SHORT NON-REFEREED PAPER

USING DRONE MULTISPECTRAL IMAGERY FOR PRECISION SUGARCANE QUALITY MANAGEMENT: PRELIMINARY RESULTS

Hoffman, N[1,2], Poona N[1], van Heerden, PDR[1,3] and Mabaso, S[1]

[1]South African Sugarcane Research Institute, P/Bag X02, Mount Edgecombe, 4300, South Africa
[2]School of Agriculture, Earth and Environmental Sciences, University of Kwazulu-Natal, Private Bag X01, Scottsville 3209, South Africa
[3] Department of Plant and Soil Sciences, University of Pretoria, Pretoria, 0028, South Africa

Natalie.Hoffman@sugar.org.za

Abstract

The use of refractometers, coupled with the PurEst® application, aids sugarcane quality management. However, the assessment of commercial fields with refractometers remains time-consuming and inefficient for large-scale operations. Drone phenotyping has the potential to rapidly estimate cane quality from aerial imagery. This study assessed the feasibility of using multi-spectral drone imagery to estimate cane quality parameters. Two field trials located in Pongola comprised fifteen varieties, with control and various registered ripener treatments. Six vegetation indices (VIs, derived from multi-spectral imagery captured with a DJI Phantom drone and Micasense RedEdge-MX camera) and two cane quality parameters (determined through laboratory analysis) were estimated at harvest, and used to build regression models. The cane quality data represented a wide range of values for Brix% (7.8-16.8%) and Pol% (3.2-14.6%), driven by varietal differences and strong ripener responses. The values of most VIs were influenced by variety and ripener treatments. Brix% and Pol% correlated poorly with the various VIs, when considering the pooled dataset (all varieties and treatments) (R^2 of 0.03-0.14), as well as the control (unripened) and ripener treatments alone (R^2 of 0.00-0.06). These correlations were improved when the individual varieties (R^2 of 0.55-0.99) were considered. This strongly suggests that variety-specific regression models are required for estimating cane quality parameters from VIs. These results show promise for the use of aerial imagery in predicting cane quality for harvest scheduling and decision-making re chemical ripening. Future research will focus on model development and testing, and will consider multi-temporal and location data, with many varieties and ripener treatments.

Keywords: Drone phenotyping, sugarcane quality management, vegetation indices, multispectral imagery

Introduction

Cane quality assessments using portable refractometers, coupled with the PurEst® application, have assisted in the identification of fields that are suitable for chemical ripening, as well as for relative harvest scheduling. However, the use of refractometers remains time-consuming and inefficient for large-scale operations. The rapid development of remote sensing techniques (based on measurements of crop reflectance in different spectral bands), as well as advances in image analysis and data processing, have provided opportunities for measuring plant traits through aerial phenotyping. Within sugarcane agriculture, aerial phenotyping offers opportunities to estimate sugarcane quality parameters, such as stalk brix content (Brix%) and sucrose content (Pol%), from multispectral satellite and drone imagery. Begue *et al*. (2012) found that there was a good relationship between Brix% and the Normalized Difference Vegetation Index (NDVI, R^2 = 0.75) derived from SPOT4 and SPOT5 satellite imagery. Although promising, the use of satellite data is limited by the need for high spatial, spectral and temporal resolution, as well as the high cost of commercial satellite data. Chea *et al*. (2018) found that there was a strong relationship between Brix% with Green NDVI (GNVDI, R^2 = 0.86) and Chlorophyll Index green (Clgreen R^2 = 0.83), derived from very high-resolution (5 cm) multi-spectral drone imagery. Chea *et al*. (2020) suggested that further work was necessary to assess whether Brix prediction models require variety-specific calibrations. To date, no study has investigated how chemical ripeners, through their well-known growth regulation effects on the plant canopy, affect predictions of cane quality parameters from vegetation indices (VIs). The aim of this study was to assess the feasibility of using drone multispectral imagery for predicting cane quality parameters in South African sugarcane varieties.

Materials and Methods

The study was comprised of two adjacent field trials at the South African Sugarcane Research Institute (SASRI) research station in Pongola (-27.415156°S, 31.592809°E). The first trial used a randomised complete block design, with six reference (unripened) varieties, and four varieties that were subjected to control and various registered ripener treatments, each replicated four times (88 plots of six 8 m-long rows, spaced 1.4 m apart). The second trial was a separate one-way randomised complete block design per variety, with five varieties subjected to control and ripener treatments, replicated six times (144 plots of six 8 m-long rows, spaced 1.4 m apart). Shortly before harvest in March 2021, five-band multispectral imagery was captured by using a Micasense RedEdge-MX camera fitted to a DJI Phantom 4 drone for each trial. The camera measures crop reflectance across the visible (475-670nm), RedEdge (RE, 720nm) and near infrared (NIR, 840nm) regions of the electromagnetic spectrum. Image processing was carried out in the Pix4D, ArcGIS and QGIS software packages. The six VIs employed in this study were NDVI (Rouse *et al*. 1974), GNDVI (Gitelson *et al*. 1996), Simple Ratio (SR) (Birth and McVey 1968), Normalized Difference Red Edge (NDRE) (Barnes *et al*. 2000), Chlorophyll Index Green (CIgreen) and RedEdge (CIrededge) (Gitelson *et al*. 2003; 2005). The cane quality parameters (Brix% and Pol%) were determined by means of conventional laboratory analysis at harvest. The data were analysed for statistical significance (p=0.05) for each genotype, ripener and ripener x genotype treatment, using two-way Analysis of Variance (ANOVA) for individual trials. Linear regression analysis was used to model the relationships between the VIs and the cane quality parameters for the pooled datasets, where trial was not considered to be a factor, given the adjacent location, the same crop age and the same crop management of the trials. Regression analysis was also considered for the individual varieties (across ripener treatments), on an individual trial basis.

Results and Discussion

The laboratory cane quality data represented a wide range of values for Brix% (7.8-16.8%) and Pol% (3.2-14.6%). Many of the varieties showed significant increases in cane quality values (relative to that of the control) in response to ripener application (data not shown). In most cases, the VI values also differed significantly between varieties, ripener, and variety x ripener treatments.

Brix% and Pol% showed poor correlations (R^2 ranging from 0.03 to 0.14) with the various VIs when considering the pooled dataset (all varieties, with the control and ripener treatments). Similar results were obtained when considering the control and ripener treatments alone (R^2 of 0.00-0.06). This indicated the inability of the VIs to predict cane quality parameters across the respective varieties. However, improved results were obtained for the individual varieties. The correlations were stronger and mostly significant, with R^2 values ranging from 0.55 to 0.99 for all varieties except N57. This strongly suggests that variety-specific models may be required for the estimation of cane quality from VIs. While the various VIs showed similar results, NDRE and Clrededge showed the best overall correlations for the individual varieties, with R^2 values ranging from 0.35 to 0.99. The results show no evidence to suggest that chemical ripeners influenced the predictive ability of VIs for estimating cane quality parameters, given the relationships of the control vs. ripener treatments (data not shown).

Table 1. Coefficient of determination (R^2) for the relationships between cane quality parameters (Brix and Pol%) and vegetation indices (NDVI, NDRE, GNDVI, Clgreen, Clrededge and SR), derived from multi-spectral drone imagery captured at harvest. Varieties were subjected to control (unripened) and various ripener treatments, including single applications of Ethephon® (Eth), Fusilade Forte® (FF) and Moddus® (Mod), and combinations thereof (Eth+FF and Mod+FF). Regressions were considered for the individual varieties, ripener and control treatments, as well as for the pooled dataset. The statistical significance at p=0.05 is marked with an asterisk

Dataset	**Quality parameter**	**Vegetation index**						
		NDVI	**NDRE**	**GNDVI**	**Clgreen**	**Clrededge**	**SR**	n
Pooled dataset (All varieties & ripener treatments)	**Brix %**	0.09	0.03	0.05	0.04	0.03	0.10	42
	Pol %	0.13*	0.08	0.09	0.07	0.07	0.14*	42
Control treatments	**Brix %**	0.02	0.00	0.01	0.00	0.01	0.01	15
	Pol %	0.06	0.04	0.04	0.03	0.04	0.05	15
Ripener treatments	**Brix %**	0.01	0.00	0.00	0.00	0.00	0.02	27
	Pol %	0.02	0.01	0.02	0.02	0.01	0.04	27
N43 *(Cont, Mod, FF & Mod+FF)*	**Brix %**	0.96*	0.99*	0.99*	0.99*	0.99*	0.97*	4
	Pol %	0.92*	0.98*	0.99*	0.99*	0.98*	0.94*	4
N46 (Cont, Mod, FF & Mod+FF)	**Brix %**	0.76	0.77	0.75	0.72	0.74	0.73	4
	Pol %	0.83	0.83	0.82	0.79	0.81	0.82	4
N57 (Cont, Mod, FF & Mod+FF)	**Brix %**	0.34	0.35	0.14	0.11	0.36	0.38	4
	Pol %	0.37	0.38	0.11	0.07	0.40	0.43	4
N60 (Cont, Mod, FF & Mod+FF)	**Brix %**	0.70	0.93*	0.89*	0.88*	0.92*	0.73	4
	Pol %	0.80*	0.95*	0.93*	0.92*	0.95*	0.84*	4
N70 (Cont, Eth, Mod, FF, Eth+FF & Mod+FF)	**Brix %**	0.64	0.69*	0.69*	0.70*	0.69*	0.69*	6
	Pol %	0.58	0.64	0.66*	0.66*	0.65	0.64	6
N71 (Cont, Eth, Mod, FF, Eth+FF & Mod+FF)	**Brix %**	0.81*	0.68*	0.72*	0.68*	0.65	0.81*	6
	Pol %	0.77*	0.63	0.68*	0.64*	0.61	0.78*	6
N73 (Cont, Eth, Mod, FF, Eth+FF & Mod+FF)	**Brix %**	0.72*	0.67*	0.61	0.57	0.64	0.77*	6
	Pol %	0.66*	0.61	0.55	0.51	0.58	0.71*	6

Conclusions

This preliminary research shows promise for the use of aerial multi-spectral imagery for predicting cane quality parameters at harvest. This research will be expanded further to include multi-temporal data from field trials located in diverse agro-climatic zones, with a wide range of varieties and ripener treatments. Future work will focus on evaluating the robustness of models (taking into account various factors that were not considered here, such as soil type, climate and crop management). This work could have valuable downstream applications for assisting harvest scheduling and identifying fields that are in need of chemical ripening.

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