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From sugar industry to cane industry: Evaluation and simultaneous selection of different types of high biomass canes

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ABSTRACT

Sugarcane breeding has traditionally been geared towards maximiing sugar production. The sugarcane crop biomass is now being recognised as an alternative source of renewable energy. The objectives of this study were to characterise and identify different types of high biomass genotypes obtainable from early generation hybrid populations. Sixty potentially high biomass genotypes with variable fibre content were screened from the MSIRI germplasm collection and were evaluated over two harvests. Randomised Complete Block design was used and four commercial varieties were included for comparison purposes. Based on inherent variations in cane quality and biomass traits, four different types of canes were identified. A selection algorithm was developed that involved culling levels for several traits. The algorithm simultaneously identified 11 high biomass genotypes with variable proportions of sucrose and fibre. The different types of varieties defined should provide additional opportunities to exploit the biomass of sugarcane crop for different end-uses. With minor adjustments to suit local realities, the selection model can be adapted in any sugarcane breeding programme for targeting and exploiting different types of canes.

1. Introduction

Sugarcane (*Saccharum* L. spp) has long been cultivated for its sucrose content in the cane stem. Until recently, sugarcane breeders have focused on increasing sucrose content and sugar yield with little importance given to fibre component. The sugarcane crop is among the finest collectors of sunlight on earth [1,2] and, contrary to other high biomass grasses, it has the added advantage of producing both sugar for consumption and fibre as a low-cost clean feedstock for renewable energy [3–5]. Sugarcane with high fibre is now being recognised as a potential dedicated energy crop, even in regions where its cultivation has not been a common practice [6].

Different types of sugarcane varieties can be defined based on the relative proportion of sugar and fibre in the cane stem [7]. The fresh weight aboveground part of the traditional sugarcane crop broadly consists of millable cane stalks (70%), cane tops and green leaves, termed as CTL, (20%) and dry leaves or trash (10%) [4,8]. Mature trash-free cane stalks are

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furthermore composed of approximately 75% water and the remainder is divided between fibre and soluble solids. Conventional commercial varieties bred in Mauritius have been found to be composed of about 13% soluble solids, mostly sucrose, and 12% fibre in the cane stem [9]. The amount of each of these three components (water, fibre and soluble solids) in the millable canes is genetically determined and varietal differences are well known [10].

Since ancient times, *S. officinarum* clones, the "noble canes", collected from centres of origin in the regions of Papua New Guinea were cultivated by humans for their high sucrose content. Improvement of sugarcane for increased sugar yield through classical hybridisation and selection has been a directed, ongoing process since 1888, following the observation in 1858 that sugarcane produced viable seed [11]. In the early 20th century, breeders initiated introgression breeding programs that used interspecific hybrids derived from crosses between *S. officinarum* (noble canes) and *Saccharum spontaneum* (wild canes) [12]. The noble canes related genera and species, namely, *Erianthus, Miscanthus, Narenga, Sclerostachya* and other *Saccharum*, forming part of the *Saccharum* complex [13,14], were known for their high fibre, negligible sugar, high vigour and resistance to important sugarcane diseases. The initial interspecific hybrids (F_1) were back-crossed successively (BC_1, BC_2, BC_3) with *S. officinarum* clones to retain sufficiently high sugar content, in a process termed "nobilisation" by sugarcane breeders [15]. Interspecific hybrid varieties that resulted from early breeding activities led to spectacular increases in cane and sugar yields worldwide and formed the genetic foundation of modern sugarcane varieties [16,17]. While most of the genomic composition of sugarcane is from *S. officinarum* [18], most of the genetic diversity is thought to be contributed by *S. spontaneum*, since it is by far the more genetically diverse of the two species [19]. In the recent decades, however, introgression breeding has not led to commensurate commercial successes and long time breeding and risk factors associated have clearly acted to reduce the level of resources devoted to it in most sugarcane breeding programmes [20–22]. Much emphasis is placed on crosses that include *S. officinarum* hybrid parents with potentially high breeding values and appreciable agronomic characteristics.

Driven by the high volatility of oil markets and the potential high value of sugarcane fibre, various sugarcane breeding institutions are showing renewed interest in introgression breeding as the biomass potential of early generation sugarcane hybrids (F_1, BC_1 and BC_2) generally exceeds those of modern cultivars [23]. Alexander [24], furthermore, stated that sucrose recovery per hectare could be greater with higher fibre 'energy canes' than with conventional cultivars, even though energy canes produce low quality juice. This is because biomass yield of energy canes far surpasses those of current sugarcane varieties.

In the new socio-economic environment, the demand on the sugarcane crop for multipurpose use becomes more complex as a multitude of variables, namely, sucrose content, fibre content, cane yield, sugar yield, fibre yield and total biomass yield, needs to be assessed during selection of different types of high biomass varieties. Simmonds and Walker [25] reported that breeders constantly make judgements and take decisions on the general balance of characters displayed by lines, clones or populations in hand. Skinner et al. [26] similarly reiterated that although breeders speak of selection for yield of cane, or some other important characters, it is impossible to select a single character; the entire variety must be selected or rejected.

The aim of this study was to develop a selection algorithm for the identification and selection of different types of sugarcane varieties simultaneously from a population of interspecific derived clones. The most appropriate threshold levels for specific traits, namely sucrose concentration, fibre content and biomass yield, had to be established. Hence, a preceding analysis of the existing variations among early generation high biomass individuals with respect to the above traits was vital. The ultimate aim was to develop a selection index that could ideally encompass all the different types of high biomass varieties of economic importance that can be potentially generated from any sugarcane breeding programme.

2. Materials and methods

The Mauritius Sugarcane Industry Research Institute (MSIRI) germplasm collection consists of 2200 imported and locally bred clones, of which about 450 are derived from early generation crosses with sugarcane wild relatives. The interspecific hybrids in the collection were assessed visually for high yield and a total of 58 genotypes were selected for the evaluation of biomass potential. They included 22 F_1's, 30 BC_1's and 6 BC_2's clones. Two high fibre clones of the genera *Erianthus arundinaceous*, for convenience termed here as wild clones, were also included for evaluation.

The trial was laid in 2005 in the sub-humid irrigated zone at Pamplemousses Experimental Station (soil type: low humic latosol (L) soil [27], altitude: 79 m, annual rainfall: 1352 mm) in the north of the island. A randomised complete block design with three replicates was used. Each plot consisted of two adjacent rows of 5 m length and the inter-row spacing was at 1.5 m. Four commercial varieties were included for comparison purposes. The layout is commonly adopted at an intermediate selection stage (third clonal stage) of the MSIRI sugarcane breeding programme. The planting material and field layout are described in Santchurn et al. [28].

Sugarcane is a perennial crop in which individual plants resprout (ratoon) after harvest. Generally, sugarcane is planted once and harvested annually over several ratoons. Data were collected from 12-months old plant cane and first ratoon crops. Cane samples, comprised of six clean millable cane stalks devoid of CTL, were taken from each plot for the determination of cane quality characteristics from laboratory analyses. Brix %, the proportion of total soluble solids in the cane juice, was derived from the diluted Brix measured in the laboratory. Pol %, the apparent sucrose content in the juice, was determined by polarisation using the method of de Saint Antoine [29]. Fibre % was obtained by direct determination of the fibre content of the cane according to the method of de Saint Antoine and Froberville [30]. Dry matter % of the cane was the sum total of soluble and non-soluble solids (Brix % + fibre %). It was used to estimate the dry weight percentages of Brix, Pol and fibre in the cane stem. Biomass yield