IN-SEASON DIAGNOSIS OF RICE NITROGEN STATUS USING AN ACTIVE CANOPY SENSOR

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ABSTRACT

Timely non-destructive estimation of crop nitrogen (N) status is crucial for in-season site-specific N management. Active crop canopy sensor is a promising tool to obtain the needed information. The objective of this study was to evaluate GreenSeeker sensor for estimating rice N status (nitrogen nutrition index, NNI) at different growth stages. Nitrogen rate experiments were conducted in 2008 and 2009, in Jiansanjiang, Heilongjiang Province, Northeast China. An active crop canopy sensor, GreenSeeker was used to collect rice canopy reflectance data across the growing season. The preliminary analysis indicated that the relationship between GreenSeeker sensor values (NDVI and RVI) and NNI varied significantly with site-years.

Keywords: GreenSeeker sensor, Nitrogen nutrition index, Rice

INTRODUCTION

In-season diagnosis of crop N status is crucially important for the implementation of in-season site-specific N management. Nitrogen nutrition index (NNI) has been proposed for such purposes (Lemaire et al., 2008), however, practical application of the NNI approach is limited due to the cost, time and labor requirements associated with destructive sampling and laboratory analysis. As a result, scientists have focused on developing fast and non-destructive approaches to estimate NNI, with some progress being made using the chlorophyll meter to estimate NNI in wheat (Prost and Jeuffroy, 2007) and corn (Ziadi et al. 2008). As an alternative, Lemaire et al. (2008) suggested remote sensing measurements as a surrogate way to determine this critical parameter, since such measurements are not invasive and can be repeated several times during the growth period.

Studies are needed to develop methods of using canopy sensors for in-season diagnosis of crop N status, which is faster than chlorophyll meter. The objective of this study was to evaluate the potential of using GreenSeeker active canopy sensor for in-season diagnosis of rice N status in Northeast China.

MATERIALS AND METHODS

Study site

The study area is located in the Sanjiang Plain (47.2 N°, 132.8° E), which is an alluvial plain of three rivers, Heilongjiang, Songhua and Wusuli River and covers about 108900 km² in Heilongjiang Province, Northeast China. Two sites were selected for this study, with the same soil type (Albic soil). Rice has been continuously planted since 1992 at Site 1, while Site 2 has a shorter rice planting history which was started from 2002. The detailed soil properties of different sites and fields are given in Table 1.

Table 1. Soil properties of the experimental fields.

Site	Year	pH	SOM	Available N	Olsen P	K	Soil type
			-g·kg^{-1}-	----------------mg·kg^{-1}---------------			
1	2008	5.9	35.1	157	30.0	133.0	Albic
	2009	5.9	36.0	202	10.8	141.0	Albic
2	2008	6.0	32.9	175	37.0	121.0	Albic
	2009	6.0	35.8	115	29.9	201.6	Albic

Nitrogen Rate Experiments Design

Two field experiments were conducted at two sites in 2008 and 2009, respectively, in Jiansanjiang, Heilongjiang Province, China. The size of each plot was 15m x 10 m. In order to estimate rice yield potential without N application at panicle elongation stage, each plot was splited into two parts: 10m x 10m as the main plot, and 5m x 10m as the compared plot without receiving the third time of

N application. In 2008, randomized block design was used with four replications and five N rate treatments with 0, 35, 70, 105 and 140 kg $N\cdot ha^{-1}$ at Site 1 and Site 2. In 2009, the experiment at Site 2 had three replications and at Site 1 had four replications. In addition to the five N rate treatments as in 2008, we added one treatment of N recommendation based on the GreenSeeker-based N management strategy developed using 2008's result. For all treatments, 135 kg $[P_2O_5]\cdot ha^{-1}$ ($[Ca(H_2PO_4)_2]$) and 210 $kg\cdot ha^{-1}$ (as K_2O) were incorporated into the soil before transplanting. The N source for all experiments was urea.

GreenSeeker Measurements

The GreenSeeker Hand-Held optical reflectance sensor (Ntech Industries, Ukiah, CA) was used in this research. It uses active radiation from red (650 ± 10 nm) and near infrared (770 ± 15 nm) band independent of solar conditions. The device uses the software to calculate normalized difference vegetation index (NDVI) directly and it generates NDVI at a rate of 10 times of readings per second. NDVI value was collected from tillering to heading growth stage. Measurements were made at three sites over each plot, 5-10 m^2 facing vertically downwards from 0.5 m above the rice canopy on five different dates: tillering, panicle initiation, booting, before heading, heading stage. The data from treatments 1 to 4 were used to calibrate the N topdressing algorithm, and the data from treatment 5 at panicle initiation stage were used to calculate the N topdressing rate based on the calibrated site-specific N recommendation algorithms.

Plant Sampling and Measurements

Aboveground biomass was collected by randomly clipping 3 to 5 hills vegetation from scanned plants following GreenSeeker optical sensor data collection in each plot. Clip 5 hills at tillering stage and panicle elongation stage, clip 3 hills rice at booting, before heading, heading stage. All plant samples were oven dried at 70 ℃ to constant weight and then weighed, ground, and analyzed for N concentration using the Kjeldahl-N method. Sampling dates were at tillering, panicle elongation, booting, before heading and heading stage. The plant N uptake (N uptake) was determined by multiplying whole-plant N concentration and dry biomass. Rice was harvested at the end of September. Yield was determined by harvesting the central three 1 by 1 m area of each plot and adjusted to a moisture content of 14.5 %.

Statistical Analysis

Correlation, regression, and analysis of variance (ANOVA) were conducted using STATISTICA 6.0 (StatSoft, Inc., Tulsa, Oklahoma, USA) and MicroSoft Excel (MicroSoft Cooperation, Redmond, Washington, USA).

RESULTS AND DISCUSSION

Relationships between GreenSeeker Sensor Readings and Nitrogen Nutrition Index

As indicated in Table 5, about 16-49% of NNI variability could be explained by GreenSeeker vegetation indices at stem elongation stage, while 21-78% could be explained at booting stage. The relationships varied significantly with site-years.

Across sites in 2008, about 55% of NNI variability could be explained by NDVI or RVI (Fig. 1).

Table 5. The relationship between NDVI , RVI and NNI in 2008, 2009.

Year	Site	Stage	Index	Equation	R^2
2008	1	SE[1]	NDVI	$y = 14.14x^2 - 16.55x + 5.328$	0.38
	1	SE	RVI	$y = 0.04x^2 - 0.290x + 1.008$	0.48
	2	SE	NDVI	$y = 5.947x^2 - 6.494x + 2.401$	0.21
	2	SE	RVI	$y = 0.031x^2 - 0.248x + 1.141$	0.28
2009	1	SE	NDVI	$y = -0.886x^2 + 1.650x - 0.098$	0.23
	1	SE	RVI	$y = -0.075x^2 + 0.517x - 0.372$	0.16
	2	SE	NDVI	$y = -4.345x^2 + 4.971x - 0.770$	0.36
	2	SE	RVI	$y = -0.058x^2 + 0.456x - 0.221$	0.49
2008	1	Booting	NDVI	$y = 28.61x^2 - 38.23x + 13.28$	0.78
	1	Booting	RVI	$y = 0.019x^2 - 0.148x + 0.748$	0.77
	2	Booting	NDVI	$y = 59.88x^2 - 82.73x + 29.14$	0.67
	2	Booting	RVI	$y = 0.045x^2 - 0.459x + 1.731$	0.65
2009	1	Booting	NDVI	$y = -1.592x^2 + 3.439x - 0.597$	0.22
	1	Booting	RVI	$y = -0.060x^2 + 0.608x - 0.562$	0.21
	2	Booting	NDVI	$y = -42.39x^2 + 56.59x - 17.89$	0.26
	2	Booting	RVI	$y = -0.092x^2 + 0.956x - 1.482$	0.29

1SE: stem elongation stage

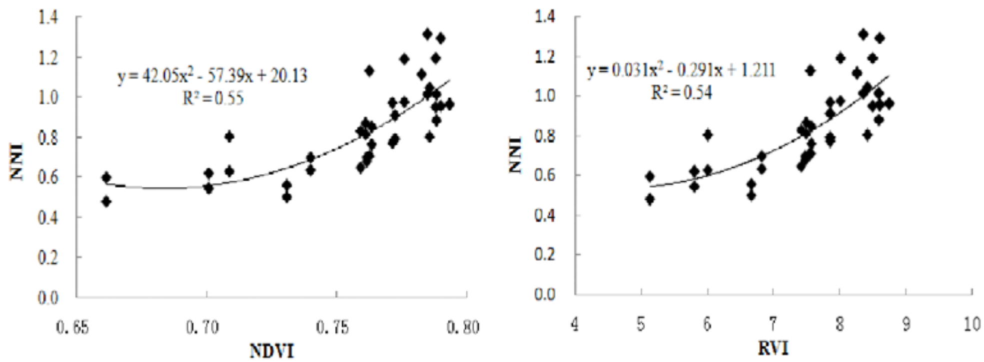

Fig. 1. The relationship between NDVI (left), RVI (right) and NNI at booting at stage in 2008 across sites.

CONCLUSION

The idea of using remote sensing technology to estimate NNI is attractive because it provides non-destructive diagnosis of crop N status. Preliminary analysis indicated that the relationship between GreenSeeker sensor values (NDVI and RVI) and NNI varied significantly with site-years. More studies are needed to develop methods of using GreenSeeker sensor for in-season N status diagnosis.

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