# ASSESSING NITROGEN MANAGEMENT AND CLAYPAN SOIL VARIABILITY EFFECTS ON SWITCHGRASS USING REFLECTANCE SENSING

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## Introduction

The topsoil depth or depth to the claypan (DTC) can be highly variable across the landscape for some Midwest soils. This makes managing crops on these soils difficult because their productivity can be highly variable. In some areas of the landscape there can be no topsoil and leave the claypan exposed (e.g., side-slope) while in other areas it can be buried (e.g., toe-slope) (Kitchen et al., 1999). Due to the high variability of theses soils, switchgrass (Panicum virgatum L.) is a potential problem solver for these soils. Switchgrass is a native warm-season, perennial grass indigenous to the Central and North American tall-grass prairie (Moser and Vogel, 1995). Because of the potential for high dry matter yield production, switchgrass has been projected as a viable option for bioenergy. Research using reflectance sensing to evaluate switchgrass growth and yield is limited. In one study it has been used to indicate when switchgrass has physiologically senesced for harvesting after $K^+$ and $Cl^-$ have leached out of the plant back into the soil (Jorgensen, 1997). Labbe et al., (2008) used light reflectance for examining variation of cultivars and ecotypes, variation in N fertilization and structural components of switchgrass. Reflectance sensing has been successfully used to predict the amount of N that is present in forages (Valdes et al. 2006) and has been related to forage compositional analysis as determined by NIR technology (Hames et al. 2003). While there are many different management strategies to be looked at when growing switchgrass, the use of reflectance sensing to assess growth and determine best management strategies is needed.

The purpose of this research was to further explore how reflectance sensing could be used to understand switchgrass growth and management. Specifically, the objective of this study was to investigate the relationship of active-light reflectance sensing on switchgrass stand and growth as impacted by management and DTC variation.

## Materials and Methods

### Site History

This study was conducted at the University of Missouri South Farm located near Columbia, MO on a study site known as Soil Productivity Assessment for Renewable Energy and Conservation (SPARC). This particular experiment was initiated in 2009, but the site was originally developed in 1983 for assessing continuous corn and soybean production as affected by DTC.

The 32 blocks of the site were separated into two experiments of 16 blocks for each experiment, each having a range of DTC. Experiment 1 was conducted to compare grain vs. switchgrass production on varying DTC of claypan soils. The four treatments of Exp. 1 are described in

Table 1. Experiment 2 was conducted to assess different components of switchgrass management as affected by DTC, and are also described in Table 1.

**Reflectance Sensing**

Canopy reflectance sensing measurements were obtained from early in the growing season until just before plants began to seed using a Crop Circle ACS210 (Holland Scientific, Lincoln NE) (fig. 1). The sensor was held between 60 and 90 cm above the canopy and two 7-m long passes along each plot were recorded at a 10 hertz rate, giving 90-120 readings per plot. Reflectance values were averaged by plot as the inverse simple ratio (ISR; ISR = VIS/NIR, where VIS is the reflectance of the visible wavelength and NIR is the reflectance of the near infrared wavelength).

Plant height measurements were taken the same day as reflectance sensing. These readings were also done within the area designated for harvest. Switchgrass population was obtained in the spring of 2010 as described by Landers, (2010). The 2010 switchgrass yields were weighed and subsamples taken for moisture and nutrient analysis.

**Data Analysis**

Regression analysis using Proc Reg within the SAS statistical computer program was primarily used for this study. The reason a regression procedure was used was to take advantage of the DTC factor as a continuous variable. We wanted in the end to have a mathematical relationship of response variables as a function by topsoil depth. Within the regression analysis we used to assess management, the K67 treatment was used as a base reference and all other managements were compared against this reference. Kanlow67 was used because 67 kg N/ha$^{-1}$ was described as being a typical N management, based on personal communication with USDA NRCS Plant Materials Center (Feb. 2009).

In addition to the regression analysis, we used the Proc NLIN (non-linear) procedure within SAS to obtain a plateau-quadratic model which we used for assessing yield relative to reflectance sensing. This type of analysis allowed us to find the point within the data that would be more easily used to predict the yield based upon in-season reflectance sensing data.

## Results and Discussion

**Canopy Reflectance as Impacted by Switchgrass Management**

The effects of the management treatments and topsoil depth on crop reflectance sensing are shown in fig. 2 (see Table 2 for regression equation). Reflectance readings of different management treatments are compared using the K67 treatment as a base reference. For 2010, ISR values of CR was less than the reference K67. This effect of switchgrass variety was because CR is a shorter growing, denser variety than Kanlow. Additionally, stand of CR on these plots was 50 to 100% higher than Kanlow (Lander, 2010), an affect of seed quality. This higher density of plants would likely have contributed to the lower ISR reflectance observed.

An understanding of the amounts of N fertilizer and timing of application is needed to interpret the differences between K67 and the other Kanlow treatments. A timeline of dates of application along with rate have been put into graphical form both years (Fig. 1). For 2010, switchgrass with no N (K0) gave higher ISR values. The treatment K34 was also different then K67. In 2010, there are distinctions among all the treatments. All treatments are significantly different from the reference. With the K101 treatment, ISR values did not change across the DTC showing sufficient N regardless of topsoil depth. These results indicate that for this relatively wet growing season, N need increased as topsoil depth increased.

In 2011, ISR measures were statistically unaffected by topsoil depth (fig.2; table 2), though a consistent trend of lower ISR values with greater topsoil was noticed. We suspect topsoil depth may have had an effect on stand and/or tillers per plant for 2010, but no measurements were taken to confirm this. Relative to switchgrass management treatments, the ISR values obtained in 2011 appeared very similar to those found in 2010 (fig. 2). Differences due to N management followed the expected outcome of lower ISR values with increasing N fertilization rate. The CR variety continued to have the lowest ISR readings across all reading dates and was significantly different from the reference treatment (table 2). Reflectance from K0 and KNL appeared similar and significantly greater than the reference. Though the legumes were frost-seeded in the early spring of 2011, they were small and inconspicuous through the periods of reflectance measurements. As such they would have had little effect on reflectance nor in contributing N to switchgrass during this first year of their establishment. As such, KNL management gave equivalent ISR values as the unfertilized K0 management. For the KWC management, one would expect similar outcomes as the KNL, yet KWC tended to have lower ISR values. We attribute this difference to the stand of white clover being dense and covering most of the ground. The K2cut treatment deviated from K67, although having the same amounts of N. The reason is because K2cut was harvested before the sensing dates and the change in height increased the sensor readings.

**Factors Contributing to ISR Differences**

To help further understand what factors may have contributed to reflectance, ISR readings were regressed against population, and height to explore potential relationships (fig. 3).

**Plant Population.** Reflectance values in 2011increased as population decreased for all four dates of sensing (fig. 3; table 3). This relationship could potentially be used for early season management of switchgrass to evaluate stand sufficiency. Eighteen plants $m^2$ has been identified as the plant-density threshold to avoid yield reductions when switchgrass is managed as a bioenergy crop (Schmer et al. 2006). Using this threshold value in the equation obtained for ISR 1 (table 3), ISR values > 0.32 would indicate areas that may have marginal stands. Since reflectance values change rapidly during early season growth, using ISR to estimate switchgrass stand would require stand counts on the day of sensing for accurate calibration. We see these findings supportive of using canopy reflectance sensing to assess stand density.

**Plant Height.** Switchgrass height was a factor that significantly impacted reflectance measurements (fig. 3). As height increased, ISR readings decreased. This relationship was expected since height would be an indicator of plant biomass (Lemus, et al, (2002) though no biomass measurements were taken in this study at the time of reflectance.

**Yield as a Function of ISR**

One of the sub-objectives of this paper was to investigate if reflectance sensing during the growing season could be used to indicate end of season yield. Yield relative to reflectance sensing, expressed as ISR, was observed in smaller plots. It was apparent that only at higher ISR values yield varied as a function of ISR. Using Plateau-Quadratic Non-Linear Regression procedure, this relationship was determined (fig. 4). Discarding the plateau section of the model, observed yield was regressed as a function of predicted yield of the model (fig. 5). Based upon the root mean square error (RMSE) and coefficient of determination ($R^2$), reflectance sensing could be reasonably used to predict yield. The interpretation of the joint values between the plateau and the quadratic portions of the regression is indicative of reflectance being saturated.

Encompassed in all the yield observations are management treatments as found in table 1. Generally, plots with high ISR values were from experimental units with combination of low stands, low topsoil or low or no N application.

## Conclusion

Switchgrass grown on varying topsoil depths was evaluated using reflectance sensing. We found the sensors were able to detect differences in management well during late June and early July. When looking at variables that contributed to differences in ISR readings, population and height seemed to be the factors contributing the most. For population, the sensors were able to recognize stand issues if actual population counts are taken on the same day.

Yield as a function of ISR showed promising results. The reflectance sensors were able to show a relationship when there would be problematic declines in yield. For predicting yield, the sensors were able to predict well the future yields and the best prediction values came from management treatments that did not receive N.

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## Tables and Figures

Table 1. Management delineations of experiment 1 and 2.

| Treatment Ref # | Annual vs. Perennial | Cropping System | Species | N Fertilizer ($kg/ha^{-1}$) | Year initiated |
|---|---|---|---|---|---|
| Experiment 1 | | | | | |
| G1 | Annual | Corn - Soybean | Corn odd yrs / Soy even yrs | 168 | 2009 |
| G2 | | Soybean - Corn | Soy odd yrs / Corn even yrs | 0 | 2009 |
| K0 | Perennial | Switchgrass | Kanlow | 0 | 2009 |
| K67 | | Switchgrass | Kanlow | 67 | 2009 |
| Experiment 2 | | | | | |
| CR | Perennial | Switchgrass | Cave-In-Rock | 67 | 2009 |
| K67 | Perennial | Switchgrass | Kanlow | 67 | 2009 |
| K101 | Perennial | Switchgrass | Kanlow | 101 | 2009 |
| K2cut | Perennial | Switchgrass | Kanlow | 67 + 34 | 2009 |
| K+WC† | Perennial | Switchgrass | Kanlow + White Clover | 0 | 2009 |
| K+NL† | Perennial | Switchgrass | Kanlow + Native Legumes | 0 | 2009 |

† Legumes were frost seeded in the spring of 2011. Therefore in 2010, 34 kg N/ha-1 was applied to these two treatments and for that year only are represented by K34.

Table 2. Switchgrass reflectance as ISR in 2010 and 2011 as affected by management and depth to claypan (DTC) The "X" variable in the equations is DTC in cm.

| Year | Treatment | Regression Equation | Statistical Difference † | | $R^2$ |
|---|---|---|---|---|---|
| | | | Intercept | Linear | |
| | | | -----------probability----------- | | |
| 2010 | | | | | |
| | K67 (Ref) | Y= 0.194 + 0.0004*X* | <0.0001 | <0.001 | 0.81 |
| | K0 | Y= 0.268 + 0.0001*X* | <0.0001 | - | 0.81 |
| | K34 | Y= 0.328 + 0.0003*X* | <0.0001 | - | 0.81 |
| | K101 | Y= 0.292 - 0.00001*X* | <0.0001 | 0.02 | 0.81 |
| | CR | Y= 0.278 + 0.0004*X* | 0.04 | - | 0.81 |
| 2011 | | | | | |
| | K67 (Ref) | Y = 0.211 - 0.0002*X* | <0.0001 | - | 0.88 |
| | K0 | Y = 0.307 - 0.0007*X* | <0.0001 | - | 0.88 |
| | KNL | Y = 0.302 - 0.0007*X* | <0.0001 | - | 0.88 |
| | KWC | Y = 0.280 - 0.0007*X* | <0.0001 | - | 0.88 |
| | K101 | Y = 0.199 - 0.0002*X* | <0.05 | - | 0.88 |
| | K2cut | Y = 0.329 + 0.0001*X* | <0.0001 | - | 0.88 |
| | CR | Y = 0.187 - 0.0005*X* | <0.001 | - | 0.88 |

Table 3. Switchgrass reflectance in 2011 as affected by stand. The "X" variable is switchgrass population in plant $m^{-2}$.

| Response Variable | Treatment | Regression Equation | Statistical Difference | | $R^2$ |
|---|---|---|---|---|---|
| | | | Intercept | Linear | |
| | | | -----------probability----------- | | |
| ISR 1 | | | | | |
| | Switchgrass | Y= 0.387 - 0.0040*X* | <0.0001 | <0.0001 | 0.48 |
| ISR 2 | | | | | |
| | Switchgrass | Y= 0.343 - 0.0040*X* | <0.0001 | <0.0001 | 0.37 |
| ISR 3 | | | | | |
| | Switchgrass | Y= 0.321 - 0.0040*X* | <0.0001 | <0.0001 | 0.35 |
| ISR 4 | | | | | |
| | Switchgrass | Y= 0.321 - 0.0034*X* | <0.0001 | <0.0001 | 0.38 |

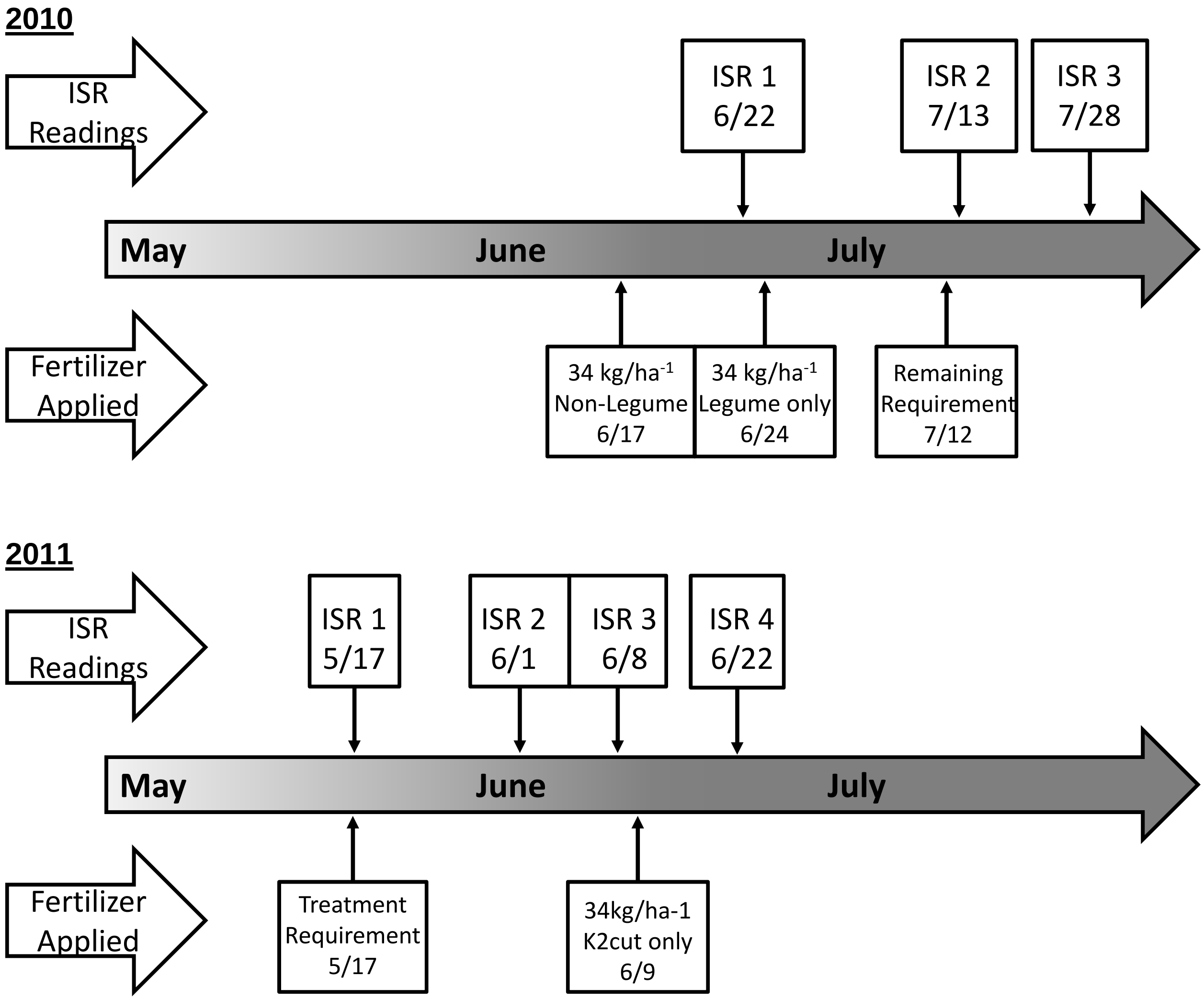

Figure 1. Timeline for 2010 and 2011 reflectance readings and fertilizer application.

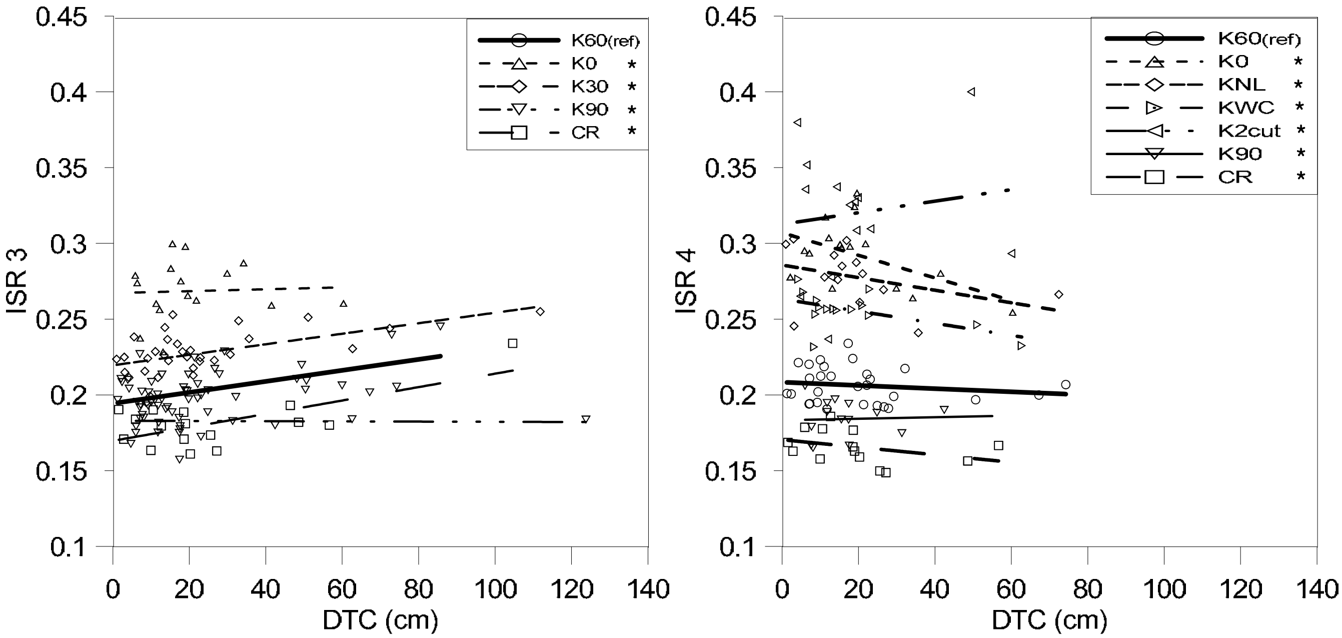


Figure 2. Switchgrass reflectance (ISR) readings for 2010 (left) and 2011 (right) by management as a function of DTC. (See table 2 for regression equation.)

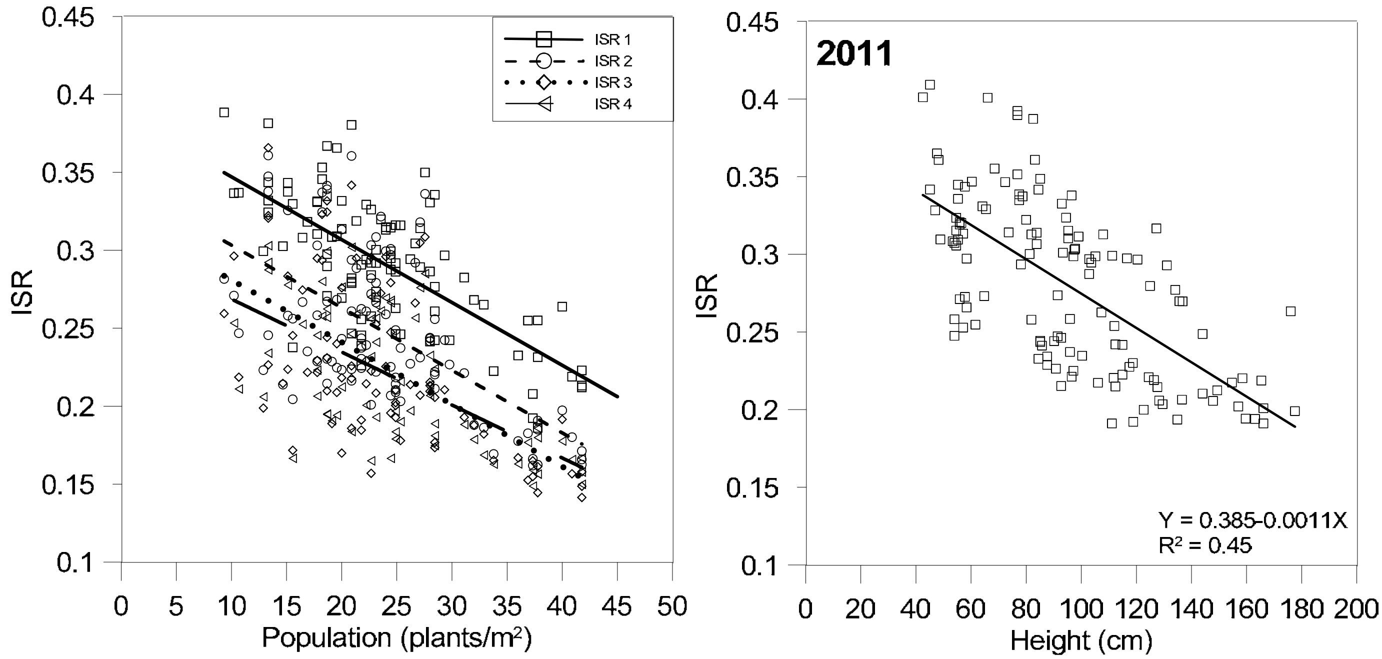


Figure 3. Switchgrass reflectance (ISR) in 2011 as a function of population (left; See table 3 for regression equation.) and of height (right).

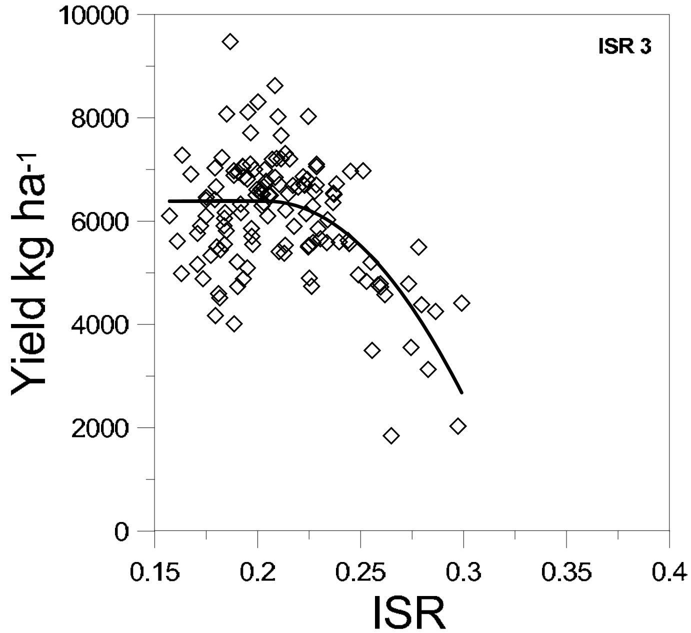


Figure 4. Switchgrass yield in 2010 as a function of canopy reflectance taken on three separate sensing dates (see fig. 1). ($Y = -10766.5 + 168025X - 411461X^2$ RMSE=981.74 $R^2$=0.34)

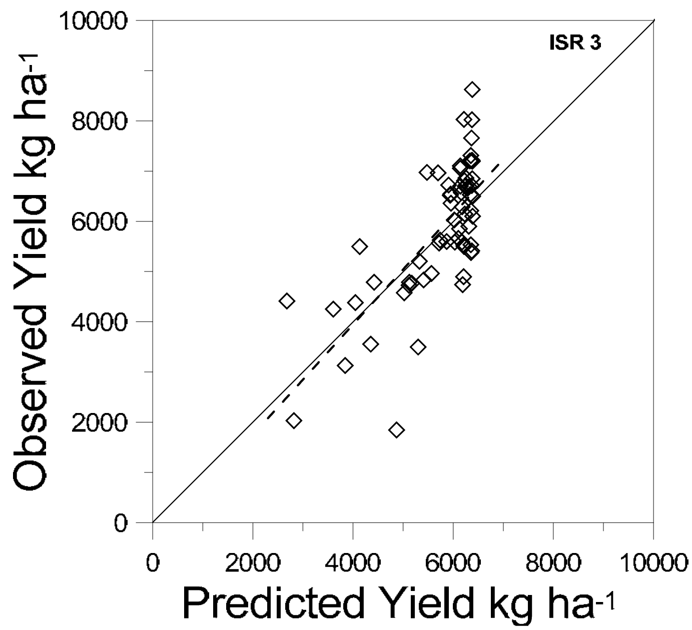


Figure 5. Observed switchgrass yield shown in relationship to predicted yield for reflectance readings. ($Y = -445.55 + 1.098X$ RMSE=911.92 $R^2$=0.53) Only reflectance values greater than the model joint value of 0.204 were used.

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