Proximal Canopy Sensing to Predict the Quality of Forage Sorghum for Optimal Time of Harvest

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INTRODUCTION

- Brown midrib (BMR) brachytic dwarf sorghum (*Sorghum bicolor* L.) is a drought-tolerant, lodging-resistant, and high quality forage species.
- Timing of harvest is critical to the trade-off between forage yield and quality parameters such as protein content and digestibility.
- Mid-season prediction of forage yield and quality can help farmers in determining the ideal harvest time.
- Proximal canopy sensing has shown potential in predicting crop yield using Normalized Difference Vegetation Index (NDVI) but research is needed to test if NDVI can be used to predict forage quality.

OBJECTIVES

- Evaluate trade-offs between BMR forage sorghum yield and quality parameters.
- Investigate the relationships between NDVI, timing of harvest, and yield and quality.

MATERIALS AND METHODS

Field design

- Two field trials were conducted from June to October 2015 in Aurora and Varna, NY.
- The trial design was a randomized complete block design with four replications. Five pre-plant nitrogen treatments (0, 56, 112, 168, 224 kg N/ha) were applied in each replication in 9×3 m plots.
- Sorghum was planted at 693,750 seeds/ha and 38 cm row spacing.

Mid-season canopy sensing

- Proximal canopy sensing was conducted with the GreenSeeker® (Fig. 1a-c) for the 112 and 224 kg N/ha treatments. The active optical sensor emitted red and near infrared (NIR) light. The amount of reflected NIR light and red light were measured, and the NDVI value was calculated as:

  NDVI = (NIR-Red) / (NIR+Red)

- For Aurora, canopy sensing was performed twice per week from 19 days after planting (DAP) until 69 DAP. For Varna, sensing took place from 38 until 81 DAP.
- Average sorghum height was measured at sensing.

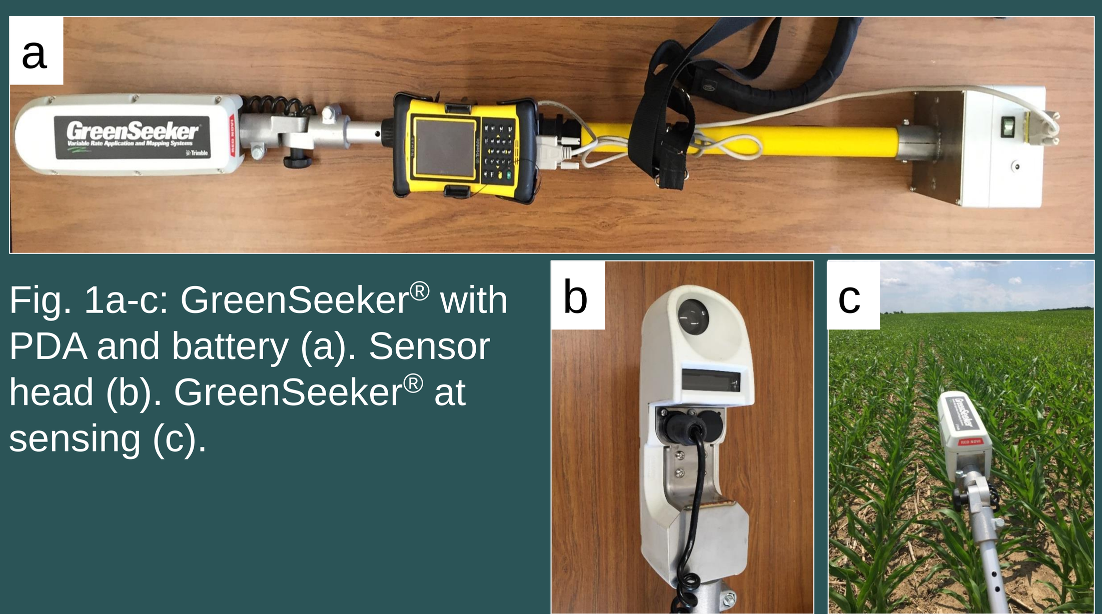

Fig. 1a-c: GreenSeeker® with PDA and battery (a). Sensor head (b). GreenSeeker® at sensing (c).

MATERIALS AND METHODS

Harvesting and quality analysis

- Sorghum was harvested by hand (Fig. 2a) on a weekly basis (8 times). For Aurora, harvest took place from 63 to 120 DAP; for Varna, from 76 to 133 DAP.
- Samples were shredded and dried (Fig. 2b). Quality parameters included crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, starch, in vitro fiber digestibility at 30-hour ($NDFD_{30}$) and 240-hour ($NDFD_{240}$), and indigestible NDF (iNDF).

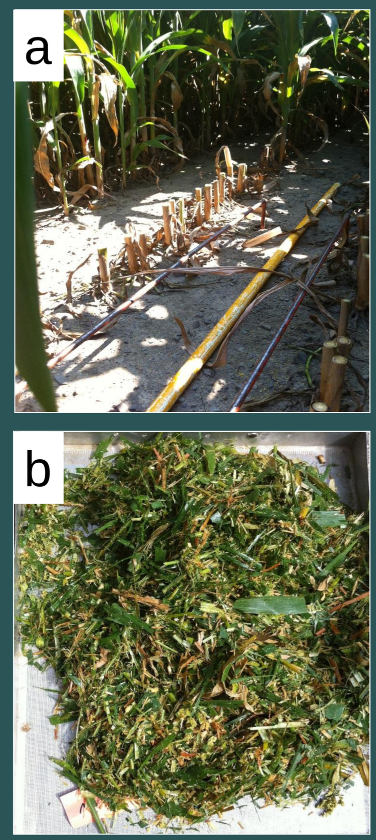

Fig. 2a-b: Sorghum hand harvest (a) and sample processing (b).

Statistical analysis

- Yield and quality parameters were graphed against timing of harvest in Excel.
- Yield, quality and sensing data from the two fields were merged using average plant height at sensing. In total, 9 plant heights (sensing dates) were determined for the combined dataset.
- For each plant height, multiple linear regression was done using SAS and the following model:

  Yield or quality = $NDVI/DAP_{at\ sensing} + DAP_{at\ harvest}$

RESULTS

Trade-offs between yield and quality parameters

- As harvest is delayed, yield, lignin and starch content increase (Fig. 3a,b) while CP, ADF, NDF, and $NDFD_{30}$ decrease (Fig. 3c,d,e,f).

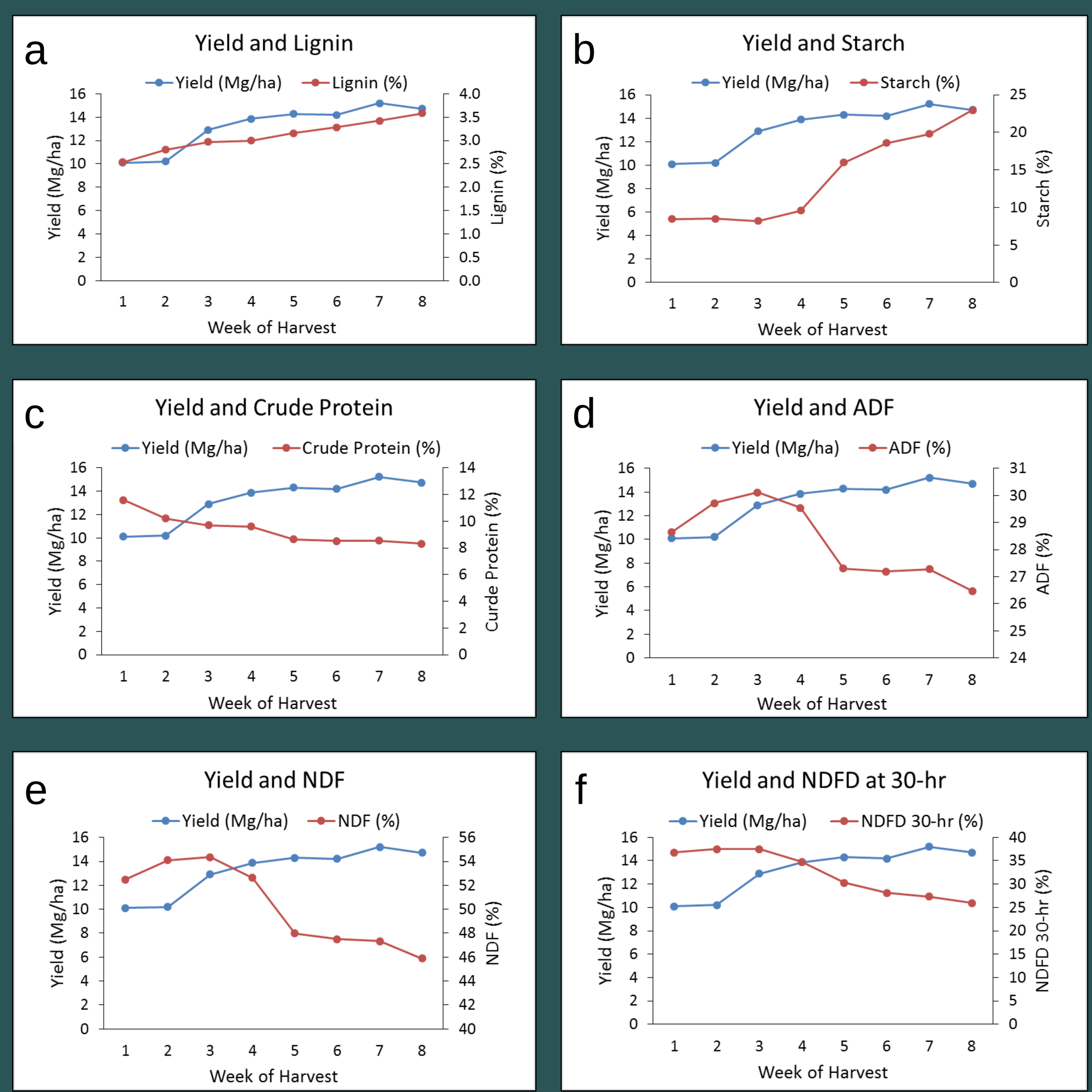

Fig. 3a-f: Trade-offs between sorghum yield and quality parameters at different harvest times in Varna, NY. Sorghum soft dough stage was at week 7. Similar results were found for Aurora, NY.

RESULTS

Prediction of yield and quality using NDVI and total DAP

- When the average plant height was 81 cm at sensing, the regression model showed high r^2 for most yield and quality parameters (Table 1).

Table 1: Relationships between yield & quality parameters, $NDVI/DAP_{at\ sensing}$, and $DAP_{at\ harvest}$. P<0.0001 for all relationships.

Yield and quality parameters	n	Adjusted r^2	Estimates for $NDVI/DAP_{at\ sensing}$	Estimates for $DAP_{at\ harvest}$	Intercept
Yield	122	0.7080	3875.113	0.137	-64.132
ADF	121	0.5922	-631.213	-0.094	48.17
NDF	125	0.7292	-2140.537	-0.210	106.612
Lignin	120	0.6693	216.409	0.014	-1.774
$NDFD_{30}$	122	0.8901	-2274.745	-0.281	97.911
$NDFD_{240}$	121	0.8875	-2546.199	-0.346	115.373
iNDF	120	0.8687	550.539	0.138	-11.451
Starch	120	0.8054	941.654	0.278	-29.507
CP	125	0.3340	-620.051	-0.045	23.805

Model predicted parameters versus actual parameters

- Predicted yield and $NDFD_{30}$ were calculated and compared with actual yield and $NDFD_{30}$ (Fig. 4a-b)

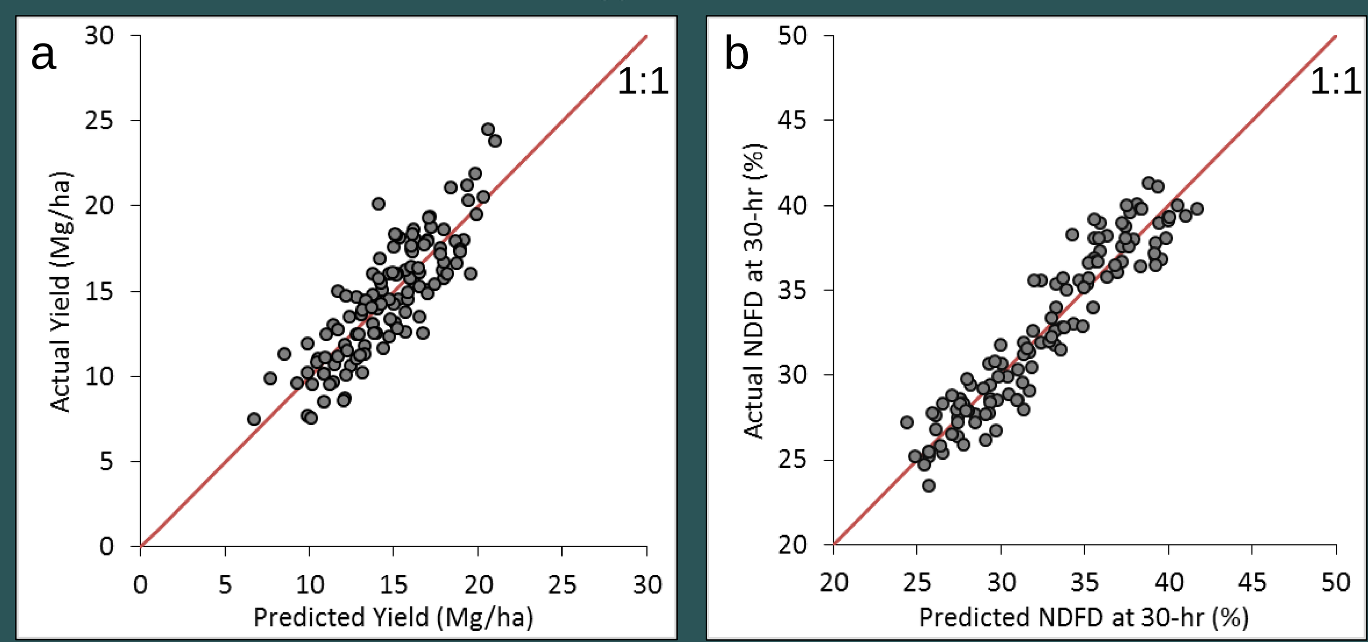

Fig. 4a-b: Actual versus model predicted values for sorghum yield (a) and $NDFD_{30}$(b).

CONCLUSIONS

- With delay in harvest yield, lignin and starch content increased, while crude protein content and digestibility decreased. These changes showed trade-offs between yield and quality over time.
- Proximal canopy sensing showed potential in predicting BMR sorghum yield as well as quality parameters; models were developed to predict forage yield and quality over time using mid-season canopy sensing data (when the sorghum is 81 cm or 32 inches tall).
- Validation studies are needed that include more locations and more growing seasons.

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