COTTON FIELD RELATIONS OF PLANT HEIGHT TO BIOMASS ACCUMULATION AND N-UPTAKE ON CONVENTIONAL AND NARROW ROW SYSTEMS

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ABSTRACT

Cotton field management remains a challenge for growers, especially due to spatial variability of soil conditions, which demands the use of variable rate application technology (VRT) for nitrogen and growth regulators. Canopy optical reflectance sensors are being studied as an option to detect infield variability but may have some limitations due to the known effect of signal saturation when used on very dense canopies. Based on that, two commercial fields located on the state of Goiás, middle west Brazil, one planted on conventional row system and other conducted on narrow rows system were investigated during the 2012/13 growing season. Each field was scanned with an optical reflectance canopy sensor three times during the season based on days after planting, followed by manual sampling for crop height, biomass and N content on 30 spots inside the area, guided by the field variability shown by the optical canopy sensor. The height of the cotton plant showed a high correlation with biomass and nitrogen uptake, and does not suffer saturation problems at late stages on both planting systems. This technology may be used as base for VRT nitrogen and growth regulator applications, or be combined with reflectance canopy sensors to improve accuracy at late split application, where canopy reflectance sensors are susceptible to lose accuracy.

Keywords: cotton, plant height, spatial variability

INTRODUCTION

Cotton (Gossypium ssp.) is among the most important fiber crops, with approximately 35 million hectares grown throughout the world. Global demand has gradually increased since the 1950s, with an average annual growth of 2 %. Brazil produce around 1.7 million tons of cotton lint per years, being placed among the top five global producers, alongside countries like China, India, Pakistan and the USA. Brazil is the third largest exporter and first in productivity in rainfed. The internal scenario also shows promise as the country's fifth-largest consumer, with nearly one million tons/year (ABRAPA 2013).

Although studied for decades, cotton field management remains a challenge for growers, especially due to spatial variability of soil conditions and crop growth, which demands the use of variable rate application technology (VRT) for nitrogen and growth regulators to improve yields and quality and/or save inputs.

Canopy optical reflectance sensors are being studied as an option to detect infield variability but may have some limitations due to the known effect of signal saturation when used on very dense canopies, as is typical the case at late growth stages when there is still a need for VRT of growth regulators.

The approach of plant height to model cotton crop parameters is not new. Kerby et al. (1990) considered plant height as an important deciding factor for plant growth regulators application. Munier et al. (1993) related plant height with plant vigor and early fruit retention, and also considered plant height as a good indicator on the use of growth regulators. Cotton plant height was also found to be significantly correlated with many vegetative indices (R^2>0.65) such as NDVI, RVI and DVI (Leon et al., 2003).

Shiratsuchi et. al (2005), using ultrasonic sensor readings were able to demonstrate that is possible to create maps measuring the variability of plant height in cotton fields. Sui and Thomasson (2006) combined plant reflectance sensor and ultrasonic height 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.

According to Vellides et al. (2009), NDVI and plant height have a good correlation in between and with stem mass, and leaf mass during the early and late season periods but not during mid-season of cotton cycle. In mid-season more than 90% of NDVI values exceeded 0.8 and nearly half were above 0.9 showed saturation of optical sensor.

Plant height, which can be automatically measured by an ultrasonic system, is presented as an alternative way to estimate cotton plant parameters and guide nitrogen fertilization and growth regulators on moments that optical reflectance sensors may be affected by the phenomenon of sensor saturation (Mutanga and Skidmore, 2004)

This paper shows data relating cotton plant height on field plots selected by reflectance sensor on two cotton growing systems (conventional and narrow rows) related to biomass accumulation and N-uptake over commercial areas as base information for variable rate application of nitrogen fertilization and growth regulators.

MATERIALS AND METHODS

Two commercial fields located on the state of Goiás, middle west Brazil, one (-52°44´21´´,-18°27´55´´) planted on conventional row (0.80m) system (100 hectares, 80.000 seeds per ha), and a second (-52°34´42´´,-18°21´35´´) conducted on narrow rows (0.40 m) system (116 hectares, 130.000 seeds per ha) were investigated during the 2012/13 growing season, both planted on no till system over high clay content soils and following corn as previous crop.

To find out the infield plant variability, each area was scanned with a commercial optical reflectance canopy sensor (N-SensorTM ALS, Yara International ASA, Research Centre Hanninghof, Duelmen, Germany) mounted on top of a high clearance vehicle three times during the season, based on days after planting (DAP) (47, 66, and 118 DAP on conventional and 51, 81 and 113 DAP on narrow).

In each field the recorded data from the optical sensor were filtered, cutting off points outside the field boundaries and the negative values; they were interpolated (inverse distance weighting) using a 10 x 10 m raster. A five-color class legend was applied for visual analysis (natural breaks). To represent the entire range of plant variability, 30 validation locations were selected in each field map (six per map color). In each validation point (sample point) located in the middle of a 10-m cell, destructive plant samples of the above ground biomass were taken by manually cutting a 1.0 m sub-plot consisting of three rows (3.0 m). In this same spot, plant height was measured before biomass harvest. Figure 1 illustrates the entire process.

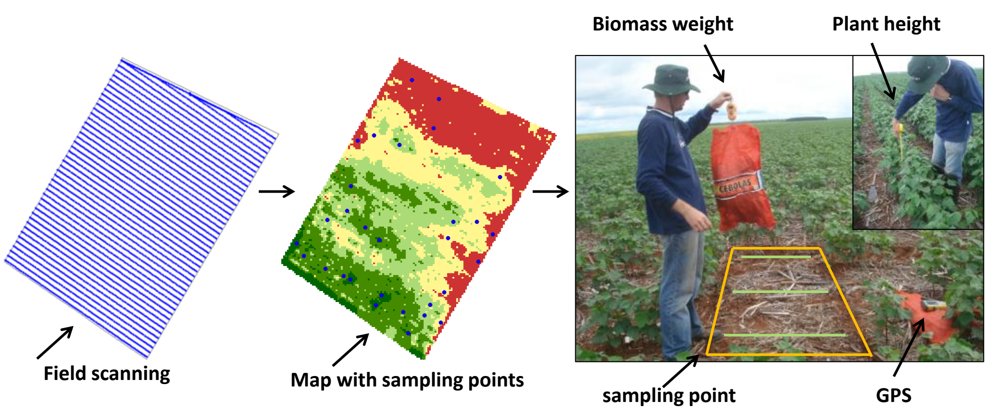


Figure 1. Biomass sampling process

The wet biomass samples were weighed in the field, processed after in the laboratory (chopped and dried) to obtain dry matter and measure its total N content (Kjeldahl method) and, ultimately, the crop N-uptake was calculated. In each of the three mapping events, the sampled plant height spot was manually measured by taking the distance from soil level to the last leaves of the canopy as shows Figure 2.

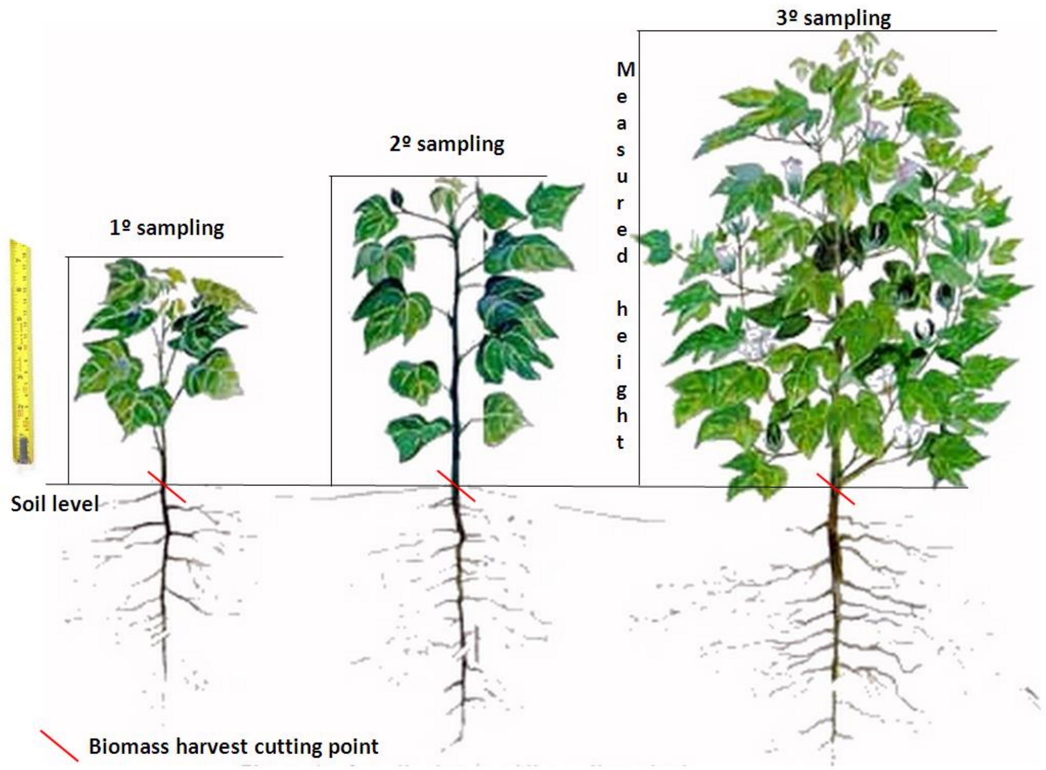


Figure 2. Height measurement and plant sampling stages

Data was submitted to analysis of variance using the different rows space planting systems as factors and plant height data were compared with wet biomass, dry biomass an N-uptake on the sampling points using regression analysis.

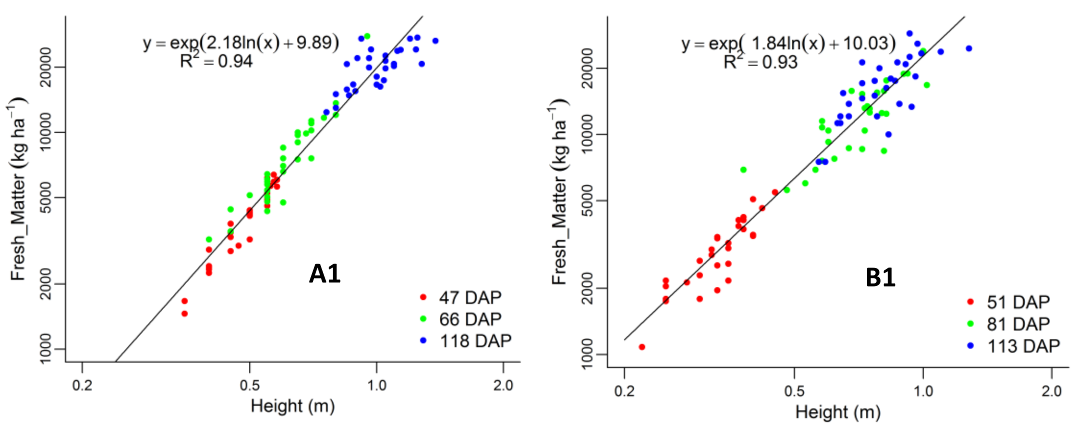
RESULTS AND DISCUSSION

Figure 3 shows the cotton field view of both row space systems during sampling moments.

Figure 3. Conventional spacing cotton at the first (A), second (B) and third (C) evaluation, and narrow spacing cotton at the first (D), second (E) and third (F) evaluation

Looking over the fields it can be seen that the narrow spacing system present higher density of plants that close the row earlier that on the conventional planting system showing already no soil at the second evaluation. At the third evaluation both systems had no soil visible anymore being that behavior a challenge for an optical reflectance sensor as it cannot distinguish plant from soil anymore.

Figure 4 shows the relations of plant canopy height with fresh matter, dry matter and N-uptake on both planting systems. Data of the four variables (height, fresh matter, dry matter and N-uptake) were initially transformed into ln (x) in order to meet the assumption of normality. There was a significant interaction between the heights and the cropping planting system, thus the data were analyzed separately for each system. Also all the relations were significant ($p < 0.01$).



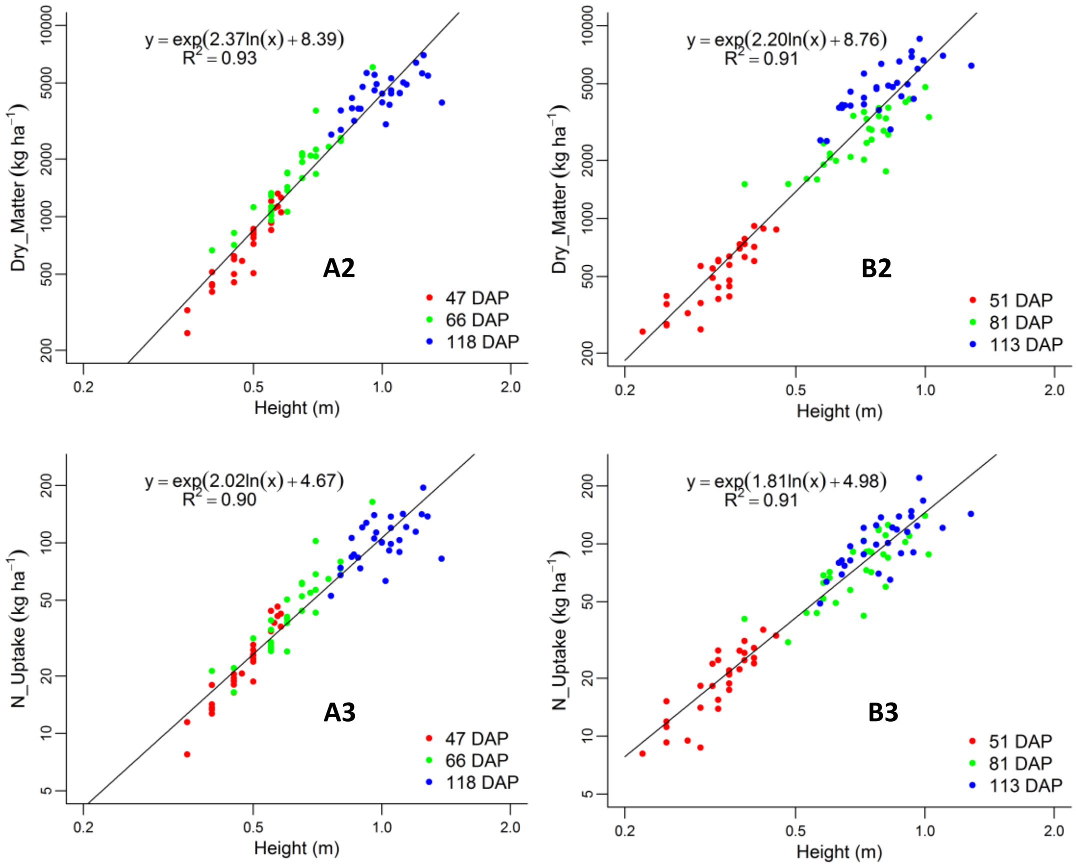


Figure 4. Conventional (A) and narrow row space systems (B) cotton height with fresh matter (1) dry matter (2) and N-uptake (3) regressions.

Cotton plant height showed high correlation with aboveground fresh matter, dry matter and nitrogen uptake. The greatest R-squared were observed in the regression using plant height to predict fresh matter.

The relationship between the variables remained linear for all ages and heights evaluated providing determination coefficients between R^2 0.90 and 0.94, showing that plant height can be used in the prediction of the variables from early stages of crop development to the reproductive stage.

Comparing the equations of the two analyzed cropping systems, it is observed that the equation slope is greater at the conventional spacing, which indicates that the increase of biomass is higher for every centimeter that the height increases. This is due to the fact that besides the vertical plant growth it also occurs in the direction of the interlines, which are wider in the conventional spacing. On the other hand, the values of fresh matter, dry matter and N-uptake for smaller heights are greater in narrow row cotton due to the presence of a larger number of plants, since the initial population in the narrow row space system is about 60% higher that the used in the conventional spacing system and competition for light and nutrients is not limiting plant development at this initial time.

As intercept and specially slope of the regressions are different for both growing systems, those are specific and should be used only on the same system as proposed.

More research should be made to obtain this regression on different locations (climates and soil types), also a validation of the regressions could be made using data from other years and locations.

CONCLUSIONS

The canopy height of the cotton plant showed a high correlation with biomass and nitrogen uptake and it does not offer saturation problems at late stages on both planting systems. The equations between height and the parameters are specific for each planting system. This data set can be used as base for VRT growth regulators and nitrogen applications using the equations of biomass and N-uptake respectively, or be combined with reflectance canopy sensors to improve accuracy at late split application, where canopy reflectance sensor are susceptible to lose accuracy.

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