In-Season Prediction of Forage Sorghum Yield Using Proximal Sensing

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Introduction

- Brown midrib (BMR) brachytic dwarf forage sorghum (*Sorghum bicolor* L.) has great potential as an alternative to corn silage in double crop rotations, if sufficient nitrogen (N) is applied to the crop.
- Crop sensing is a promising approach in predicting yield and developing N application recommendation systems.

Project objectives

- Evaluate the impact of sensor orientation and distance from canopy on reflectance measurements.
- Evaluate the impact of timing of scanning to predict end-of-season forage sorghum yield.
- Develop a model to estimate yield from mid-season reflectance measurements a first step in developing algorithms for sensor-driven N recommendations.

Materials and methods

- Trials with 5 to 7 treatments (different N rates: 0, 56, 112, 168, 224, 280, 336 kg N/ha).
- Randomized complete block design with four replications.
- Two year experiment
  - 2014: two trials (Varna and Aurora; central NY)
  - 2015: two trials (Varna and Aurora; central NY)

Table 1. Measurements.

Measurement	Method	Timing
Soil sampling	One composite sample per replication (15 cores)	Before fertilizer application
NDVI scans	2014: Using GreenSeeker handheld Crop Sensor HCS 100 2015: GreenSeeker 505 Handheld Sensor	2014: 3 times at growth stage 3 2015: twice per week from stage 2 until boot stage
Growth stage	Method defined by Vanderlip and Reeves (1972)	With the scans
Plant height	Measure the distance of the canopy from ground	With the scans
Harvest	Hand-harvest an area of 2.3 m^2 (1.52 m by 1.52) m; four adjacent rows in the middle of the plots	At soft dough stage
Stand count	Count plants within the harvest area (2.3 m^2)	At harvest
Forage quality	10 plants from each plot chipped and dried	At harvest

Results

Sensor orientation and height

- Higher NDVI values were measured at lower proximity from canopy setting (H1: 1.2 m above the ground) for each timing and location, suggesting that height of scanning impacts readings of the hand-held sensor (Table 1).
- Orientation impacted NDVI values at the two earliest dates of sensing. Holding the sensor head perpendicular to the row direction resulted in higher NDVI readings. When the canopy was fully developed, orientation no longer impacted readings (Table 1).

Table 1. Normalized difference vegetation index (NDVI) measurements as influenced by the sensor settings (orientation; sensor head parallel or perpendicular to plant rows, and height; 1.2 m from ground or 0.9 m from canopy), at the three sensing timings (days after planting, DAP)

	Aurora, NY						Varna, NY					
Sensor setting	df	NDVI1	df	NDVI2	df	NDVI3	df	NDVI1	df	NDVI2	df	NDVI3
		39 DAP		44 DAP		48 DAP		40 DAP		46 DAP		49 DAP
Orientation												
Parallel	70	0.696b	70	0.796b	52	0.796a	70	0.765b	59	0.824b	39	0.820a
Perpendicular	70	0.727a	70	0.809a	52	0.803a	70	0.779a	59	0.834a	39	0.826a
Height												
1.2 m from ground	70	0.724a	70	0.817a	53	0.820a	70	0.784a	59	0.844a	40	0.845a
0.9 m from canopy	70	0.699b	70	0.787b	53	0.781b	70	0.761b	59	0.814b	40	0.801b
ANOVA												
Source of variation												
Orientation	1	***	1	***	1	NS	1	**	1	**	1	NS
Height	1	***	1	***	1	***	1	***	1	***	1	***

**Significant at the 0.01 probability level
***Significant at the 0.001 probability level
Within columns, means followed by the same letter are not significantly different (p<0.05)

Timing of sensing

- Sensing 49 days after planting (DAP) gave the best relationship between sensor measurements and end of season yield (Fig. 1).
- The optimal timing of sensing was at 0.76 m plant height (49 DAP).

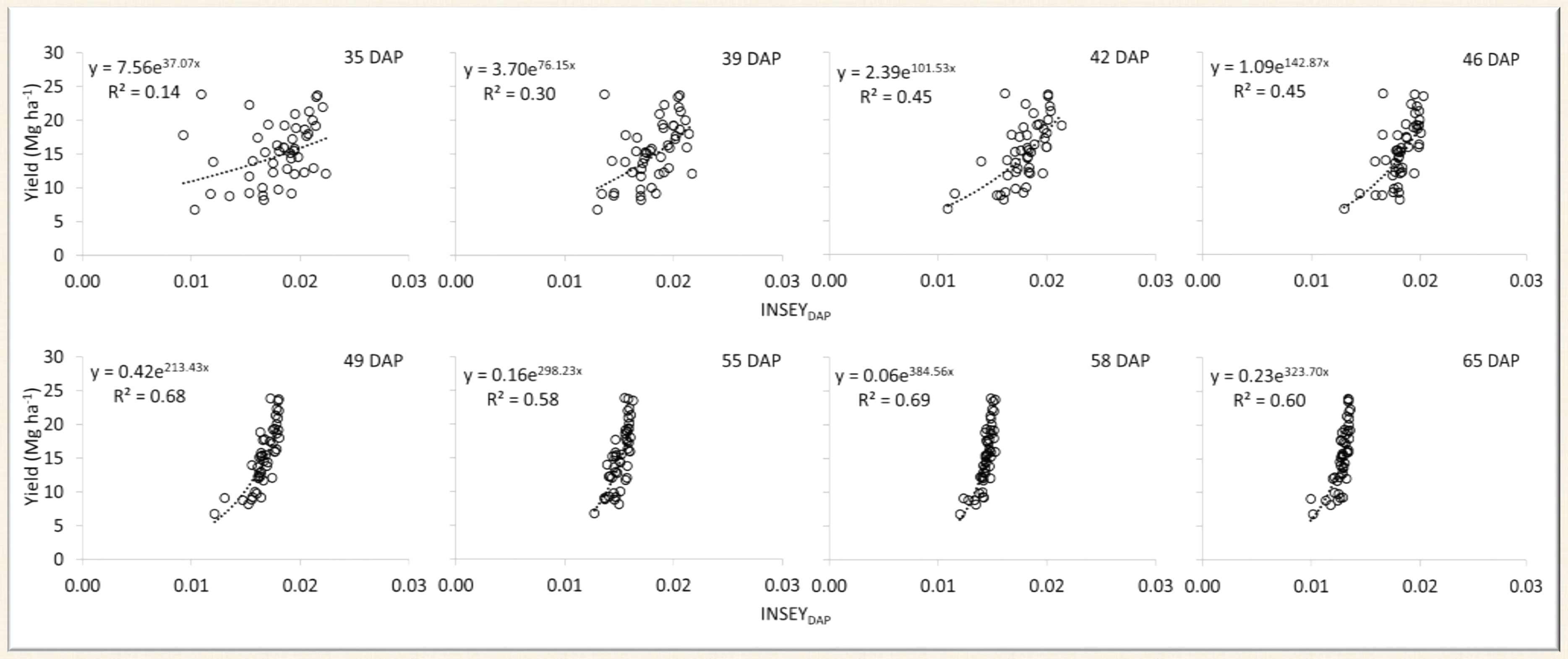

Fig 1. Relationships between final yield and normalized difference vegetation index (NDVI) for trials conducted in Aurora, NY (a) and Varna, NY (b), measured at three dates in 2014 and at two height settings (Part A); 1.2 m from ground (H1) and 0.9 m from canopy (H2), using the GreenSeeker Handheld Crop Sensor HCS 100 (Trimble).

- Literature reports a second criteria for the optimum sensing timing; when the variability expressed as coefficient of variation (CV) of the NDVI measurements is maximized.
- In our study CV of the sensor measurements showed a maximum 32 DAP and then decreased showing a minimum at 52 DAP (Fig. 2).
- Yield estimations were unreliable with scans done prior to 39 DAP suggesting that the CV in NDVI across a field might not be a reliable indicator for time of sensing across all locations.

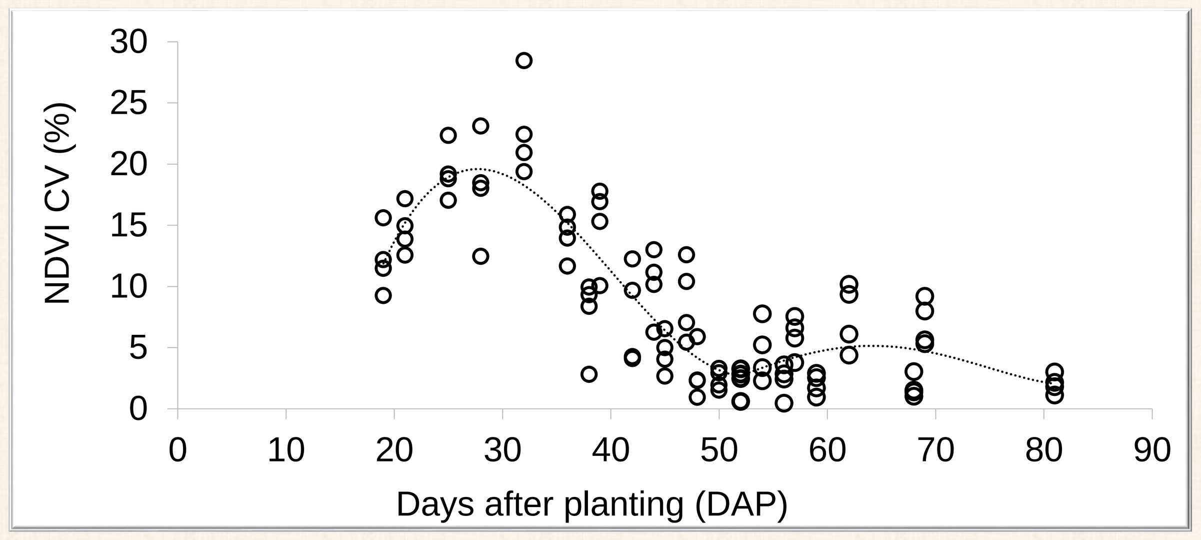

Fig. 2. Fig. 4. Relationship between the days after planting (where GDD>0) and normalized difference vegetation index (NDVI) measurement variability of brown midrib brachytic dwarf forage sorghum expressed as percentage of coefficient of variation (CV%).

Yield prediction

- In season estimated yield $INSEY_{DAP}$ (NDVI/DAP) was better correlated to end-of-season yield than $INSEY_{GDD}$ (NDVI/GDD) and NDVI.
- The relationship is described by the equation (Fig. 3):

$$Yield = 0.32 * e^{(227.35 * INSEY_{DAP})}$$

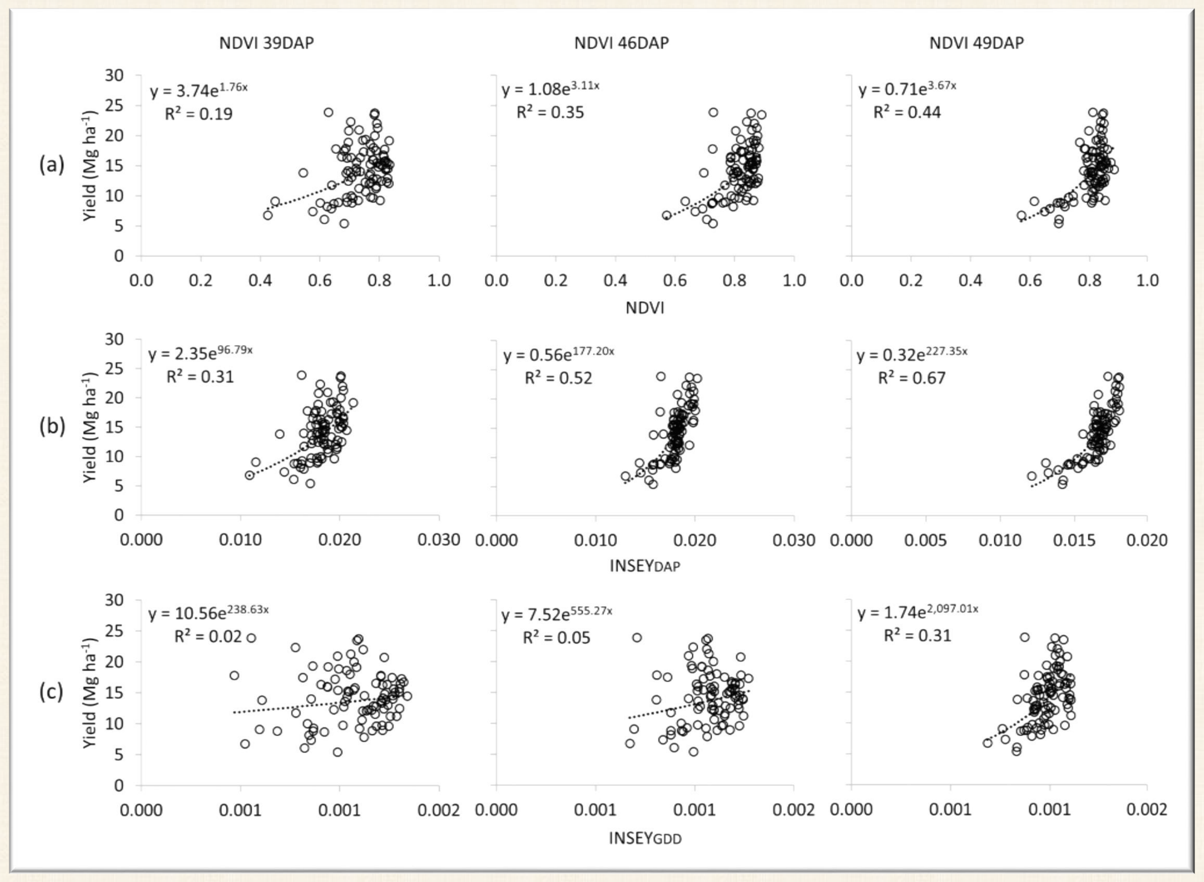

Fig. 3. Relationships between final yield and NDVI (a), in season estimated yield (INSEY) calculated using the days after planting (DAP) (INSEYDAP = NDVI/DAP) (b), and in season estimated yield (INSEY) calculated using the growing degree days (GDD) ($INSEY_{GDD}$ = NDVI/GDD) (c) for trials conducted in Aurora and Varna, NY in 2014 and 2015.

Conclusions

- Proximal sensing provide reliable estimation of end-of-season yield.
- Sensor orientation doesn't impact the measurement after canopy closure.
- Sensor height impacted sensor readings.
- Optimal sensing timing is 49 DAP at 0.76 m plant height.

Contact information

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