MEASURING SUGARCANE HEIGHT IN COMPLEMENT TO BIOMASS SENSOR FOR NITROGEN MANAGEMENT

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ABSTRACT

Although extensive studied, nitrogen management remains a challenger for sugarcane growers, especially the nutrient spatial variability management, which demands the use of variable rate application. Canopy reflectance sensors are being studied, but it seems to saturate the sensor signal when the crop achieves stem heights over 0.6 – 0.7 m. Sugarcane, different from other grasses (poaceae) like winter cereals, presents a linear growth at this stage, distant from its maturity period when it stores sugar. Eight commercial fields of a sugar mill located in the state of São Paulo, Brazil, varying from 16 to 21 ha where monitored during two growing seasons. Conditions varied involving four varieties, soils from sandy to heavy and the previous harvesting occurred in May and October (early and late season), including first to fourth ratoon stages. Each field was scanned with a reflectance canopy sensor three times in the first season (approximately at 0.2, 0.4, and 0.6 m of stem height) and two on the second season (0.3 and 0.5 m), followed by tissue sampling for biomass, crop height and nitrogen uptake on ten spots inside the area, guided by the different values shown by the canopy sensor. As well as the canopy sensor data, the height of the crop presented high correlation with biomass and nitrogen uptake and should be considered as a complementary data to be used to guide nitrogen applications to improve accuracy at late stages of crop growth.

Keywords: sensors, growth stages, variable rate of nitrogen

INTRODUCTION

Brazil is the main sugarcane producer, having more than um third of the global production (719 million tons), followed by India (277 million tons), summarizing the word production 1660 million tons in 2010 that responds for 80% of the sugar and 35% of the ethanol word consumption (FAO, 2012).

Sugarcane producers, despite research on the nitrogen nutrition contributions, continue with the challenge of making better use of the input, especially due to the spatial variability of the nutrient and soils found in production areas, often in short distances (Solie et al., 1999).

Canopy reflectance sensors are being studied on the crop with good perspectives, but it seems to saturate the sensor signal when the crop achieves stem heights over 0.6 – 0.7 m (Portz et al., 2012). Sugarcane, different from other grasses presents a linear growth at this stage, and is far away from its maturity period when it grows over 2.0 m of stem and stores saccharose (sugar). Brazilian sugarcane commercial producers, to gain time, normally apply nitrogen (N) right after harvesting, or in an early stages when sugarcane starts to really uptake N, but at the late season (wet time of the year) the crop grows very fast and is common to growers apply fertilizers when sugarcane height is over the machines clearance limit and in some years even living areas behind without fertilization.

On these late stages the use of canopy reflectance sensors can be limited by sensor signal saturation. During an earlier phase of this work Portz et al. (2012) observed that there is a relationship between plants heights measured during biomass samplings and N-uptake. This fact instigated a research on this subject.

Freeman et al. (2007) working with a reflectance sensor on corn, also took measurements of plant height during the investigation and concluded that plant height alone was a good predictor of plant biomass at all stages of growth sampled. Similarly, Shiratsuchi et al. (2009) reported correlations between height, biomass and nitrogen in corn and presented results from the merge of vegetation reflectance sensor and ultrasound measurement of plant height to estimate N-uptake by corn during the vegetative cycle. The results showed that at growth stages V10 to V13 plant height sensor data using a sonar and reflectance were significantly correlated, both having the same ability to predict N-uptake, but the simultaneous use of two sensors did not increase the correlation with nitrogen extraction.

Sui and Thomasson (2006) combined plant reflectance sensor and ultrasound sensor to determine the nutritional status of N in cotton. The results showed that the spectral information and plant height was significantly correlated with the concentration of nitrogen contained on cotton leaves.

This paper shows data of sugarcane stem height on plots selected by reflectance sensor during two growing seasons compared to biomass accumulation and N-uptake on commercial sugarcane fields.

MATERIALS AND METHODS

During the 2009/10 and 2010/11 growing seasons eight commercial fields of sugarcane located around São Martinho Sugar Mill (21°19’11”S, 48°07’23”W), in the state of São Paulo, Brazil, were evaluated. Conditions varied from sandy to clay soils, with all crops being mechanically green harvested (with no burn). On four fields, harvesting of the previous crop occurred at the beginning of the season (May/Jun) corresponding to the dry time of the year, and on the other four fields, in late season (Oct/ Nov), corresponding to the wet time of the year. The crops under investigation included first, second, and third ratoon stages at 2009/10 and second, third and fourth at 2010/11. The first four fields were planted with the varieties CTC 9 over sandy soil and RB 855453 over clay soil and all were harvested in the dry season. The last four fields were planted with the varieties CTC 2 on sandy soil and SP 80–3280 on clay soil, and harvested during the wet season (Table 1).

Table 1: Variables of the studied fields

Field	1	2	3	4	5	6	7	8
Varity	CTC 9		RB 855453		CTC 2		SP 803280	
Size (ha)	21	16	18	17	20	18	21	16
Harvest	may/jun (dry season)				oct/ nov (wet season)			
Soil	sandy		clay		sandy		clay	
Ratoon 09/10	1°	2°	1°	3°	1°	2°	1°	3°
Ratoon 10/11	2°	3°	2°	4°	2°	3°	2°	4°

Shortly after harvesting all fields were fertilized with a uniform dose of 100 kg ha^{-1} of nitrogen using ammonium nitrate (30 % N) as the N source, spread over the sugarcane rows surface.

Each of the eight fields was scanned using the N-Sensor TM ALS (Yara International ASA, Duelmen, Germany) (Jasper et al., 2009) mounted behind the cabin of a high clearance vehicle, three times in the 2009/10 growing season (at 0.2, 0.4, and 0.6 m average stem height) and two times during the 2010/11 (at 0.3, and 0.5 m average stem height).

The sensor was connected to a GPS receiver and the vehicle was driven through the whole field spaced by 10 rows of 1.5 m. After the scanning, the sensor data was processed generating sensor vegetation index maps of the fields and over this maps 10 sample plots were located guided by the different values shown by the canopy sensor and followed by tissue sampling for biomass, crop height and nitrogen uptake as explain by Portz et al. (2012).

The sugarcane crop height of each sample plot was defined as the average stem distance from the soil to the insertion of the Top Visible Dewlap leaf (TVD) (Dillewiijn, 1952) on the stem as shows Fig 1.

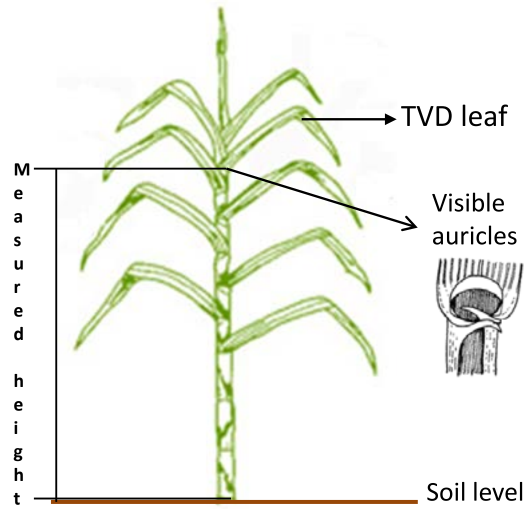

Figure 1: Sugarcane height measurement

Sugarcane height data of each field were combined on seasons and years and evaluated by correlating with biomass and nitrogen uptake from the respective sample points. Simple linear regression models were used.

RESULTS AND DISCUSSION

As well as the canopy reflectance sensor data (Portz et al., 2012), the height of the sugarcane crop presented high correlation with biomass and nitrogen uptake. Figure 2 presents the results of height compared to biomass (dry matter) and N-uptake for the first year. All eight fields had data combined showing a unique tendency despite the differences on soil, variety and ratoon.

For the early season (dry season) measuring the field average heights of 0.2, 0.4 and 0.6 m the height amplitude found was between 0.1 and 0.8 m. The coefficient of determination reached values of $R^2 = 0.80$ for biomass and $R^2 = 0.81$ for N-uptake. Biomass was little more than 6000 kg ha^{-1} at 0.8 m and N-uptake of 80 kg ha^{-1}.

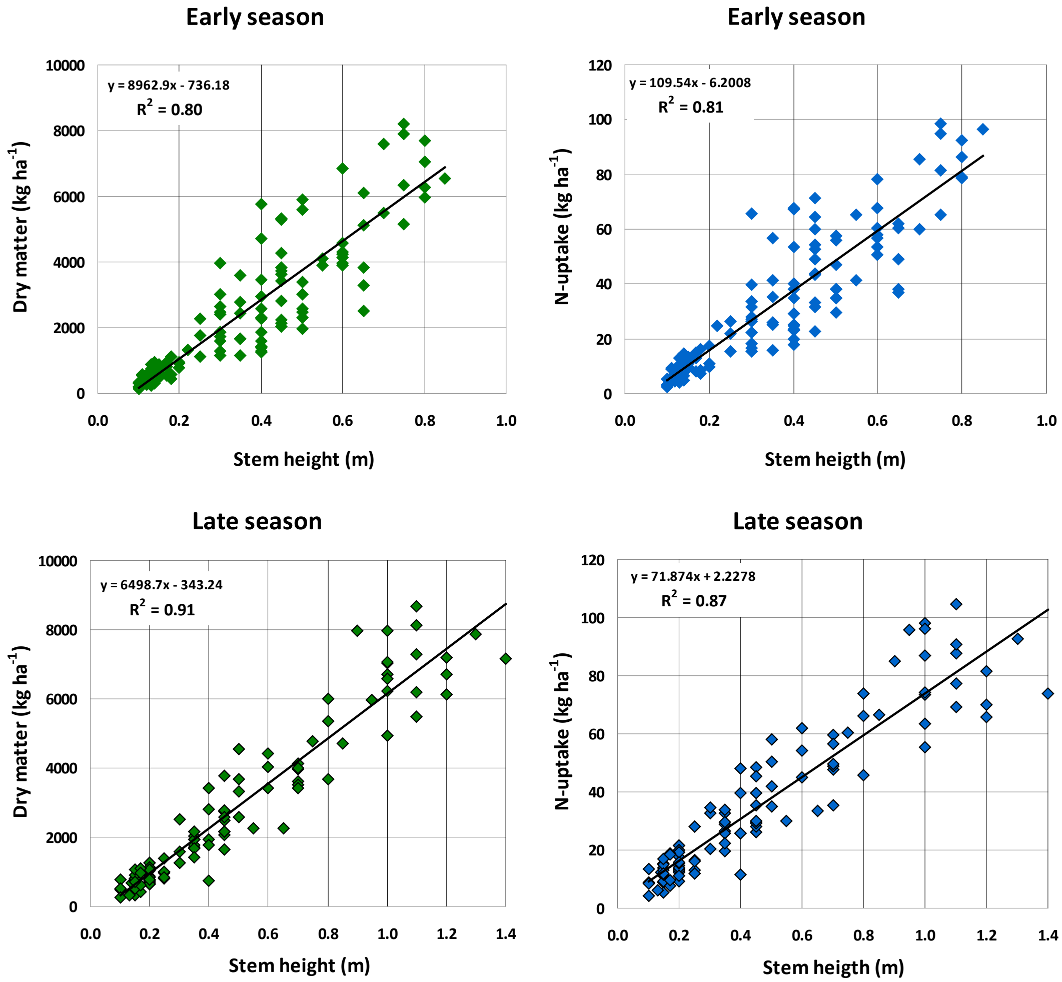

Figure 2: Biomass and N-uptake for early and late seasons sampled on the 2009/10 crop for 0.2, 0.4 and 0.6 m of average stem height

During the late season (wet season) measurements heights got up to 1.4 m because of a delay on sampling the 0.6 m height, especially at the sandy soil fields that presented a very rapid stem growth rate. Despite that, the late season measurement presents high coefficient of determination ($R^2 = 0.91$) for biomass and for N-uptake ($R^2 = 0.87$) in an amplitude of 1.3 m of stem height with a linear tendency. These results show that with sugarcane stem height is possible to predict biomass and N-uptake without the limitation of sensor saturation signal (Portz et al., 2012).

During the second year (2010/11) the field average heights of 0.3 and 0.5 m were sampled (Figure 3). Lower coefficients of determination were observed on the early season ($R^2 = 0.69$ for biomass and $R^2 = 0.60$ for N-uptake) even with almost the same amplitude of measured heights (0.2 to 0.8 m) as from the first year. The explanation may be related to the fact that the early season of the second year had lower precipitation than normal, with much less available water than the previous year (not showed data) resulting in less biomass and especially a lower N-uptake.

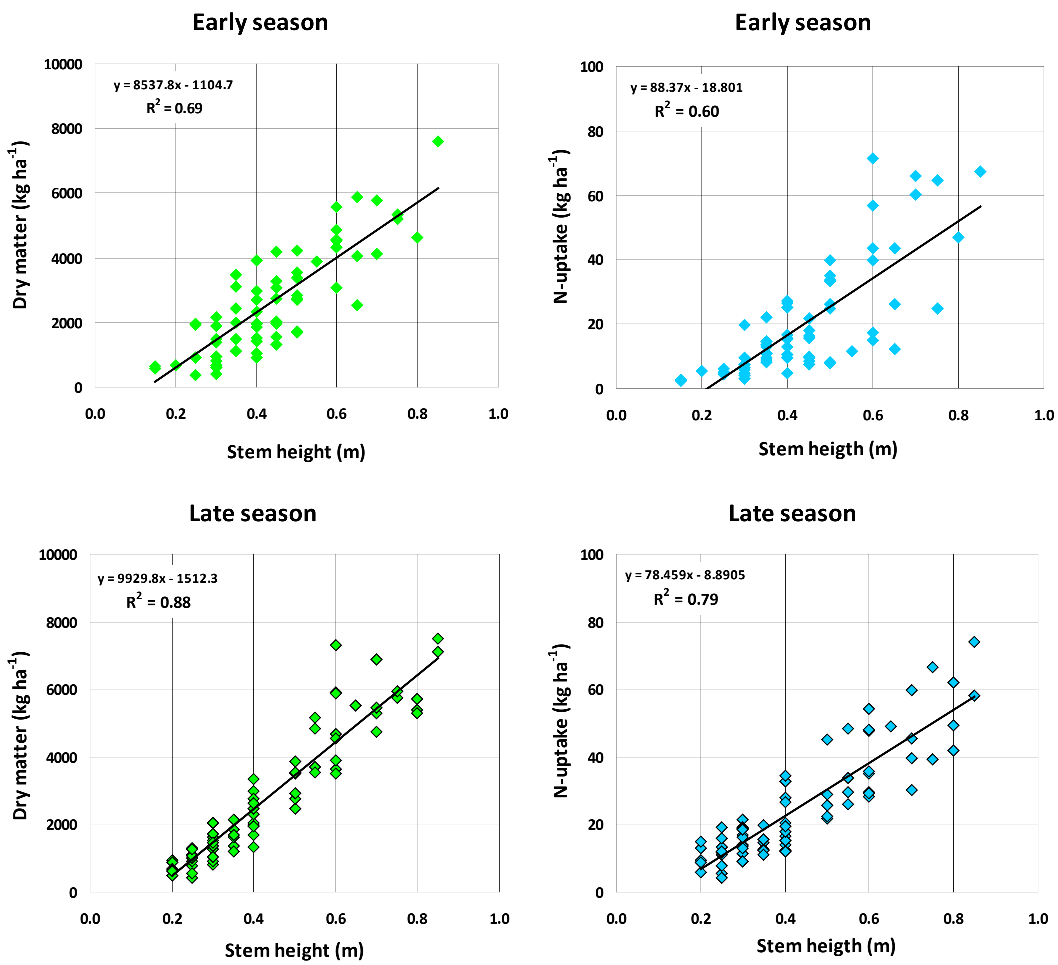

Figure 3: Biomass and N-uptake for early and late seasons sampled on the 2010/11 crop season for 0.3 and 0.5 m of average stem height

On the late season, with the return of the rains the quality of the correlations improved again. With no delays on sampling, stem height amplitude was between 0.2 and 0.85 m. Coefficients of determination raised to $R^2 = 0.88$ for biomass and $R^2 = 0.79$ for N-uptake.

Figure 4 shows the combination of data from the two sampled years for biomass and N-uptake against stem height.

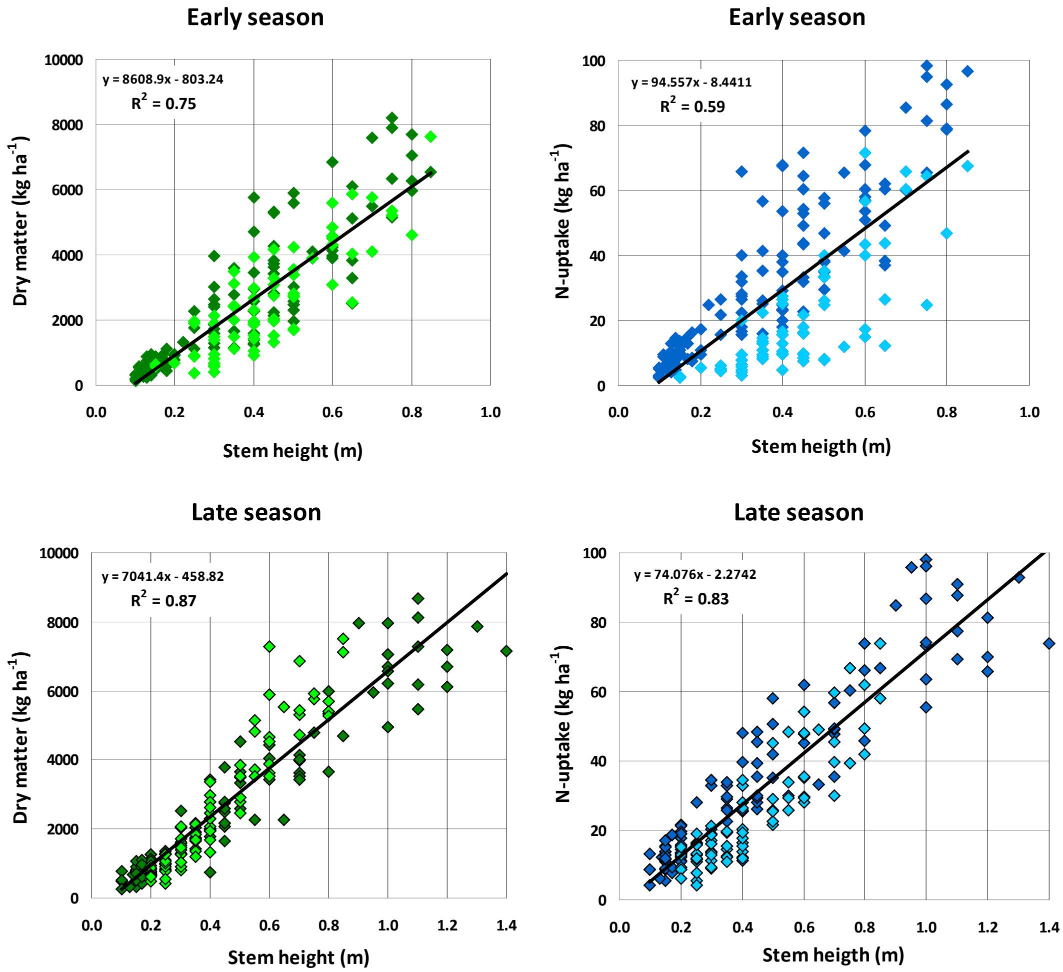

Figure 4: Biomass and N-uptake for early and late seasons sampled on the 2009/10 and 2010/11 crops for 0.2 to 0.6 m of average stem height

The overlay of data from the two years shows an early season with lower coefficients of determination (R^2 = 0.75 for biomass and R^2 = 0.59 for N-uptake) caused mainly by the strong drought of the second year. Despite the drought, biomass does not show discrepant values for the two years. In the other hand N-uptake presents different tendencies for the two years, probably related to effects of the drought.

The experimental data comes from a region (Brazilian Cerrado) where the late season offers regular rain. Under those conditions coefficients of determination (R^2 = 0.87 for biomass and R^2 = 0.83 for N-uptake) were high. For biomass the two years data is comparable, with some deviation. Unlikely, for N-uptake the two years data had almost a unique tendency being the late season results a good data to use to predict N-uptake by the sugarcane crop stem height.

Figure 5 presents the joint of the entire data set separated on biomass and N-uptake by height. The union of the good data of the late season with the less accurate data from the early season decreases the overall data quality as can be seen by the coefficients of determination (R^2 = 0.80 for biomass and R^2 = 0.70 for N-uptake). For better predictions of biomass and N-uptake by the sugarcane height, data should be season dependent.

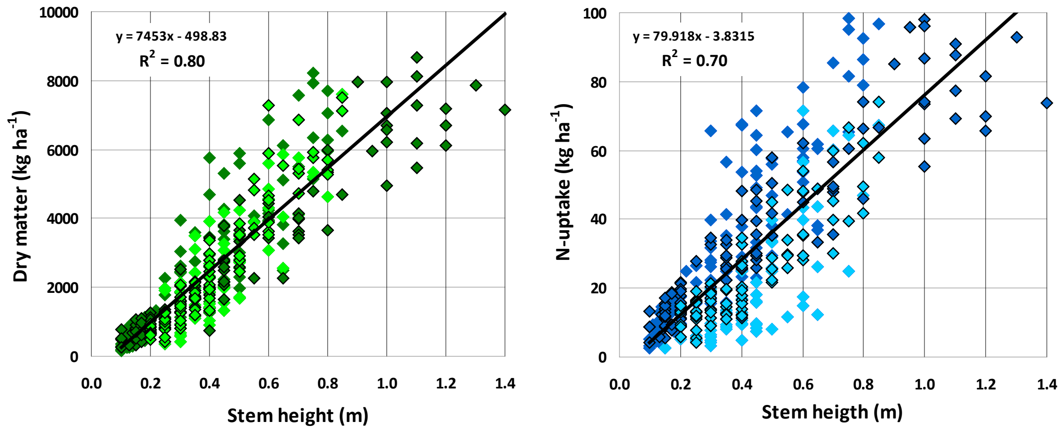

Figure 5: Biomass and N-uptake for both seasons sampled on the 2009/10 and 2010/11 crops for 0.2 to 0.6 m of average stem height

For both years, the best correlation between height, biomass and N-uptake occurred in the late season (rainy season) where sugarcane growth is faster and where plant covers ground quickly. Exactly at this time, with high stem heights, the reflectance sensor shows the lowest correlations for biomass and N-uptake (Portz et al., 2012) suggesting that one can complement the other.

The combined use of a reflectance sensor and a height sensor can increase the accuracy of the diagnostic from the nitrogen nutrition variability found in areas cultivated with sugarcane, especially when the crop is in advanced stage of development, above 0.6 m stem height. More studies have to be done aiming to investigate the relationship of biomass and N-uptake measured over the sugarcane canopy. Distance sensors should be tested on measuring sugarcane canopy against biomass and N-uptake.

CONCLUSIONS

The height of the sugarcane crop presented high correlation with biomass and nitrogen uptake and should be considered as a complementary data to be used together with reflectance sensor to guide nitrogen applications to improve accuracy especially above 0.6 m stem height of crop growth.

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