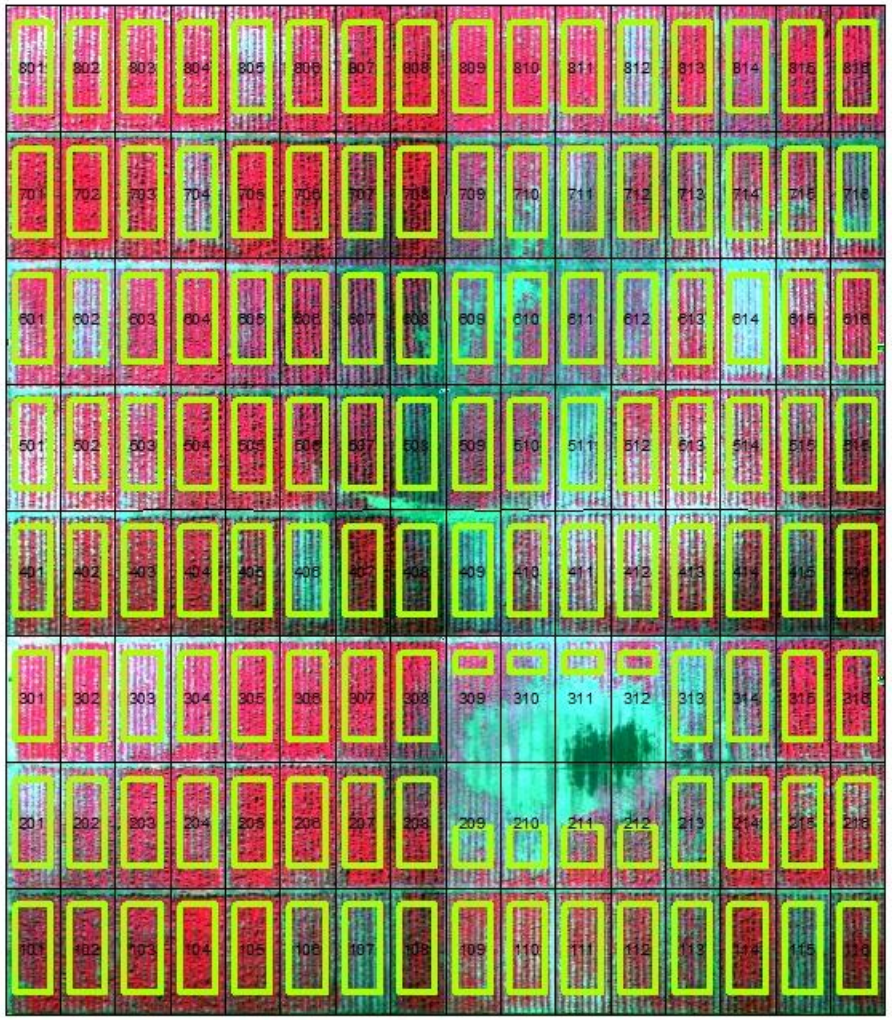
Moving Forward

- We need to have some confidence that we can accurately predict response to N
  - In a production field how do we know yellow corn is due to N
- We still need to have reference strips
  - All values are derived in relation to a normal area
- There are many sensing options out there, how do we choose the right one

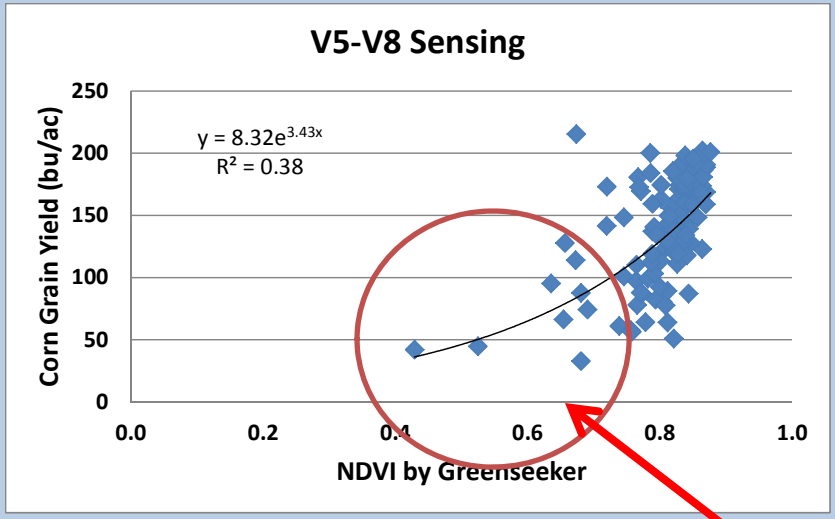
Willmar NUE Study – V5 False Color

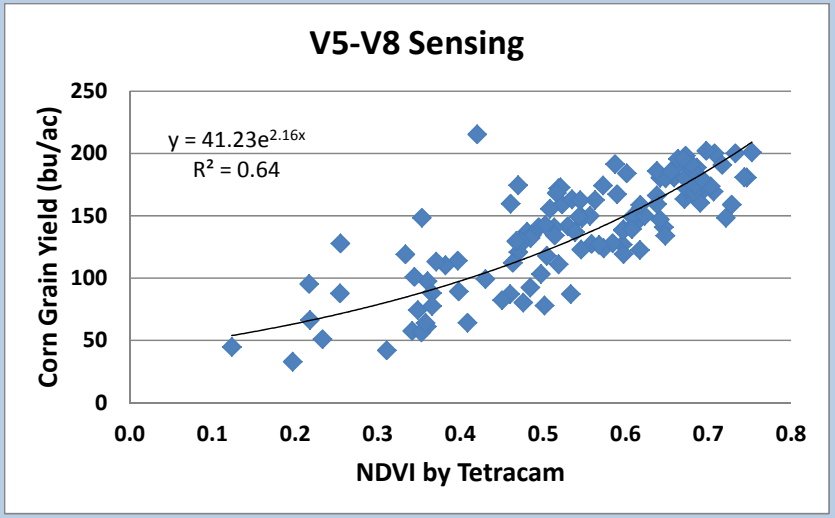
40 280 240 160 0 80 120 200

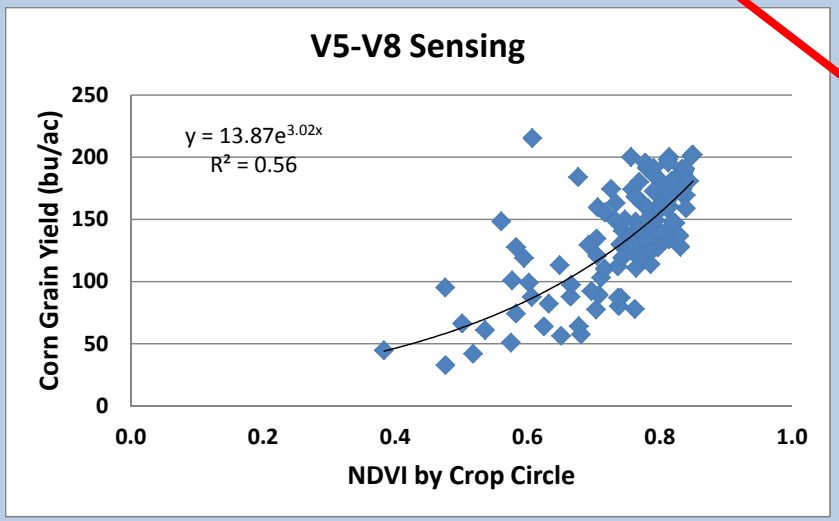




Early Season NDVI Measurements







- Canopy saturation tends to occur for the Greenseeker (values ~ 0.80-0.85)
  - Toss out the low points would result in no correlation
- Slightly better data for the crop circle
- Greater range in values for the Tetracam (aerial)
  - Sampling a larger area
  - Some variation due to population

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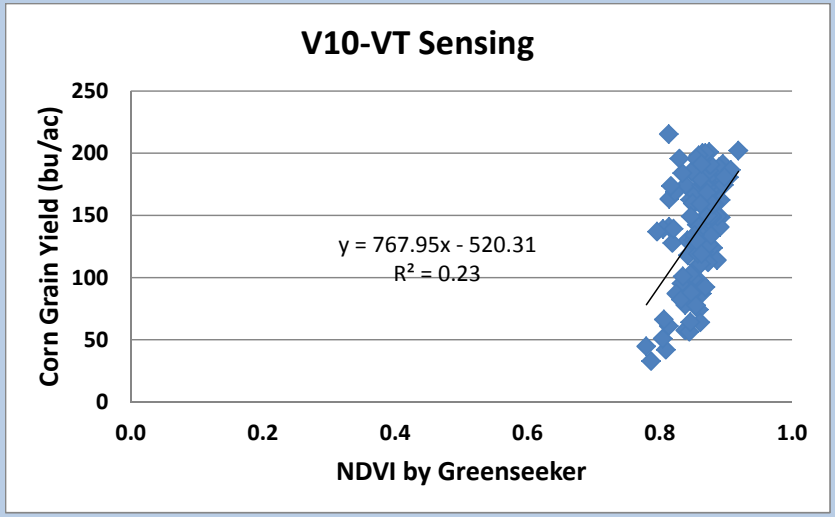
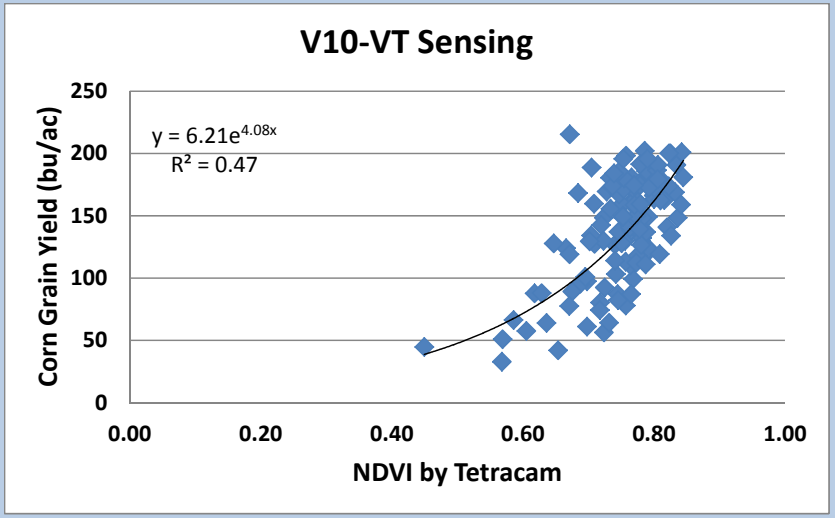
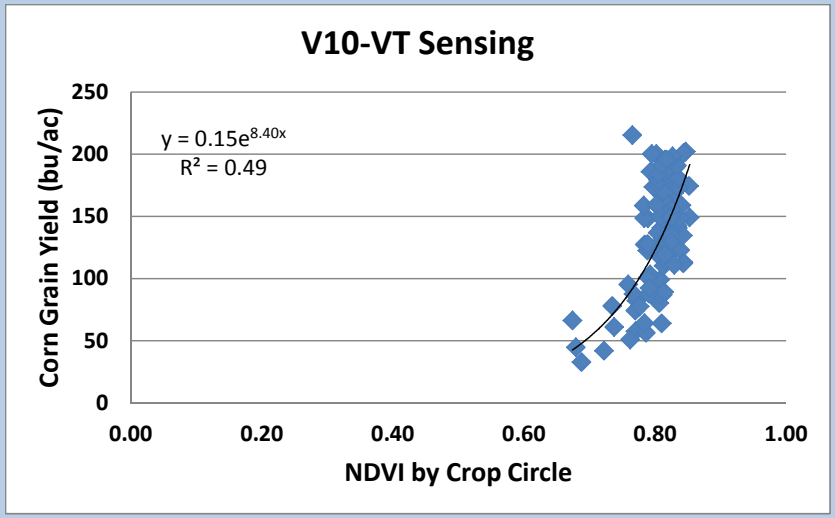
Mid-Season NDVI Measurements







- Poor relationship for the Greenseeker
- Slightly better for the Crop Circle but very few points < 0.80
  - Both are at Saturation
- Tetracam showing the greatest amount of variation

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NDVI - Limitations

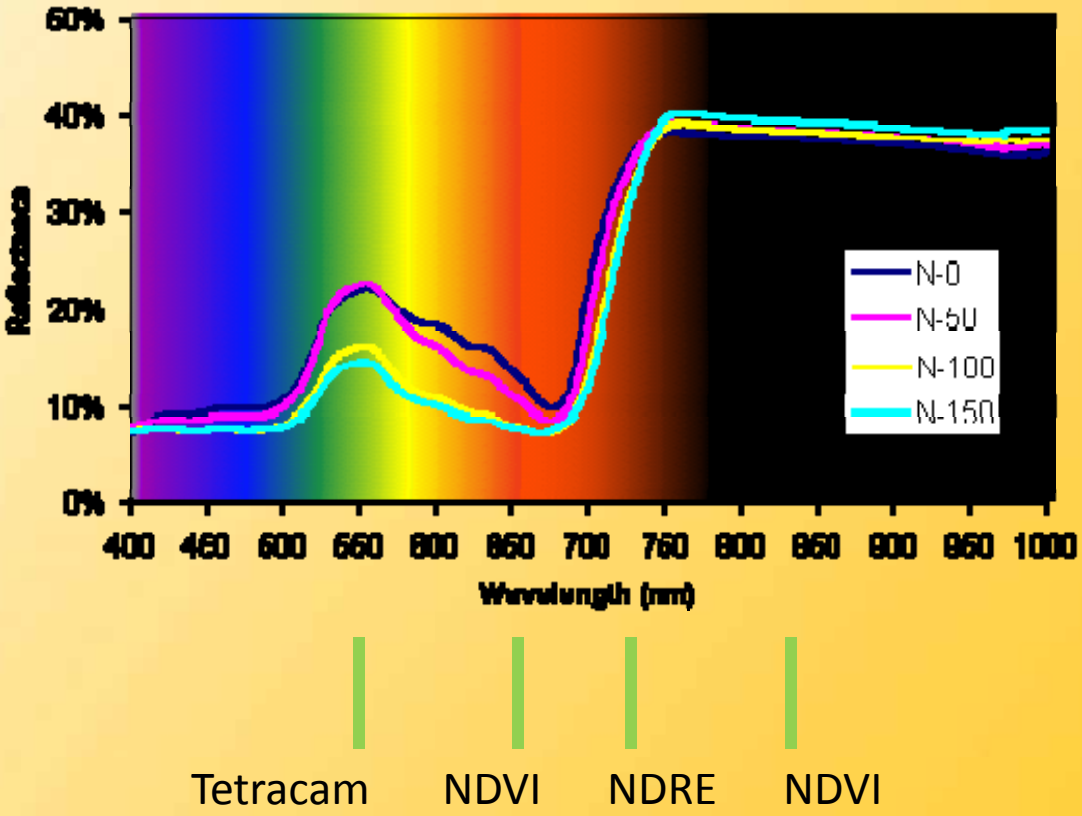
- NDVI is predicated on differences among treatments are expressed as differences in plant growth
  - Greenness does not factor in to this measure
  - Measure of stand density
- Poorly growing plants can be due to a number of factors
- NDVI reaches saturation early in the growing season

Options

- NDRE – Normalized difference Red-Edge
  - Ratio of red-edge to NIR
  - Red-edge is measured in the region between red and NIR
- GNDVI – Green normalized difference vegetation index
  - Ratio of Green to NIR

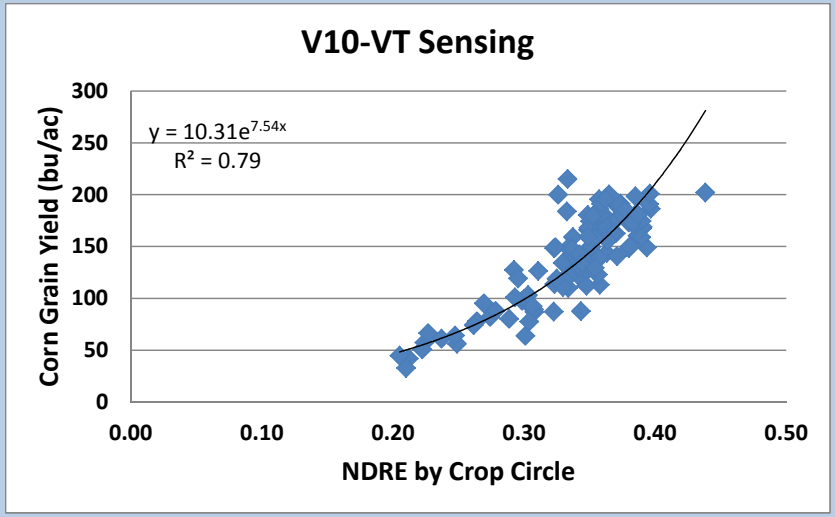
Properties of N deficient Plants

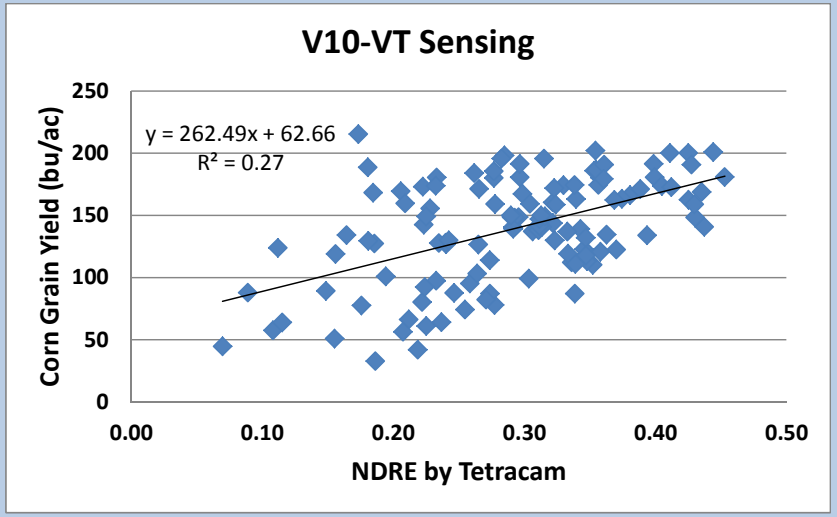
- Green reflectance increases
- Red reflectance increases & NIR reflectance decreases
- Differences in reflectance greatest between 550 – 600 nm, followed by red-edge (680 – 730 nm)

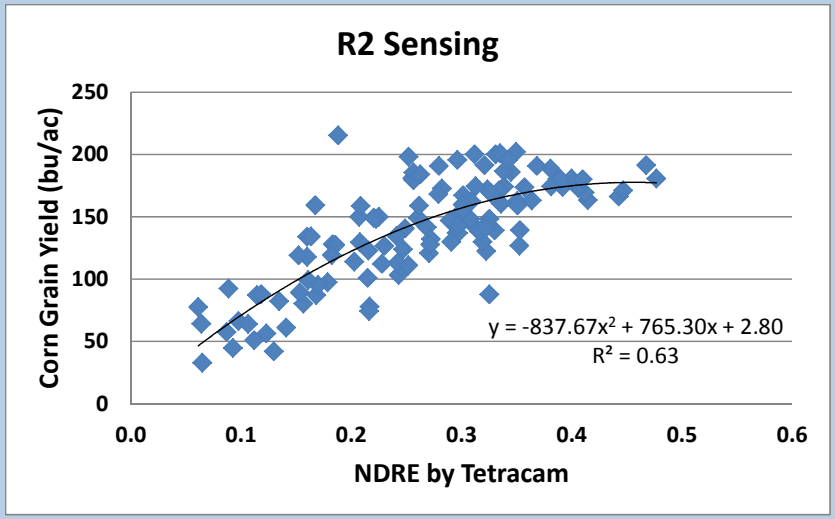


D.J. Mulla, University of Minnesota

Mid-Season NDRE Measurements







- NDRE with the crop circle has correlated well to yield using considering data taken at V10 for the 2012 and 2013 data
- Tetracam V10 data was ugly
  - Measurement is taken using ambient
- NDRE correlates better to SPAD

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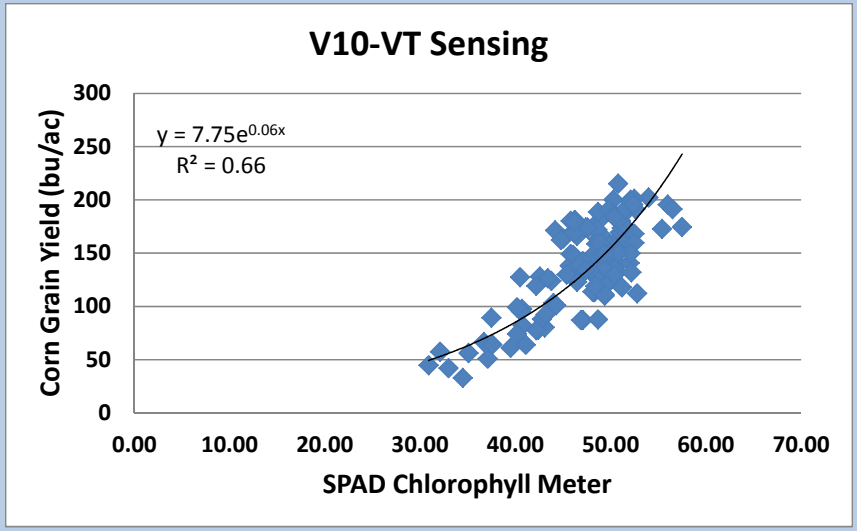
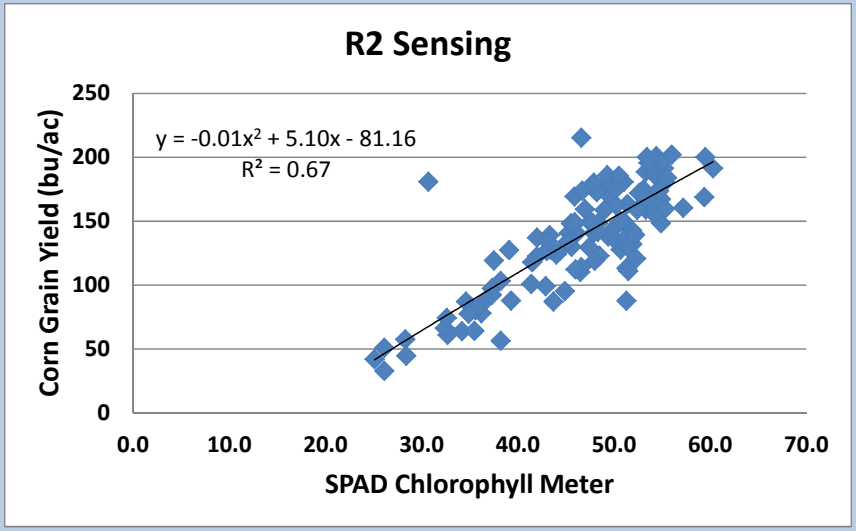
SPAD Chlorophyll Meter





- SPAD meters consistently provide the best correlation to final yield
- V10 measurements taken from the uppermost fully developed leaf, R2 taken from the ear leaf
- Not a popular test and cannot be completed on-the-go
- Easy to do in plots but how do you sample a large field

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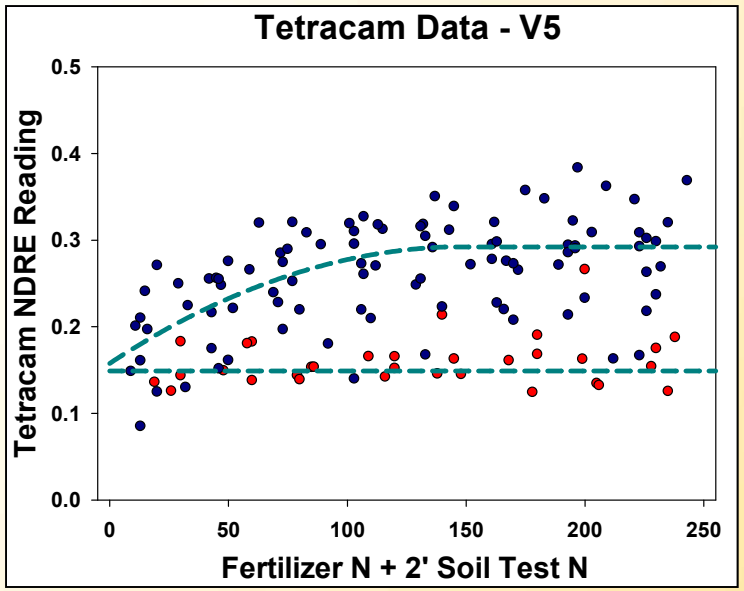
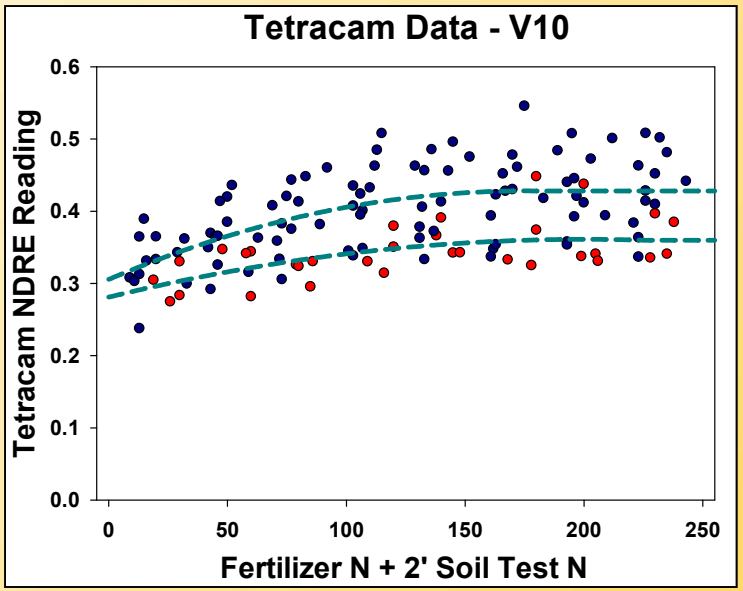
New Richland, MN V5 Corn: 2014

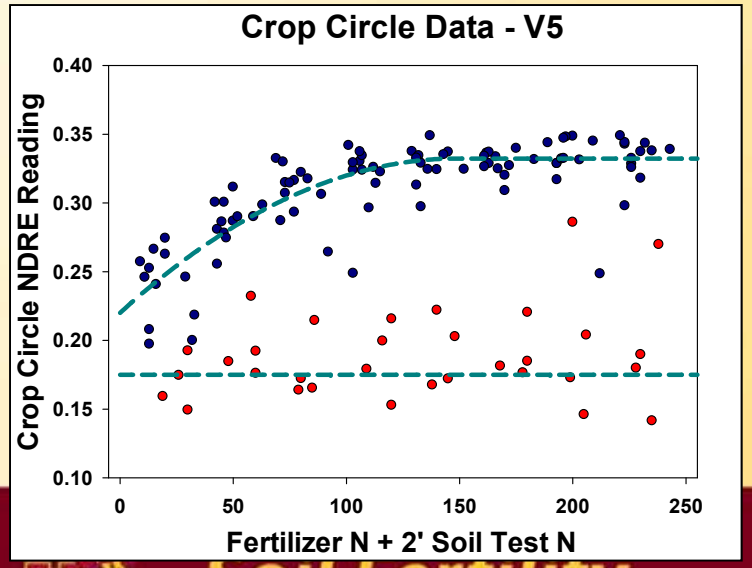
Water Free Area

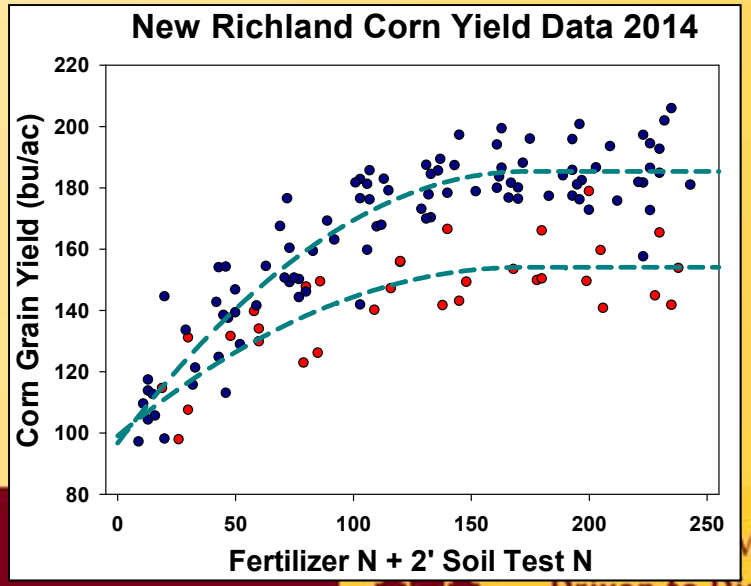
Previously flooded area

New Richland 2014









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Soil Fertility

MINNESOTA | EXTENSION

Driven to Discover℠

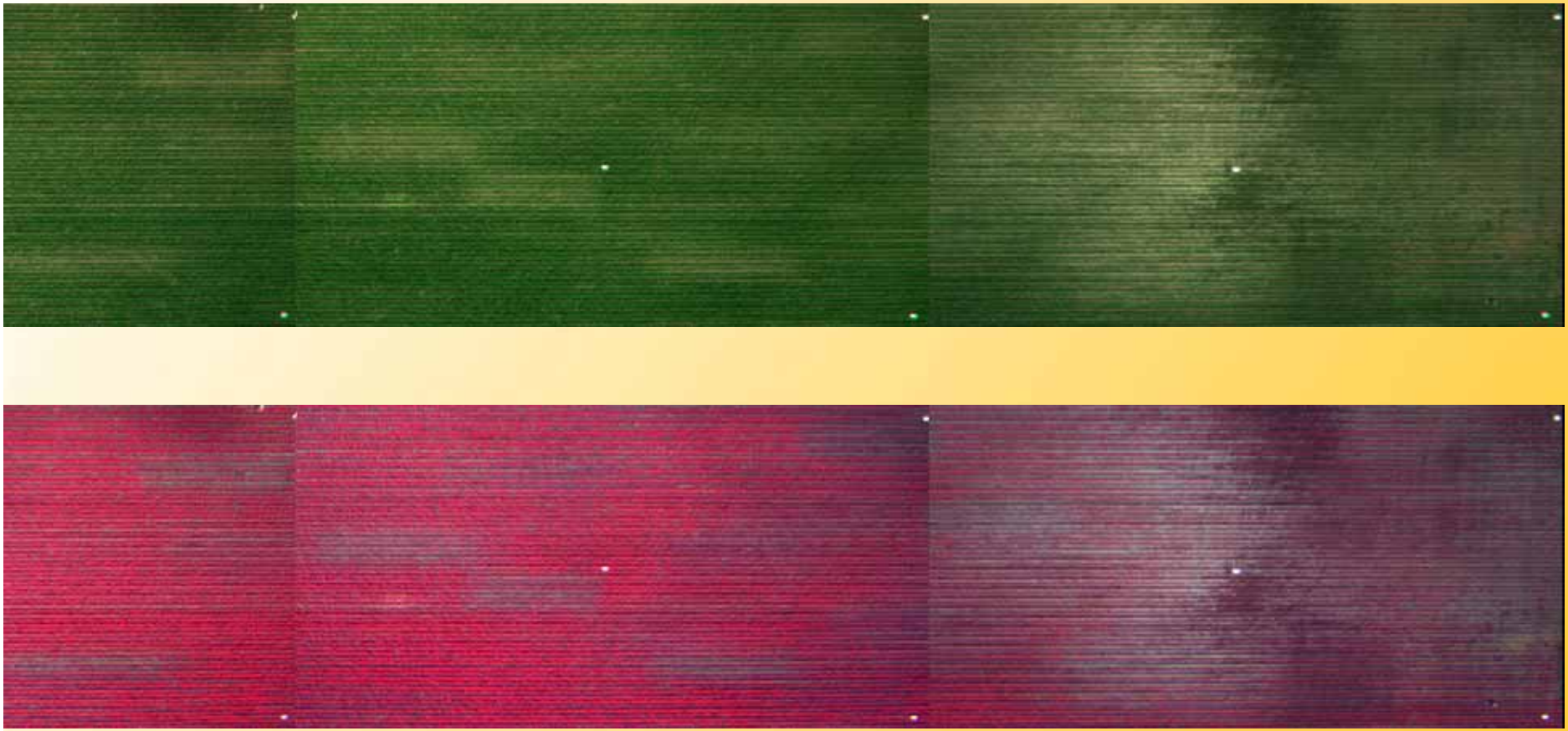
What is the best Index of N Availability

- Red/NIR indices from active sensors are not adequate to determine yield differences due to N unless soil N availability is low
- SPAD data provides better prediction but is more labor intensive
  - May not get a good representative sample
- NDRE may be a better index overall
  - $(NIR-R_{edge})/ (NIR+R_{edge})$
- GNDVI may relate better to N stress as well

Is Aerial Imagery Better Able to Detect N Stress

- Aerial imagery may offer better flexibility in determining N stress
  - Appears to offer a better sensitivity in some cases
  - Scanning a larger area may have benefits
- Selecting the right wavelengths is important
  - Red, NIR, Red Edge, Green, Blue, Yellow…..
- How certain are we that we are actually seeing a N deficiency and not something else?
- Still dependent on ambient lighting
  - Increased variability due to variations in reflectance when pictures are taken

New Richland, MN V5 Corn: 2014



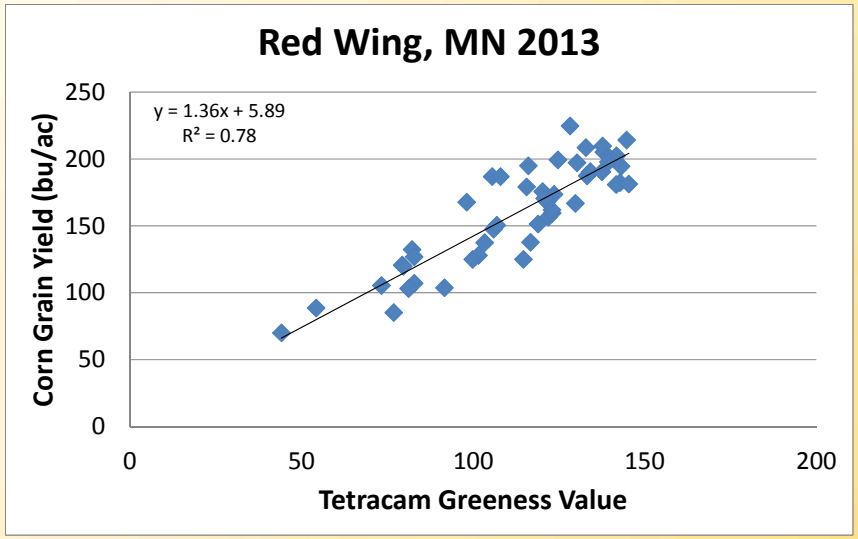
Deficiency Detection

Nitrogen

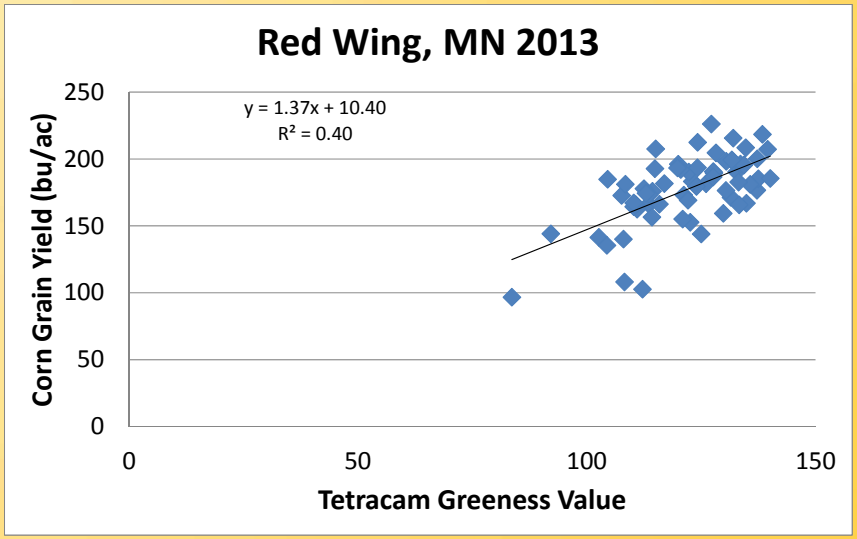
Sulfur

Greenness Versus Grain Yield
Red Wing, MN 2013

N x S Study



P x K x S Study

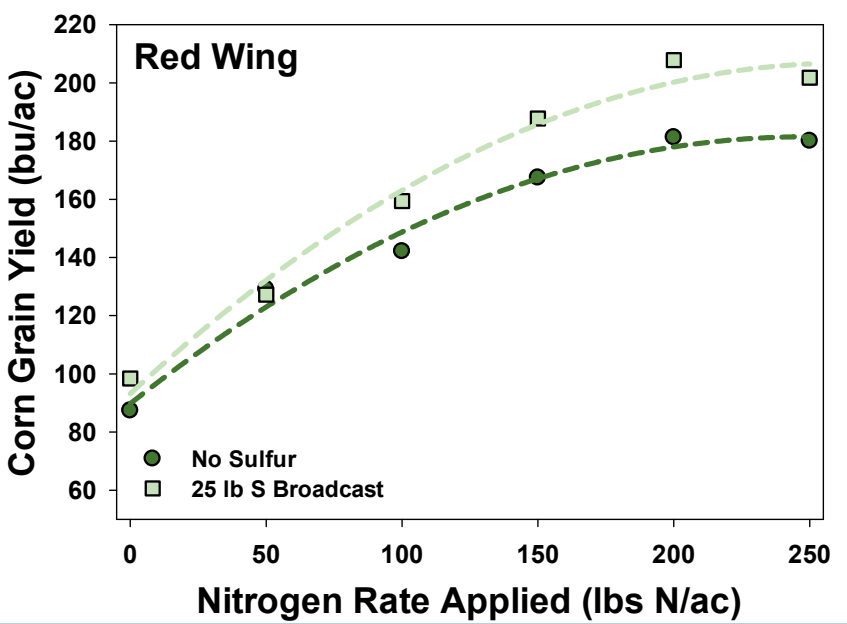


- Strong correlation between the greenness index value and yield for the N x S study
- Weaker correlation in the P x K x S study – but it is still significant

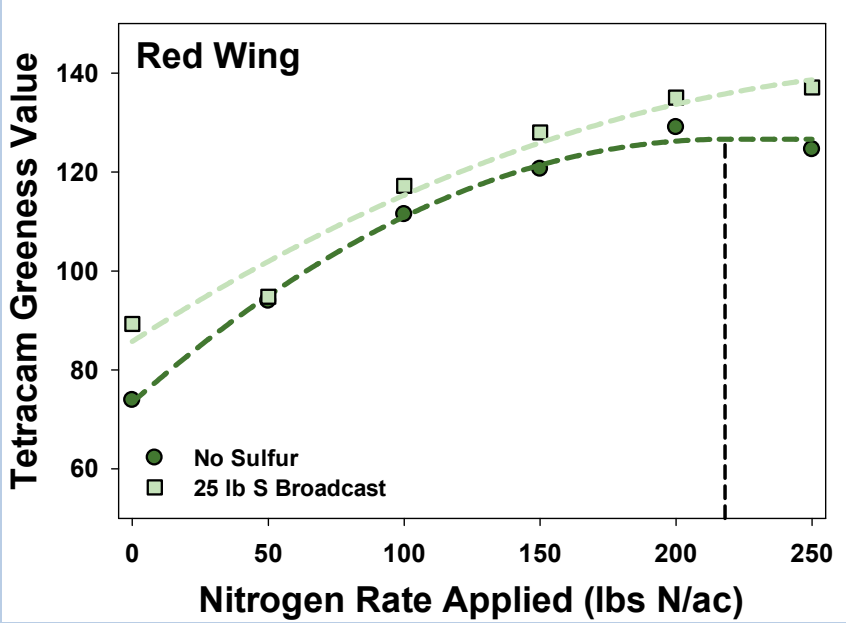
Corn Yield Response to N

with and without S

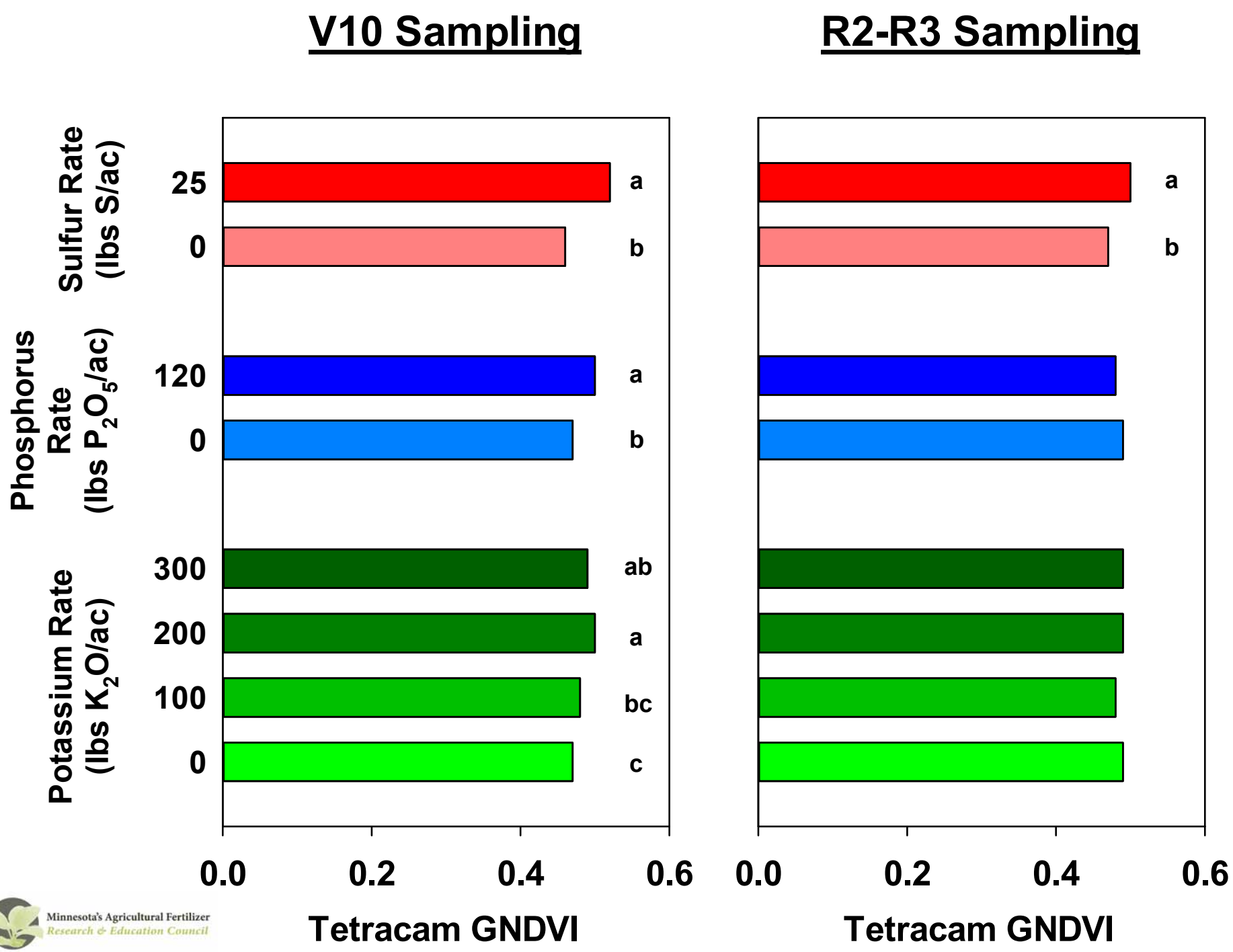
Corn Grain Yield



Plant Greenness



- Plots with sulfur averaged ~8 greenness units higher
- Average difference in yield was ~25 bu with sulfur when >150 lb N applied
- Sulfur deficiency can result in slight differences in greenness
  - Does not result in large discrepancies in plant N requirement


V10 Sampling
R2-R3 Sampling
Sulfur Rate (lbs S/ac)
Phosphorus Rate (lbs P_2O_5/ac)
Potassium Rate (lbs K_2O/ac)
25
0
120
0
300
200
100
0
a
b
a
b
ab
a
bc
c
0.0
0.2
0.4
0.6
Tetracam GNDVI
Minnesota's Agricultural Fertilizer Research & Education Council

Sensing and Crop Nutrients

- Sulfur will likely prove to be the most challenging nutrient when sensing for N deficiency
  - Deficiencies are not mutually exclusive
  - S deficiency not as apparent as N late in the season, but yield differences can be large
- P and K may have an i
  deficiencies
  - Especially for biomass
- What about zinc?

UAV's Everywhere?

Sensing Possibilities

- A future for use of cameras with UAS/Drones
  - Offers greater flexibility for sample timing and multiple possibilities for use throughout the season (general scouting, sensing)
  - Higher resolution images
- They need to a good database on correlation/calibration
  - Make the pictures useful for making decisions - research
- Active sensors may still have a place
  - Crop circle (470) seems to be outperforming the Greenseeker in our studies
  - Not all crop circles are the same (our research unit has three bands, production units may only have 2)
  - Being able to measure the Red Edge band it important

Limitations for Use: Aerial Images

1. Data turn around – training
2. Ability to correct deficiencies early
3. Wavelength selection (picking an index)
4. Data calibration (i.e. how much fertilizer should be applied based on the sensing value)
5. Cost of equipment/value returned?
6. FAA Regulations on use

My View of the Current State of UAV Use for detecting Nutrient Deficiencies

Final Comments

- Things can be built faster than we can figure out how to use them
- I think there still may be some benefits to using UAV's
  - General scouting tool
- Nutrient detection may get better
  - Many deficiencies result in chlorosis
  - Important question: is the deficiency due to N?
- UAV's may provide another tool to use but will not replace soil testing or common sense
- Still will require a reference strip

Thank You
Questions?

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Minnesota's Agricultural Fertilizer Research & Education Council

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MN Soybean Research & Promotion Council