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Sugarcane growth and yield responses to a 3-month summer flood

R.A. Gilbert [a,*], C.R. Rainbolt [a], D.R. Morris [b], J.M. McCray [a]

[a] University of Florida, EREC, 3200 E. Palm Beach Road, Belle Glade, FL 33430, United States
[b] USDA-ARS, Sugarcane Field Station, 12990 US Hwy. 441, Canal Point, FL 33438, United States

ARTICLE INFO

Article history:
Received 30 April 2007
Accepted 7 October 2007
Published on line 26 November 2007

Keywords:
Sugarcane
Flood
Growth
Nutrient concentration
Yield
Florida
Water table

ABSTRACT

Sugarcane (*Saccharum* spp.) in south Florida is often subjected to flooding due to interacting effects of soil subsidence, pumping restrictions, and tropical storms. While there has been considerable research on the response of sugarcane cultivars to high water tables and periodic flooding, there is a lack of information on commercial cultivar yield response to long-term flooding. An experiment was established in Belle Glade, FL to examine the effect of a 3-month summer flood (July–September) on the growth and yield of cultivars CP 80-1743 and CP 72-2086 during the plant cane (2003) and second ratoon (2005) crop. Harvest samples were taken early-, mid-, and late-season. Flooding sugarcane in the summer caused sequentially greater yield reductions throughout the harvest season in plant cane. Sucrose yields for flooded cane, compared with the non-flooded control, were 9.6 t sucrose ha^{-1} versus 11.7 t sucrose ha^{-1} early, 9.2 t sucrose ha^{-1} versus 12.8 t sucrose ha^{-1} mid-season and 7.8 t sucrose ha^{-1} versus 12.3 t sucrose ha^{-1} at late harvest. In the second ratoon crop, flooding reduced sugarcane tonnage and sucrose yield by 54–64% across sampling dates, and preliminary results indicated that flooding reduced leaf nutrient content by 10–78%. Yield reductions due to flooding in both crops were attributed more to reduced tonnage rather than sucrose content. CP 72-2086 yielded 18–28% greater sucrose than CP 80-1743 when harvested late. However the flood $\times$ cultivar interaction was not significant as both cultivars recorded similar yield reductions under flooded conditions. Our results identified severe yield losses caused by a 3-month summer flood in these cultivars, particularly in ratoon crops. Strategies to increase summer on-farm water storage in Florida should focus on short-duration periodic flooding rather than long-term flooding.

1. Introduction

Sugarcane (*Saccharum* spp.) is an important economic crop in the tropics and sub-tropics due to its high sucrose content and bioenergy potential. Sugarcane in south Florida is often subject to flooding during the summer. Florida sugarcane is grown primarily in the Everglades Agricultural Area, a 280,000 ha basin of Histosols drained for agricultural use. When drained, the high-organic matter soils are subject to microbial oxidation and soil subsidence at the rate of approximately 1.4 cm year^{-1} (Shih et al., 1998). As soils become shallower, each rainfall floods a greater percentage of the soil profile, making drainage more difficult. In addition, best management practices to reduce pumping and keep more water on-farm have been implemented to reduce P in farm water exported to the natural Everglades (Rice et al., 2002). Finally, south Florida is subject to flooding from tropical storms which may inundate sugarcane fields in the late summer and fall (Sartoris and Belcher, 1949).

* *Corresponding author*. Tel.: +1 561 993 1535; fax: +1 561 993 1582.
E-mail address: ragilber@ufl.edu (R.A. Gilbert).
0378-3774/$ – see front matter
doi:10.1016/j.agwat.2007.10.009

Floods, particularly if prolonged, have the ability to negatively affect sugarcane yields (Berning et al., 2000). There is evidence, however, of tolerance to high water tables and periodic flooding in Florida (Canal Point, ''CP'') sugarcane germplasm. Pitts et al. (1990) found that sucrose yields were not affected in CP 72-1210 when grown at water table depths of 45 and 75 cm. Glaz et al. (2002) recorded variability among commercial CP cultivars in tolerance to high water tables. CP 72-2086 was not affected while CP 80-1743 yields were reduced 25% in the high water-table treatment. They recommended screening of genotypes under high water tables. Glaz et al. (2002) reported a mean yield reduction of 8% in a wet field (average water table levels 13–17 cm below the soil surface) compared with a drier field (average water tables levels 29–39 cm below the soil surface). Glaz et al. (2004a) reported yield reductions of 18 and 28% in genotype CP 95-1376 when exposed to 7-day flood cycles (water 0–2.5 cm above the soil surface), whereas yields of genotype CP 95-1429 were not affected by the same 7-day floods. Additionally, Glaz et al. (2004b) found neutral or positive responses of sugarcane photosynthesis, transpiration and stomatal conductance to periodic 7-day floods. Glaz and Gilbert (2006) found that 2-day periodic floods increased cane and sucrose yields in plant cane crops of CP 72-2086 and CP 80-1827, and Chabot et al. (2002) reported that sugarcane transpiration rates were maintained under high water tables in cultivar CP 66-345.

While many studies have indicated that CP germplasm can tolerate high water tables and periodic floods, long-term flooding has been less studied, particularly for commercial cultivars, and yield losses appear to be greater. Sartoris and Belcher (1949) reported that CP sugarcane clones survived a 105-day flood following two tropical storms in 1947. Srinivasan and Batcha (1962) flooded 68 clones of *Saccharum* and related genera for 6 months. They found that *S. spontaneum* and *S. robustum* clones were flood tolerant but *S. officinarum* clones died when flooded. They also noted a significant reduction (magnitude not reported) in leaf area index (LAI) with flooding. Webster and Eavis (1972) noted a reduction in LAI of 25% in 1-month old sugarcane plants flooded for 14 or 30 days. Deren et al. (1991) screened 160 CP clones for flood tolerance to a 5-month flood during July–November. They found that several clones produced >70% sucrose yield in flooded compared with non-flooded conditions. They surmised that CP germplasm was inadvertently selected for flood tolerance due to repeated exposure to flooding in the history of the breeding program, and concluded flood tolerance was present in modern CP clones. Morris and Tai (2004) examined 12 sugarcane genotypes subjected to 0, 15 and 30 cm deep water tables for 8 months. Shoot dry weight of the 0 cm treatment was reduced compared with the 30 cm water table.

While there is reasonable evidence to indicate that some CP cultivars may tolerate high water tables and periodic flooding, there is a lack of information on commercial cultivar growth and yield under long-term floods of less duration than 5 months. We suspect that sugarcane cultivar tolerance and yield response to long-term flood may be different than high water tables due to increased anoxia in the root zone and associated morphological and nutrient uptake changes in the plant. Sugarcane yield response to long-term flood would be useful information for Florida growers since subsiding soils, increased restrictions on pumping, and increased frequency of tropical storms (Emmanuel, 2005; Klotzbach, 2006) have increased the incidence of flooding on their farms.

The objective or our study was to determine the effect of a 3-month summer flood on sugarcane growth and yield in two commercial cultivars, CP 72-2086 and CP 80-1743, known to have different tolerance to high water tables.

2. Materials and methods

2.1. Experimental design

The experiment was planted on 27 February 2003 at the University of Florida Everglades Research and Education Center (EREC; 26°39′N, 80°38′W) in Belle Glade, FL on a Lauderhill muck (euic, hyperthermic and Lithic Haplosaprist) soil. Fields formerly used for rice paddy experiments (Deren et al., 1991) were chosen because these fields were equipped to isolate floods hydrologically. The experiment was planted as a 2 × 2 factorial in a split-plot arrangement of a randomized complete block design with four replications, with water table as the main plot and cultivar the sub-plot. Each sub-plot was 15.2 m long × 4 rows wide, with 1.5-m between row spacing. The two cultivars used in this study, CP 72-2086 (tolerant) and CP 80-1743 (not tolerant), were chosen based on a previous report of their different tolerance to high water tables (Glaz et al., 2002). Water tables were maintained at either a target height of 15 cm above the soil surface (flooded), or at natural hydrological levels (non-flooded), which averaged from 11.2 to 18.4 cm below the soil surface (Table 1). The flood treatment was imposed from 1 July through 30 September each year, the period of greatest rainfall during which flooding is most likely to occur in the EAA. The flooded treatment was maintained by pumping water into the fields throughout the flood period. Boards were installed in drainage ditches at the field outlets to maintain water height at

Table 1 – Climatic variables and water table heights for the plant cane (2003) and second ratoon (2005) sugarcane crops at the Everglades Research and Education Center, Belle Glade, FL

Year	Average air temperature (°C)	Total precipitation (cm)	Water table height, July–September (flooded) (cm above soil surface)	Water table height, July–September (non-flooded) (cm above soil surface)
Plant cane				
2003	26.1	45.1	13.6	−11.2
Second ratoon				
2005	26.7	34.6	10.7	−18.4