Proc S Afr Sug Technol Ass (2014) 87: 358 - 361

SHORT NON-REFEREED PAPER

RESOURCE CAPTURE AND CONVERSION EFFICIENCY OF TWO CONTRASTING SUGARCANE GENOTYPES UNDER WATER STRESS

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Abstract

There is growing interest in cultivating high-fibre sugarcane as a feedstock for biofuel production, possibly in marginal areas. However, there is a lack of quantitative information about their productivity, drought tolerance, resource (water and radiation) use and efficiency of conversion to biomass. This study compared crop development, growth and resource use of a high-fibre sugarcane hybrid (04G0073) and a traditional sucrose cultivar (N19) under well-watered and water stressed conditions. Setts were planted in four plots in a rainshelter facility at Mount Edgecombe in 2011. Water stress was imposed after four months by withholding irrigation from two plots. Green leaf area index (GLAI), radiation interception and soil water content were measured regularly. Dry aerial biomass and its components were measured at harvest. Evapotranspiration was derived from soil water content. Well-watered 04G0073 developed canopy cover more rapidly, enabling it to intercept 4% more radiation, and use 3% more water than N19. Well-watered 04G0073 also converted resources more efficiently than N19 to produce a 12% higher biomass yield. However, 04G0073 was found to be more sensitive to severe water stress than N19. GLAI, radiation interception and biomass at harvest were reduced by 66, 18 and 44% (compared to 55, 4 and 16% of N19), respectively. Radiation use efficiency and water use efficiency of 04G0073 were reduced by water stress and were lower than that of stressed N19. The information gathered in this study will be used to calibrate crop models for determining the feasibility of growing high-fibre cane for bio-fuel production in marginal areas.

Keywords: biomass, high fibre cane, water stress, water use efficiency, radiation use efficiency.

Introduction

Sugarcane is an ideal feedstock for ethanol production. Apart from the fermentation of stalk sugars, second generation ethanol technology also allows the production of ethanol from cellulosic plant material (fibre). There are indications that high-fibre sugarcane genotypes can tolerate water-deficit conditions better and achieve higher biomass yields than traditional genotypes (Alexander, 1985; Kim and Day, 2011). Higher yields can be achieved by increased capture of resources (water and solar radiation) and/or increased efficiency of conversion of interception radiation (radiation use efficiency, RUE) and water use (water use efficiency, WUE).

However, there is very little information available for high-fibre sugarcane with respect to their resource capture, or the efficiency of resource use and their reaction to water stress. The aim of this study was to quantify resource capture and conversion efficiency of two contrasting sugarcane genotypes and their response to water stress, and to relate this to crop development and growth parameters. This will assist the improvement of models to predict crop productivity and resource use in marginal areas.

Materials and Methods

A high-sucrose sugarcane cultivar (N19) and a high-fibre sugarcane hybrid (04G0073) were planted in October 2011 at the South African Sugarcane Research Institute rainshelter facility at Mount Edgecombe, South Africa. The soil consisted of 82% sand, 11% clay and 7% silt and had a rooting depth of 1 m. Field capacity (FC) and wilting point were determined *in situ* and found to be 0.18 $m^3/m^3$and 0.131 m^3/m^3, respectively. Stress point (SP) was taken as 0.155 m^3/m^3, which was determined from the laboratory.

The trial was divided into four plots with one plot per genotype used as the control (well-watered) and the other for the water stress treatment. All treatments received adequate irrigation for five months. Thereafter, irrigation was withheld from stress treatments while control treatments continued receiving adequate water for almost three months. This resulted in two periods of water stress for the stress treatments of 21 and 31 days respectively, interspersed by a period of 28 days with adequate soil water brought about through an unintended intrusion of storm water through the drainage system.

Soil water content (SWC) was measured twice a week from planting until harvest (May 2012) using a neutron water meter. Green leaf area index (GLAI) was derived as a product of leaf length, leaf width and a shape factor. Fractional interception of photosynthetically active radiation (FI_{PAR}) by the green canopy was measured weekly with a line quantum sensor.

ET was calculated using a water balance approach, from measured SWC, or from weather data on days when drainage occurred. WUE and RUE were calculated as the ratio of total dry aboveground biomass to seasonal ET (in units of kg/m^3) and to seasonal intercepted shortwave radiation (in units of g/MJ). Intercepted shortwave radiation was calculated as the product of FI_{PAR} and incoming shortwave radiation measured at a nearby weather station.

Results and Discussion

Well-watered 04G0073 produced more tillers and green leaves, resulting in a 10% higher GLAI that intercepted 4% more radiation and used 3% more water (Table 1). GLAI and FI_{PAR} at harvest were reduced by 65 and 18% (compared to 55 and 5% in N19), respectively. Water stress reduced ET of both genotypes by 27%, but that of 04G0073 remained 3% higher than N19. As the second stress event progressed it was clear that 04G0073 extracted water at higher rates and for longer than N19, eventually causing a more severe stress response as soil water reserves became depleted sooner. Well-watered 04G0073 produced 14% more dry biomass than N19 (Table 1). Stress reduced dry biomass yield of 04G0073 and N19 by 44% and 17%, respectively. Well-watered 04G0073 partitioned 7% less biomass to stalks than N19. Stress increased the trash fraction from 0.24 to 0.38 in 04G0073 and from 0.22 to 0.3 in N19. Well-watered 04G0073 partitioned more stalk biomass to fibre and less to sucrose than well-watered N19. Stress had no significant effect on stalk fractions.

Well-watered 04G0073 had a 12% higher WUE than N19 (7.6 vs 6.9 kg/m^3) (Table 1). Stress increased WUE of N19 by 15% and reduced that of 04G0073 by 25%. Well-watered 04G0073 had a 9% higher RUE than well-watered N19, although this difference was statistically insignificant. Stress reduced RUE of 04G0073 more severely (38% reduction) than N19 (2%), because of the much larger reduction in biomass yield. The WUE and RUE values obtained here compared well with the literature (Thompson, 1976; Muchow *et al.,* 1997).

Table 1. Plant development, dry biomass yield, biomass and stalk fractions, water use efficiency (WUE) and radiation use efficiency (RUE) at final harvest. The green leaf component includes leaf blade, sheath and meristem whereas trash includes dead leaves and dead stalks.

Parameter		**Well-watered treatment**		**Stress treatment**		**Well-watered x stress treatment**	
		04G0073	**N19**	**04G0073**	**N19**	**04G0073**	**N19**
Peak stalk population (stalks/m^2)		33	25	33	25		
Final stalk population (stalks/m^2)		15	11	14	9		
Maximum leaf number/stalk		26	23	23	21		
Final GLAI (m^2/m^2)		4.7	4.2	1.6	1.9		
ET (mm)		443	428	322	314		
Fraction of intercepted seasonal global shortwave radiation		0.66	0.62	0.54	0.59		
Total dry biomass yield (kg/m^2)		3.39	2.97^{NS}	1.89	2.47*	**	NS
Biomass fractions	Stalk	0.55	0.59^{NS}	0.49	0.58**	NS	NS
	Trash	0.24	0.22^{NS}	0.38	0.3*	**	*
	Tops	0.21	0.19^{NS}	0.13	0.12^{NS}	**	**
Stalk fractions	Fibre	0.58	0.45**	0.59	0.48**	NS	NS
	Sucrose	0.24	0.36**	0.24	0.33**	NS	NS
	Non-sucrose	0.18	0.19^{NS}	0.17	0.19^{NS}	NS	NS
WUE (kg/m^3)		7.6	6.9^{NS}	5.8	7.8*	*	NS
RUE (g/MJ)		1.52	1.39^{NS}	0.95	1.36*	**	NS

*indicates significance at $p \leq 0.05$, ** indicates significance at $p \leq 0.01$ and NS indicates non-significance of treatment differences.

Conclusion

Although more research is required to evaluate other high-fibre genotypes, the study demonstrated the different strategies of resource capture, biomass partitioning and coping with drought that are used by contrasting sugarcane genotypes. Well-watered 04G0073 invested more assimilates to structural growth of leaves and tillers, and less to sugar storage, allowing it to develop canopy cover more rapidly, and enabling it to capture 4% more radiation, and use 3% more water than N19. Well-watered 04G0073 also converted resources more efficiently than N19 to produce a 12% higher biomass yield. During the unfolding of stress events, 04G0073 extracted soil water more rapidly, eventually leading to more severe stress, and growth was limited more than in N19. GLAI, radiation interception and biomass at harvest were reduced by 66, 18 and 44% (compared to 55, 4 and 16% of N19), respectively. RUE and WUE of 04G0073 were reduced by water stress and were lower than that of stressed N19.

The information gathered in this study will be used to calibrate crop models for determining the feasibility of growing high-fibre cane for biofuel production.

Acknowledgements

The authors acknowledge Yuriy Tsupko for the trial design and the South African Sugarcane Research Institute (SASRI) technical team for assistance with data capture.

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