Assessment of Sugarcane Growth and Yield across Genotypes Using Canopy Reflectance Measurements

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Abstract

A field experiment was conducted on a sand soil in 2011–13 to investigate relationships between sugarcane canopy reflectance and yield traits, including cane yield (TCH), commercial recoverable sucrose (CRS), sucrose yield (TSH) across 18 genotypes. Canopy reflectance were measured in the growing seasons. The number of millable stalks, stalk length, stalk diameter, mean stalk weight, TCH, CRS, and TSH were determined at mature. The normalized difference vegetation index (NDVI) was calculated based on reflectance values in red (680 nm) and near infrared (NIR, 800 nm). Among yield components, the number of stalks and TCH most highly correlated with NDVI. Although stalks and TCH were highly and linearly (r = 0.66 – 0.83***) related to NDVI measured in April to August, the best time of measuring canopy reflectance for yield assessment in Florida across genotypes was in May or during early grand growth. Therefore, measurements of NDVI during early grand growth of sugarcane could be useful for predicting plant growth and yield potential across genotypes and used as an agronomic management and research tool.

Introduction

Development of high-yielding sugarcane cultivars with resistance or tolerance to biotic and abiotic stresses is critical for sustainable sugarcane production. Estimation of yield potential based on growth and physiological traits during early growth stage is essential for breeders to screen sugarcane varieties and is especially important for sugarcane growing on sand soils in Florida. Canopy reflectance measurements using remote sensing technologies during growing season may be useful for predicting plant growth and yield potential of sugarcane genotypes and evaluate their field performance.

Objectives

1. To identify if there were any relationships between canopy reflectance and the yield traits.
2. To determine the best timing of reflectance data collection for yield prediction.

Materials and Methods

Plant Culture and Measurement

Eighteen sugarcane genotypes were planted in November 2010 with RCB design & four replications. Growth and canopy reflectance were measured five times with a 4-week interval during tillering and grand growth phases from three crops (plant cane, first ratoon, and second ratoon). Yield components were determined at mature (December).

Plate 1. Measurements of canopy reflectance using a multispectral radiometer for (A) plant cane, (B) first ratoon, and (C) second ratoon crops in 2011, 2012, and 2013, respectively.

Table 1. Specific dates, days after emergence (DAE) or harvest (DAH), and days of year (D of Y) of five times of measuring canopy reflectance for plant cane (PC), first ratoon (FR), and second ratoon (SR) crops.

Time	2011 (PC)			2012 (FR)			2013 (SR)		
	Date	DAE	D of Y	Date	DAH	D of Y	Date	DAH	D of Y
1	Mar. 9	108	69	May 11	32	131	May 6	47	127
2	Mar. 31	130	91	Jun. 5	57	156	Jun. 4	76	156
3	Apr. 26	156	117	Jun. 28	80	179	Jun. 25	97	177
4	May 12	172	133	Jul. 19	101	200	Jul. 9	111	191
5	Jun. 23	214	175	Aug. 9	122	221	Aug. 8	141	221

Data Analysis

1. Variation in yield components across genotypes
2. Reflectance variability across genotypes and across measurement dates in the season
3. Correlation and regression of canopy reflectance or the normalized difference vegetation index [NDVI=(R800-R680)/(R800+R680)] and yield traits using simple linear regression & multiple regression

Results

I. Changes in NDVI

NDVI increased as plant growth and reached maximum when plant canopy got closure or 100% ground coverage. Dates of canopy closure differed among the three crops with much earlier for plant cane than ratoon crops. Plant cane had greater NDVI than ratoon crops at the same day of year (Fig. 1).

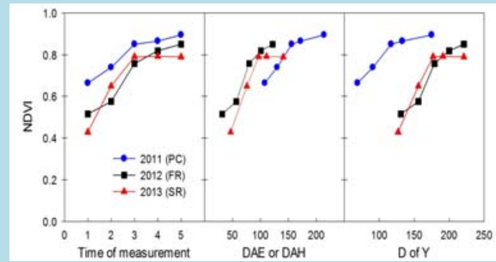

Fig. 1. NDVI of plant cane (PC), first ratoon (FR), and second ratoon (SR) based on measurement timing, days after emergence/harvest (DAE, DAH), & days of year.

II. Yield Components

Plant cane had significantly higher cane and sucrose yield than ratoon crops. Of the seven yield traits, stalk diameter and CRS had lowest, while stalk population and TCH had highest variation across 18 genotypes (Table 2).

Table 2. variation in sugarcane yield traits across 18 genotypes for three crops of plant cane (PC), first ratoon (FR), and second ratoon (SR) .

Year	Parameter	Stalk diameter	Stalk length	Stalks	Stalk weight	TCH	CRS	TSH
		(mm)	(m)	(No. ha^{-1})	(kg stalk^{-1})	(Mg ha^{-1})	(g kg^{-1})	(Mg ha^{-1})
2011	Max.	27.9	2.41	136105	1.70	187.8	145.3	25.3
(PC)	Min.	25.1	1.73	86792	0.89	90.8	123.6	13.0
	Mean	26.2	2.10	112415	1.26	141.0	136.6	19.2
	CV	3.40	9.06	12.05	15.32	18.44	4.72	18.17
2012	Max.	26.3	2.32	129167	1.22	128.4	141.6	18.0
(FR)	Min.	18.6	1.61	73553	0.56	54.1	125.5	7.1
	Mean	23.4	1.96	98261	0.86	84.1	135.6	11.4
	CV	7.67	10.54	16.36	19.28	21.76	3.38	22.69
2013	Max.	24.96	2.18	133831	1.08	124.1	143.1	17.0
(SR)	Min.	21.13	1.37	63328	0.52	33.6	122.7	4.7
	Mean	23.02	1.82	97432	0.77	76.4	136.0	10.4
	CV	3.41	12.31	23.81	20.71	31.99	3.62	32.05

III. Correlation (r) between Yield Traits and NDVI

The number of stalks, cane yield (TCH), and sucrose yield (TSH) had the greatest and commercial recoverable sugar (CRS) had the lowest r values with NDVI (Fig. 2). The date of measuring canopy reflectance also influenced correlation between the yield traits and NDVI. It seemed to be that the NDVI data collected at the second time had the greatest r values with stalk numbers, TCH, and TSH. The pattern clearly showed in plant cane and first ratoon, but not in second ratoon (Fig. 2).

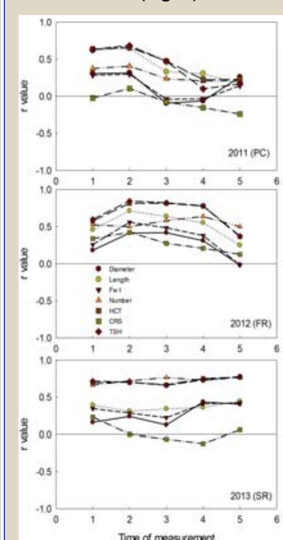

Fig. 2. Changes in r values as NDVI measurement timing for plant cane (PC), first (FR), and second ratoon (SR) crops.

IV. Linear Regression of Stalks, TCH, and TSH with NDVI

When regressing the number of stalks, TCH, and TSH with mean NDVI values of five-time measurements in season, we found that NDVI could explain 35-66% of yield variability across genotypes in the season and 66-80% over three seasons(P < 0.01-0.001, Fig. 3).

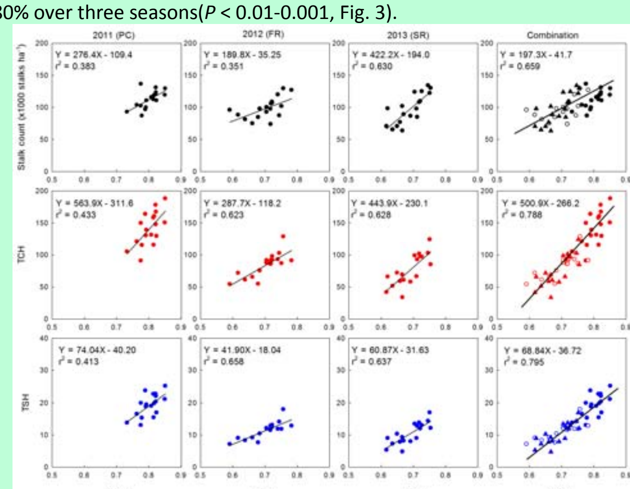

Fig. 3. Linear regression of stalk number, TCH and TSH with mean NDVI values in season across genotypes for plant cane (PC), first (FR), and second ratoon (SR) crops.

Conclusions

- Of sugarcane yield traits, the number of stalks, TCH, and TSH had greatest correlation with NDVI.
- The relationships between the yield traits and NDVI depend on NDVI measurement date. The ideal timing of reflectance measurements is around plant grand growth or before canopy getting complete closure.
- Canopy reflectance or NDVI measurements can be useful for predicting yield potential across large numbers of genotypes and used as an agronomic management and research tool.