SHORT, NON-REFEREED PAPER

QUANTIFYING THE NEGATIVE IMPACT OF LODGING ON IRRIGATED SUGARCANE PRODUCTIVITY: A CROP MODELLING ASSESSMENT

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Abstract

Lodging of cane stalks often takes place during stormy weather in varieties with low tolerance that are tall and heavy. Lodging causes yield loss and increases harvest and transport costs. Quantitative information is required to support lodging-related crop management and crop improvement decisions.

The objective of the study was to develop and implement a new simulation approach to quantify the impacts of genotype, crop cycle and climate on the extent of lodging (*LE*, the fraction of stalks lodged), and the impacts of lodging on cane yield and profitability.

The Canesim® sugarcane model and weather data were used to simulate yield and lodging for 12-month irrigated crops started in different months of the year (April to December) at Pongola and Mhlati (Malelane). Simulations were conducted for three standard varieties: N14 (medium yield, high lodging tolerance), N25 (high yield, medium lodging tolerance), N41 (medium yield, low lodging tolerance), and two high yielding hypothetical varieties. Harvest and transport costs, as well as gross margins, were calculated from long term average yield and *LE*.

Long term average simulated yields and *LE* increased as crops started later in the season and were higher for Malelane than for Pongola. Yields were highest for N25, while the *LE* was highest for N41. Lodging had minor impacts on yields (maximum reduction of 1.5 t/ha), but significant impacts on harvest and transport costs and hence gross margins (maximum loss of R2800/ha).

Results suggest that varieties with low tolerance to lodging should not be grown late season. Lodging resistance could, however, be a desirable trait to improve profitability of irrigated cane production. The method developed here can be applied to other agro-climatic situations.

Keywords: lodging, Canesim®, variety, crop cycle, yield, gross margin, harvest cost

Introduction

Lodging typically occurs in high-yielding crops under conditions of wet soil, wet leaf canopy and strong wind. Lodging is known to reduce the productivity of sugarcane. This is caused by a reduction in radiation interception, radiation use efficiency, stalk smothering, and stalk damage in lodged crops (Muchow *et al.*, 1995; Singh *et al.*, 2002; Park *et al.*, 2005). More labour input is also required to harvest lodged cane and reduced payloads are common.

The Canesim® model (Singels, 2007) has an algorithm for simulating the occurrence of lodging events and their impact on crop processes. Recently, experimental evidence acquired from field experiments were used to evaluate the existing model for predicting the onset and progression of lodging and its impacts on crop productivity (van Heerden *et al.*, 2015). It was shown that the Canesim® model simulated the onset, progression and final extent of lodging realistically for various soil/crop/atmospheric conditions. It was also highlighted that genotype tolerance/sensitivity to lodging should be assessed in the context of crop size (van Heerden *et al*., 2015).

The objective of the study was to progress the research by van Heerden *et al*. (2015) further by developing and implementing a new simulation approach or framework to quantify the impacts of genotype, crop cycle and climate on the extent of lodging (*LE*, defined as the fraction of stalks lodged), and the impacts of lodging on cane yield and profitability.

Methods

The Canesim® model (Singels, 2007) was used to simulate lodging and the consequent decrease in yield for various scenarios. Canesim® simulates the onset of lodging when the aerial mass of the crop plus any rainfall and irrigation water held by it exceeds a variety specific critical threshold, when the topsoil is saturated with water and/or when strong winds occur. The lodging algorithm has been described in detail by van Heerden *et al.* (2015).

Simulation studies

Study 1: Simulations were conducted for Pongola and Malelane using daily weather data for the period 1970 to 2014. Twelve month ratoon crops started at six different times of the year were simulated for each of three varieties, namely N14 (medium yield, high lodging tolerance), N25 (high yield, medium lodging tolerance) and N41 (medium yield, low lodging tolerance). Crops received optimal irrigation in the simulations, with a recommended drying off period. Yield, *LE,* and gross margin results (see below) were assessed by comparison with an unlodged control simulation.

Study 2: This study explored the potential financial benefit of breeding for high lodging tolerance in high yielding varieties. Simulations were conducted for two hypothetical very high yielding 'N25-type' varieties, with medium (N25S_M) and high (N25S_H) tolerance to lodging, grown in Malelane. Genetic parameters were based on those of variety N25, but with a maximum radiation use efficiency of 2.65 g/MJ as opposed to 2.2 g/MJ (a 20% increase). Gross margins and yields of these varieties were compared to those of the standard variety N25.

Calculation of gross margins

Gross margins were calculated for each crop as the difference between 2015 income and allocated costs. Income was calculated as the product of cane yield and the value per ton of cane (assuming a Recoverable Value (RV) content of 12% and RV price of R3841/t respectively). Allocated costs consisted of (1) pre-harvest costs (taken as R8508/ha) and (2) harvest and transport costs that were yield dependent. The latter consisted of costs regarding cutting, and loading and transport. Base costs for erect cane of R25/t and R71/t were assumed for these. For lodged cane a cost multiplier was applied to each of these in linear proportion to the simulated *LE*. The maximum multipliers for fully lodged cane were 2.0 for cutting and 1.19 for loading and transport costs. These are based on information from Boote ([1]personal communication) and Cole ([2]personal communication).

Results and Discussion

Study 1: Long term average simulated yield and *LE* increased as crops started later in the season, and were higher for Malelane than Pongola (Table 1). Yields were highest for N25, while *LE* was highest for N41. Lodging had negligible impacts on cane yields (a maximum reduction of 1.5 t/ha), but substantial impacts on harvest and transport costs and hence gross margins (max loss of R2800/ha). Lodged N25 (high yield, medium lodging tolerance) had higher gross margins than unlodged N14 (medium yield, high lodging tolerance), even though N25 was less tolerant to lodging. This suggests that it is better to target high yields than to avoid lodging at yield levels of around 120 t/ha.

Study 2: N25S_M produced higher average simulated yields and gross margins than N25 (about R5300 and R3000/ha for April and December respectively) (see N25S_M vs N25, Figure 1) despite higher *LE*. Increased lodging tolerance (N25S_H) led to decreased *LE* and further increases in average yield, but a substantial increase in average gross margins (about R3000 and R3800/ha for April and December respectively) compared to N25S_M.

Conclusions

LE increased as crops started later in the season, with December crops showing the greatest *LE* and loss of gross margin, regardless of the region. Results suggest that breeding for lodging tolerance is important, and that significant gains in profitability can be made, especially when yields are already high. It should be noted that results are sensitive to the magnitude of cost multipliers and more work is required to confirm these. The study puts forward a new simulation framework for analysing the impact of lodging on sugarcane production profitability that can be used for other scenarios.

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Table 1. Long term average final simulated lodging extent (*LE*, a value between 0 (no lodging) and 1 (fully lodged)) and cane yield for different varieties and crop starting times. The difference in simulated yield and gross margin between lodged cane and the unlodged control are also shown.

		Lodging	Yield		Gross margin
Variety	**Cycle**	**LE (0-1)**	**Lodged (t/ha)**	**Loss (t/ha)**	**Loss (R/ha)**
MALELANE					
N14	Apr	0.0	118.2	0.0	0
	Jun	0.0	120.8	0.0	0
	Aug	0.0	121.8	0.0	0
	Oct	0.0	122.5	0.0	0
	Dec	0.0	125.0	0.0	0
N25	Apr	0.0	127.1	0.0	25
	Jun	0.0	131.5	0.0	54
	Aug	0.1	133.6	0.2	580
	Oct	0.2	134.3	0.5	1387
	Dec	0.3	136.3	0.5	1600
N41	Apr	0.0	114.8	0.0	148
	Jun	0.1	117.9	0.1	347
	Aug	0.3	120.0	0.8	1466
	Oct	0.4	121.4	1.3	2456
	Dec	0.5	123.1	1.5	2791
PONGOLA					
N14	Apr	0.0	110.9	0.0	0
	Jun	0.0	112.4	0.0	0
	Aug	0.0	112.2	0.0	0
	Oct	0.0	111.2	0.0	0
	Dec	0.0	114.8	0.0	0
N25	Apr	0.0	118.7	0.0	0
	Jun	0.0	122.2	0.0	0
	Aug	0.0	122.9	0.0	33
	Oct	0.0	122.1	0.0	79
	Dec	0.0	125.8	0.1	196
N41	Apr	0.0	106.7	0.0	0
	Jun	0.0	109.2	0.0	0
	Aug	0.0	110.6	0.1	130
	Oct	0.1	111.0	0.1	455
	Dec	0.2	113.9	0.3	958

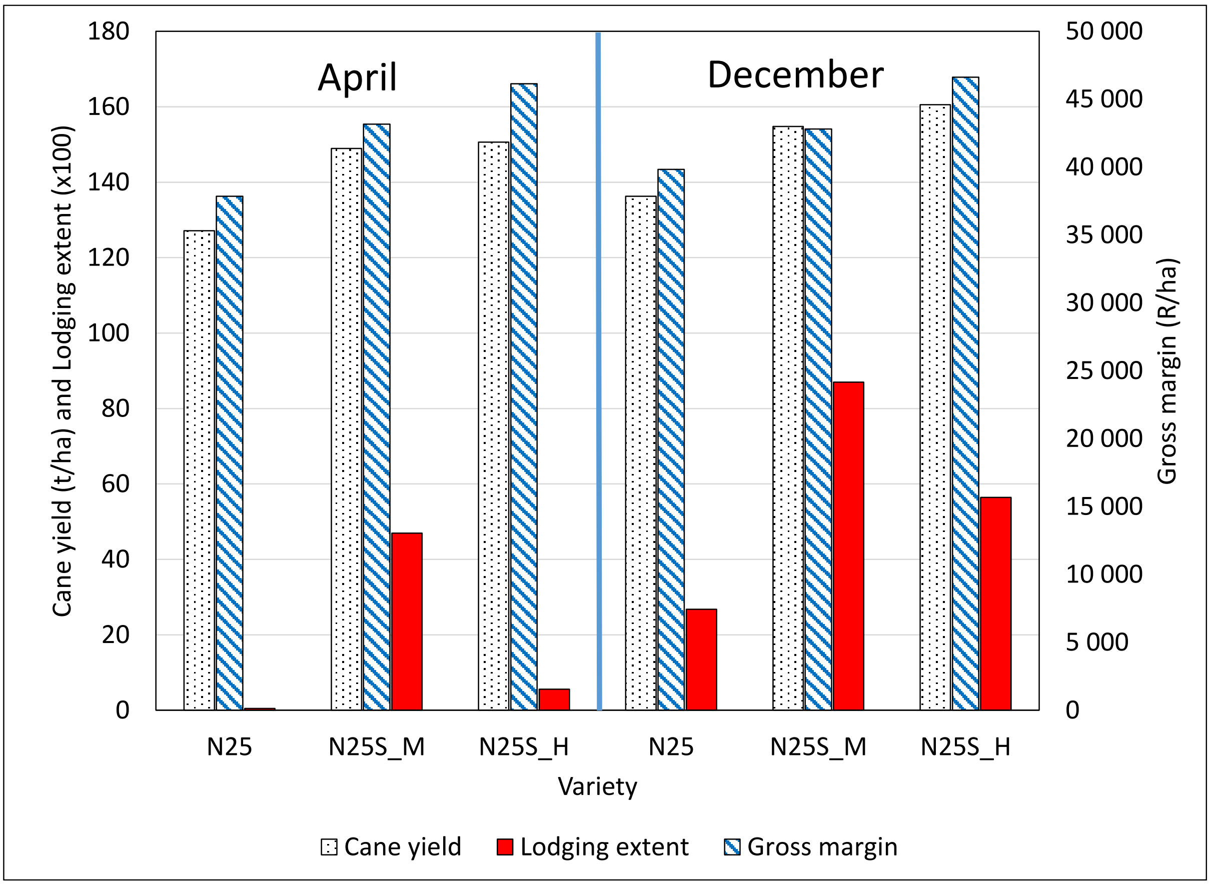

Figure 1. Long term average simulated cane yield, lodging extent and gross margin for the standard N25 (high yielding, medium lodging tolerance) and very high yielding varieties (N25S) that have medium (M) and high (H) tolerance to lodging for the April and December crop cycles for Malelane.