Field Crops Research 183 (2015) 276–281

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Interactions affecting the optimal harvest age of sugarcane in rainfed regions of South Africa

S. Ramburan*

South African Sugarcane Research Institute, Private Bag X02, Mount Edgecombe, Durban, South Africa

ARTICLE INFO

Article history:
Received 10 June 2015
Received in revised form 31 July 2015
Accepted 5 August 2015
Available online 28 August 2015

Keywords:
Cultivar
Eldana Saccharina Walker
Harvest age
Sugarcane

ABSTRACT

Recent changes in cultivar composition, the renewed drive to increase harvest age (HA), and the impacts of the Eldana borer (*Eldana Saccharina* Walker: *Lepidoptera Pyralidae*) in the rainfed regions of South Africa have created uncertainty about the optimal HA of sugarcane. This study aimed to (i) review the optimal HA of sugarcane in the coast and inland regions, (ii) determine the variability in optimal HA with cultivar, and (iii) investigate the interactions between cultivar eldana resistance levels and HA on productivity. A secondary objective was to summarise the results of dedicated cultivar × HA experiments to evaluate the importance of this interaction. Cultivar evaluation trial data from 1980 to 2014 were categorized by region, HA, cultivar, and cultivar eldana resistance category. Mean estimated recoverable crystal yields (TERC) and percentage internodes bored (%IB) by eldana were plotted against HA using polynomial regression to investigate effects of region, cultivar, eldana resistance, and their interactions. Additionally, three separate cultivar × HA factorial trials were analysed using linear mixed models. The HA and its associated interaction terms were highly significant ($P < 0.001$) and generally accounted for more variation than the cultivar and crop main and interaction terms in the trial-based analyses. The combined data mining analysis showed that on average, the optimal HA in the coast and inland regions were 15 and 22 months, respectively. A cultivar × HA × region × eldana infestation level interaction was demonstrated, suggesting that a generic optimal HA for specific cultivars cannot be recommended. There was a reduction in optimal HA for newer released cultivars, suggesting possible indirect selection for early maturity in the breeding programs for these regions. Eldana susceptible cultivars were more sensitive to damage as HA increased (4.1 compared with 3.1%IB per additional growth month for susceptible vs. resistant cultivars, respectively). Eldana resistance was essential for achieving the benefits of increased HA in the coastal region. The study highlights the importance of HA to sugarcane productivity and illustrates how an experimental database can be used to inform breeding strategies and gain insights into a key management factor of industrial importance.

1. Introduction

Sugarcane (*Saccharum* spp.) is a crop of tropical origin with a wide range of adaptability to sub-tropical and temperate regions of the world. The concept of harvest maturity in sugarcane is rather vague, and is based on a combination of factors such as maximum sucrose accumulation, economic optima within the production system (number of profitable crops harvested from a single planting), and agronomic limitations. These factors vary considerably across industries and regions within industries. In tropical industries, or temperate regions with high temperatures and irrigation, the crop typically reaches harvest maturity between 9 and 12 months of age (Lonsdale and Gosnell, 1975; Onginjo and Olweny, 2011; Rao et al., 1997). Factors such as lodging (Rostron 1972), flowering (Bond and De Haas, 1990), or pests (Leslie, 2004) often restrict farmers from growing the cane for longer. In cooler temperate climates, in the absence of the above limitations, sugarcane may be harvested at up to 36 months of age (Evenson et al., 1997). In many industries, the optimal harvest age (HA) of sugarcane was determined through knowledge of historic production and local conditions, or through early experiments involving production and physiology of older cultivars (Inman-bamber, 1991). Most sugarcane industries have experienced massive shifts in cultivar composition over decades (Glaz and Gilbert, 2005; Ramburan, 2013), yet the assumptions about optimal HA generally remained unchanged in many cases, and are still based on older cultivar responses. This is despite

* Fax: +27 31 5087597.
E-mail address: Sanesh.Ramburan@sugar.org.za

http://dx.doi.org/10.1016/j.fcr.2015.08.003
0378-4290/

numerous examples of the importance of cultivar × HA interactions to sugarcane production (Donaldson, 1985; Lonsdale and Gosnell, 1975; Moberly, 1971; McIntyre and Nuss, 1998; Milligan et al., 1990; Ramburan et al., 2009). In many cases, the effects of HA supersede the effects of cultivar and time of harvest (Khandagave and Patil, 2007), yet the latter two factors have received more attention in sugarcane literature. Additionally, plant breeders routinely select for general growth vigour (particularly in earlier selection stages), high cane yields, and high sucrose content (an indication of maturity) in breeding programs worldwide (Jackson and McRae, 2001; Kimbeng and Cox, 2003; Pedrozo et al., 2011; Zhao et al., 2012). This general selection for vigour may have inadvertently selected against cultivars that grow and mature more slowly. Therefore, a key question that breeders and agronomists need to ask is: "has the optimal HA in an industry shifted, or is it likely to shift based on changes in cultivar composition?"

This question may be answered through the use of crop growth model simulations, however, current sugarcane models do not incorporate a wide range of genetic coefficients to do this accurately (Donaldson et al., 2003; Sexton et al., 2014). Furthermore, sugarcane crop models do not account for key pest threats, or other agronomic issues such as lodging that may restrict HA. Individual trial-based approaches may also be used, however, these are costly and restricted by the number of HA iterations and cultivars that can be tested. In contrast, post-release cultivar trial databases provide an opportunity to explore HA dynamics in relation to older and newer cultivars, across multiple seasons and ratoons, under commercial production conditions (trials established and managed by grower co-operators). The potential of such databases to explore HA dynamics needs to be investigated further.

The rainfed parts of the South African sugar industry may be broadly separated into the coastal and inland regions. The current recommended HA in the inland region is 24 months; a HA identified through historic production and experimentation with cultivars such as NCo376 and N12. Both plant and ratoon crops are typically harvested at 24 months and milled from April to December. In the coastal region, the optimal HA was identified as approximately 18 months in past studies with older cultivars such as N12, NCo376, and N16 (Inman-Bamber, 1991; McIntyre and Nuss, 1998; Rostron, 1972). However, infestations of the stalk borer *Eldana Saccharina* Walker (*Lepidoptera Pyralidae*) in the 1970s (Atkinson et al., 1981) have restricted the ageing of sugarcane beyond 12 months in this region. Eldana damage increases in sugarcane that is aged and carried over to the following milling season. Consequently, the recommended HA in the coastal region was reduced to 12 months in an attempt to avoid and reduce losses due to eldana infestations. In this region, plant crops (either autumn or spring plantings) are typically grown to an age of 13 months, and subsequent ratoons (up to 8 ratoons usually) are harvested at 12 months of age thereafter. Breeding strategies in the region were also manipulated to account for the eldana issue, with selection programs aligned to eldana avoidance (12 month harvesting) and eldana resistance (18 month harvesting). In contrast to the coastal region, comparatively fewer studies involving HA have been conducted for the inland region.

The release of new eldana resistant cultivars, the availability of insecticides against eldana (Leslie, 2009), and the drive to increase productivity along the coast have prompted growers to revert back to older HAs. However, given the large shifts in cultivar composition that have occurred over the last 40 years (Ramburan, 2013), there is current uncertainty around the optimal HA in the coastal region. Additionally, the optimal HA of a cultivar is linked to its eldana susceptibility (only eldana resistant cultivars are recommended for 18 month harvesting) (Leslie, 2004). This interaction has been shown to be valid at the experimental level (Ramburan and Sewpersad, 2009), however, under more commercial conditions the relationship between cultivar, HA, and eldana damage needs to be investigated.

This study aims to summarise the results of dedicated cultivar × HA experiments to evaluate the importance of this interaction relative to other sources of yield variation (such as crop–year effects). Thereafter, the specific objectives of this study were to use a cultivar evaluation database to (i) review the optimal HA of sugarcane in the coast and inland regions, (ii) determine the variability in optimal HA for individual cultivars and ascertain if the optimal HA will change with changes in industry cultivar composition, and (iii) investigate the effects of cultivar eldana resistance levels and HA on eldana damage and subsequent yields. The information derived from the study will provide insight into the general management of HA in the coastal and inland regions, and will help identify target HAs within the breeding programs for these regions. The study also illustrates an approach to using an experimental database to investigate a key sugarcane management factor.

2. Materials and methods

The database used in this study comprised post-release cultivar evaluation trials established as part of the South African Sugarcane Research Institute's (SASRIs) Variety Evaluation Project (VEP) from 1980 to 2014. In total, trial results from 150 trials, harvested over a combined 2650 crops (plant and ratoon crops) were used in the analysis. Trials in the database consisted of six to thirteen cultivars each, planted in randomised complete block designs, with four to six replications per trial. Experimental plots consisted of five or six rows (two outer guard rows not harvested) that were between eight to ten meters long and spaced 1 m (inland region) and 1.2 m (coastal region) apart. All trials were conducted under rainfed conditions and managed commercially by grower co-operators who were responsible for land preparation, fertilization, and weed control. Each trial was harvested for as many ratoon crops as the commercial field within which it was established, and this ranged from a minimum of three crops (plant and two ratoons), to a maximum of ten crops. The intended HA of each trial, which was pre-determined in consultation with the grower co-operator, was based on the overall objectives of the trial, and was aligned to the prevailing commercial practice in the region. At each harvest, a series of traits of commercial relevance were determined for cultivar characterisation and recommendation purposes. Only the traits relevant to this study are described below.

Net sugarcane rows (inner rows of the experimental plot) were manually harvested and weighed using a mechanical grab apparatus and load cell fitted onto a four-wheel drive vehicle, to determine cane yields in tonnes per hectare. Samples of 12 stalks were taken from each plot at each harvest to determine the estimated recoverable crystal percent (ERC%). The ERC% is a quality parameter in the South African sugar industry that is derived from sucrose, non-sucrose, and fibre contents in cane deliveries. The ERC yield (TERC) is determined as the product of cane yields (tons/ha) and ERC%, and is the commercial unit on which cane payments are based. At each harvest plot-wise surveys of eldana damage levels were performed by splitting 15–20 stalks longitudinally and counting the number of damaged and undamaged internodes. Levels of eldana damage were expressed as the percentage of internodes bored (%IB) according to Anon. (2005).

Each treatment mean in the dataset was subsequently categorized by region (coastal or inland), harvest age (one month increments ranging from 9 to 26 months), cultivar, and eldana resistance rating of each cultivar (resistant or susceptible). For each region, mean TERC was fitted as a function of HA using curvilinear regression, and optimal HA was interpreted from the peaks of the fitted curves. A similar method was used to fit individual cul-