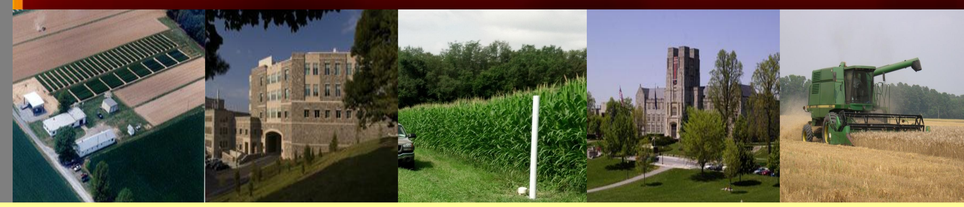
Improving Early Season Detection of Corn Nitrogen Stress Using NDVI

Justin R. Jones, Wade E. Thomason, Marcus M. Alley and Mark S. Reiter
Virginia Tech, Dept. of Crop & Soil Environ. Sciences, 330 Smyth Hall, Blacksburg, VA 24061

VirginiaTech *Invent the Future* | College of Agriculture and Life Sciences



Abstract

Reducing nitrogen (N) losses while increasing N use efficiency (NUE) has become a major goal of corn (*Zea mays*) N fertilization (Robertson and Vitousek, 2009). Active remote sensing with the GreenSeeker® sensor has proven effective at determining N rate prescriptions at the V7 to V9 growth stage (Teal et al., 2006). However different background types can influence NDVI values (Huete et al., 1985). Delaying N application until the V7 stage can result in yield loss due to early season N deficiencies. Our objective was to evaluate the effect of sensor orientation, field of view, soil type and soil cover on corn NDVI readings from the V2 to V6 stage. Five field studies were conducted in 2011 and 2012 in Virginia. Along with GreenSeeker® NDVI readings, destructive tissue analysis, SPAD chlorophyll meter readings and yield data were collected at the V2 to V6 stages. In addition, one experiment was performed to quantify NDVI variation due to background soil color, residue cover, and different sensor orientations

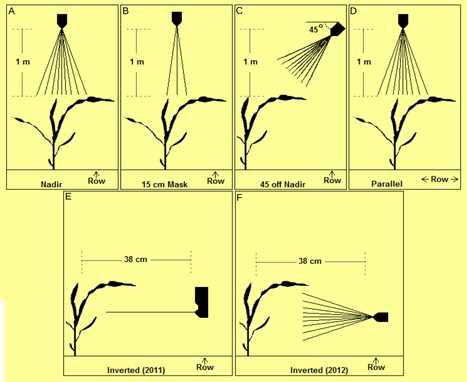
Objectives

1. Determine if changes in GreenSeeker sensor orientation or agronomic practices associated with N-rich reference strips can improve the ability to detect differences in corn N needs and make accurate sidedress N rate prescriptions during early vegetative growth.
2. Quantify NDVI variation generated by soil color, soil moisture, crop residues and sensing orientations using the GreenSeeker®.

Materials and Methods

- Five field experiments throughout VA in 2011 and 2012
- Ten fertilizer treatments included pre-plant and sidedress applications (Table 1)
- Experiments were conducted using a RCB design with all treatments replicated 4 times
- The hybrids Pioneer 1185HR in 2011 and Mid-Atlantic 5121GT3 in 2012 were planted at 67,000 seeds ha^{-1} in no-till non-irrigated fields on 76cm row centers
- Sidedress applications were made at V6 following final NDVI reading
- NDVI readings were taken from treatments 1, 2 and 10 at the V2 through V6 growth stages using the GreenSeeker RT200® (N Tech Industries, LLC, Ukiah, CA)
- Corn was sensed at five GreenSeeker RT200® orientations at each growth stage (Fig. 1)
- A SPAD meter (Konica Minolta Holding, INC., Marunouchi, Chiyoda, Tokyo) was used to determine chlorophyll status of the sensed plots at each growth stage
- Whole plant samples were collected from the sensed plots on each date from 60cm of non-harvest rows and biomass was calculated
- Tissue samples were analyzed for C and N via dry combustion analysis using a Vario MAX CN analyzer (Elemntar, Hanau, Germany)
- N uptake was calculated as the product of biomass yield (kg ha^{-1}) and N concentration (%)
- Grain yield was determined via a Massey Ferguson 8XP plot combine or via hand harvest, depending on location
- Grain moisture was determined with a Dickey-John GAC2000 grain sampler (DICKEY-john, Auburn, IL)
- Statistical analyses were conducted using the GLM procedure available from SAS (SAS Inst. Cary, NC). Due to significant interaction between years and locations NDVI was analyzed using the protected LSD as a mean separation technique, when analysis of variance indicated significant differences

Sensor Orientations (Figure 1)



Materials and Methods (cont.)

Treatments (Table 1)

	Pre-Plant Fertilizer				Sidedress Fertilizer			
	N	P	K	Source	N	P	K	Source
Treatment	----------kg ha^{-1}----------				----------kg ha^{-1}----------			
1	0	0	0	---	0	0	0	---
2	224	112	90	Urea	0	0	0	---
3	34	0	0	UAN	0	0	0	---
4	34	0	0	UAN	45	0	0	UAN
5	34	0	0	UAN	90	0	0	UAN
6	34	0	0	UAN	135	0	0	UAN
7	34	0	0	UAN	179	0	0	UAN
8	34	0	0	UAN	90	0	0	Urea
9	34	0	0	UAN	135	0	0	Urea
10	224	0	0	NPK Blend	0	0	0	---

- Single controlled experiment conducted by placing each of four soil series commonly found in VA; Davidson loam, Bojac loamy fine sand, Hayter loam and Pamunkey fine sandy loam in wooden boxes (102cm x 102cm x 14cm) (Boxes can be seen in Fig. 2)
- Soils were dried and passed through a 2.5cm sieve and amended with lime, P, and K to achieve a pH of 6.5 and optimal nutrient levels
- Experimental design was a RCB. Four rows were planted in which the residue treatments were imposed. Observations were made from each row which served as replications, treatments were replicated 4 times
- Prior to planting, NDVI readings were measured from each soil at four GreenSeeker RT200 sensor® (N Tech Industries, LLC, Ukiah, CA) orientations (Fig. 1, A-D) from dry soil and after the addition of 15L of water (wet soil)
- Corn was planted at a depth of 4cm on 64cm row spacings at a seed population of 71,600 seeds ha^{-1}
- A foliar fertilizer was applied containing N, B, Cu, Mn and Zn and pelletized gypsum was applied after emergence (rates Table 2)
- NDVI was measured for corn growing in each soil at the V2 through V6 growth stages using the GreenSeeker RT200® (N Tech Industries, LLC, Ukiah, CA) at orientations A-D (Figure 1)
- Also at each growth stage, three crop residue covers, Glycine Max, Zea mays and Triticum turgidum, were placed over each soil type and NDVI of corn was measured. Bare soil served as the control
- Crop residue was maintained at 70% for each reading and determined using the line transects method
- Drip irrigation was installed to supplement precipitation as needed to ensure optimum corn growth
- Statistical analyses were conducted using the GLM procedure available from SAS (SAS Inst. Cary, NC). Due to significant interaction between soils and effect of Sensor Orientation on NDVI; NDVI was analyzed using the protected LSD as a mean separation technique, when analysis of variance indicated significant differences

Fertilizer Rates (Table 2)

Rate	----------Nutrient----------					Rate	-----Nutrient-----	
	N	B	Cu	Mn	Zn		Ca	S
g ha^{-1}	112	28	112	84	84	kg ha^{-1}	49	38

Plant Box (Table 2)

Results

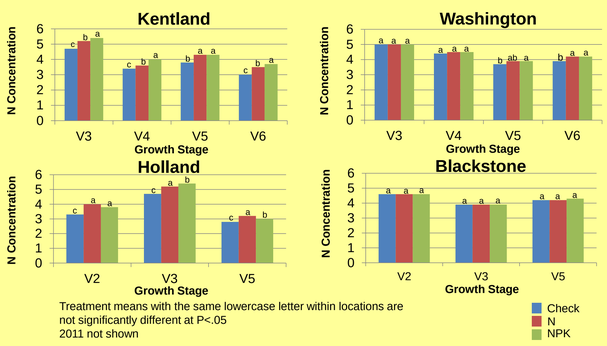
NDVI Means

Year	Site	Orientation	Growth Stage V2	V3	V4	V5	V6
			----------Mean NDVI----------				
2012	Blackstone	45°	0.35 c†	0.31 a	na	0.40 c	na
		Inverted	0.47 a	0.32 a	na	0.58 a	na
		15 cm Mask	0.29 e	0.25 b	na	0.28 e	na
		Parallel	0.32 d	0.27 b	na	0.45 b	na
		Nadir	0.38 b	0.30 a	na	0.37 d	na
	Holland	45°	0.31 b	0.26 b	na	0.35 b	na
		Inverted	0.44 a	0.42 a	na	0.53 a	na
		15 cm Mask	0.25 d	0.19 d	na	0.26 c	na
		Parallel	0.29 c	0.25 b	na	0.32 b	na
		Nadir	0.29 c	0.23 c	na	0.32 b	na
	Kentland	45°	na	0.40 b	0.32 b	0.41 b	0.41 b
		Inverted	na	0.55 a	0.49 a	0.55 a	0.55 a
		15 cm Mask	na	0.30 d	0.27 c	0.33 c	0.33 c
		Parallel	na	0.40 b	0.32 b	0.41 b	0.41 b
		Nadir	na	0.37 d	0.31 b	0.35 c	0.35 c
	Washington	45°	na	0.33 b	0.36 c	0.39 b	0.57 b
		Inverted	na	0.39 a	0.43 a	0.44 a	0.61 a
		15 cm Mask	na	0.24 c	0.28 e	0.32 c	0.44 d
		Parallel	na	0.33 b	0.39 b	0.38 b	0.58 ab
		Nadir	na	0.32 b	0.33 d	0.34 c	0.47 c
2011	Kentland	45°	0.42 b	0.63 c	0.61 bc	na	na
		Inverted	0.62 a	0.82 a	0.68 a	na	na
		15 cm Mask	0.35 d	0.45 d	0.34 d	na	na
		Parallel	0.39 c	0.70 c	0.64 ba	na	na
		Nadir	0.41 cb	0.62 c	0.56 c	na	na

Year	Site	Orientation	Growth Stage V2	V3	V4	V5	V6
			----------Mean NDVI----------				
2012	Blackstone	Check	0.36 a	0.29 a	na	0.41 a	na
		N	0.36 a	0.29 a	na	0.41 a	na
		NPK	0.36 a	0.29 a	na	0.43 a	na
	Holland	Check	0.32 a	0.26 a	na	0.35 ab	na
		N	0.31 a	0.26 a	na	0.32 b	na
		NPK	0.32 a	0.28 a	na	0.41 a	na
	Kentland	Check	na	0.39 a	0.32 a	0.38 b	0.39 a
		N	na	0.41 a	0.35 a	0.44 a	0.45 a
		NPK	na	0.41 a	0.37 a	0.44 a	3.16 a
	Washington	Check	na	0.33 a	0.37 a	0.40 a	0.56 a
		N	na	0.31 a	0.33 a	0.36 b	0.51 ab
		NPK	na	0.30 b	0.34 b	0.35 b	0.50 b
2011	Kentland	Check	0.43 a	0.63 a	0.54 a	na	na
		N	0.45 a	0.66 a	0.58 a	na	na
		NPK	0.44 a	0.65 a	0.58 a	na	na

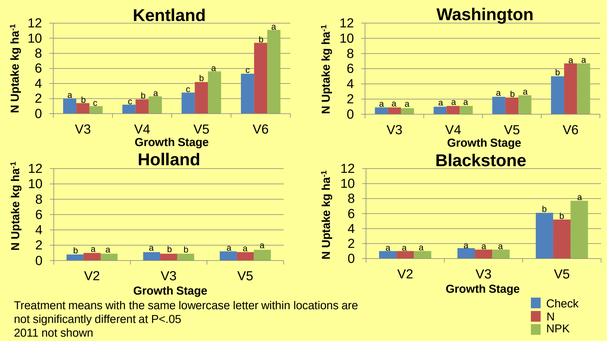
† Values within a column followed by the same lowercase letter within locations are not significantly different at p<0.05
-- Data not shown was not collected

N Concentration, g N 100 g^{-1} Tissue



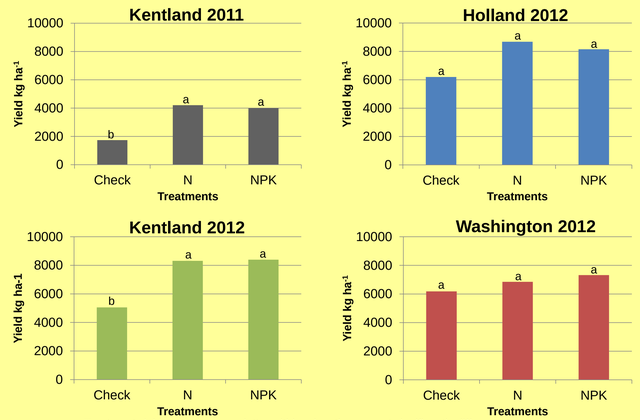
Treatment means with the same lowercase letter within locations are not significantly different at P<.05
2011 not shown

N Uptake, kg N ha^{-1}



Treatment means with the same lowercase letter within locations are not significantly different at P<.05
2011 not shown

Grain Yield, kg ha^{-1}



Treatment yields with the same letter within a location are not significantly different at p<.05
Yield was not collected from Blackstone

Crop Residue NDVI Means

Site	Orientation	Growth Stage V2	V3	V4	V5	V6
		----------Mean NDVI----------				
Bojac	45°	0.48 a†	0.55 a	0.56 a	0.55 b	0.55 cb
	15 cm Mask	0.37 b	0.34 b	0.45 a	0.51 c	0.49 cb
	Parallel	0.49 a	0.53 a	0.59 a	0.61 ab	0.64 a
	Nadir	0.49 a	0.55 a	0.60 a	0.65 a	0.57 b
Davidson	45°	0.45 a	0.48 a	0.51 a	0.59 ab	0.64 b
	15 cm Mask	0.33 c	0.34 c	0.39 c	0.45 c	0.47 c
	Parallel	0.37 b	0.41 b	0.46 b	0.56 b	0.72 a
	Nadir	0.46 a	0.46 ab	0.52 a	0.63 a	0.71 a
Hayter	45°	0.45 a	0.49 a	0.51 a	0.63 a	0.57 b
	15 cm Mask	0.41 a	0.39 b	0.35 a	0.61 a	0.48 c
	Parallel	0.43 a	0.44 ab	0.53 a	0.60 a	0.68 a
	Nadir	0.47 a	0.49 a	0.54 a	0.43 a	0.65 a
Pamunkey	45°	0.48 b	0.51 a	0.63 a	0.57 a	0.67 a
	15 cm Mask	0.34 c	0.37 c	0.47 b	0.43 a	0.46 b
	Parallel	0.43 bc	0.46 b	0.59 a	0.57 a	0.71 a
	Nadir	0.50 a	0.53 a	0.60 a	0.63 a	0.66 a

Site	Orientation	Growth Stage V2	V3	V4	V5	V6
		----------Mean NDVI----------				
Bojac	Blank	0.49 a	0.56 a	0.55 a	0.53 b	0.46 b
	Soybean	0.43 b	0.50 ab	0.56 a	0.57 ab	0.57 a
	Corn	0.39 b	0.43 b	0.55 a	0.57 ab	0.61 a
	Wheat	0.51 a	0.50 ab	0.56 a	0.64 a	0.60 a
Davidson	Blank	0.36 b	0.42 ab	0.48 ab	0.60 a	0.57 a
	Soybean	0.41 ab	0.40 b	0.44 b	0.52 b	0.64 a
	Corn	0.40 ab	0.40 b	0.50 a	0.54 ab	0.65 a
	Wheat	0.44 a	0.48 a	0.46 ab	0.57 ab	0.67 a
Hayter	Blank	0.50 a	0.49 a	0.49 a	0.52 a	0.58 a
	Soybean	0.40 b	0.41 b	0.47 a	0.57 a	0.59 a
	Corn	0.44 b	0.46 ab	0.48 a	0.59 a	0.60 a
	Wheat	0.43 b	0.45 ab	0.48 a	0.59 a	0.62 a
Pamunkey	Blank	0.47 a	0.48 a	0.63 a	0.52 a	0.57 a
	Soybean	0.42 ab	0.45 a	0.55 b	0.54 a	0.62 a
	Corn	0.39 b	0.46 a	0.56 b	0.57 a	0.65 a
	Wheat	0.48 a	0.50 a	0.55 b	0.55 a	0.65 a

† Values within a column followed by the same lowercase letter within soils are not significantly different at p<0.05

Conclusions

- While differences in N concentration and N uptake were observed at earlier stages, NDVI was not significantly different between treatments until the V5 growth stage.
- The addition of P and K to the reference strip did increase N uptake in all site years once the plants reached V5. Before V5, N uptake differences between the N and NPK reference strips were negligible.
- During the field study no single orientation was able to consistently distinguish between treatments before the others. NDVI measured at any orientation were significantly different between treatments beginning at V5.
- SPAD readings were effective at distinguishing between N treatments beginning at the V3 stage and continuing through V6 (Not shown).
- The NDVI collected from wet soils was higher than NDVI collected from dry soils across all soil types. Sensing should be conducted at constant soil moisture to reduce the impacts of background NDVI variation.
- Values for NDVI were different among the different crop residues at the V2 growth stage on all soils. As plant biomass increased NDVI variation across treatments decreased, at V6 only one of four soils showed a difference in NDVI across treatments.
- The use of NDVI to distinguish between N rates is not practical until the plants reach the V5 growth stage. Neither the addition of P and K to the reference strips nor the use of different sensor orientations makes the use of the GreenSeeker® practical before V5.