United States Department of Agriculture-Agricultural Research Service, Sugarcane Field Station at Canal Point, Florida: Past, present and future

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Abstract

The USDA-ARS Sugarcane Field Station at Canal Point has a long history of sugarcane research and cultivar development. It was established in 1920 at Canal Point and had a small impact until the 1960s when the Florida sugarcane industry expanded. During the 1970s, CP-cultivars developed by the cooperative program between the USDA-ARS, the University of Florida, Institute of Food and Agricultural Sciences and the Florida Sugar Cane League expanded in the Florida industry. Currently, the Sugarcane Field Station produces true seed for cultivar development programs in Florida, Louisiana and Texas and cultivars developed in programs in the three states from true seed made from crosses made at the Canal Point facility occupy 90, 88 and 100 % of the acreage, respectively in these states. CP-cultivars are also grown in several foreign countries and occupy a major acreage in several Central American countries.

Mission

The mission of the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) Sugarcane Field Station is to develop high-yielding, disease and stress-tolerant sugar-cane cultivars, and conduct agronomy, pathology, and soils, research that results in improved production efficiency and soil conservation. In order to accomplish this mission, the USDA-ARS Sugarcane Field Station cooperates with the University of Florida, Institute of Food and Agricultural Sciences (IFAS) and the Florida Sugar Cane League in the CP-cultivar development program. Sugarcane seeds are also supplied for cultivar development in Louisiana and Texas from crosses made cooperatively with the USDA-ARS, Sugarcane Research Unit in Houma, Louisiana and the Texas Agricultural Experiment Station, of the Texas A&M University System, Weslaco, Texas for cultivar development for the sugarcane industries in those states.

History

The USDA-ARS Sugarcane Field Station at Canal Point, Florida has a long and productive history. The present site was established in 1920 by USDA under the direction of Dr. E. W. Brandes after he first tried to establish a site at Collins Key (Miami Beach) in 1918-19. Canal Point (26.52°N and 80.36°W) was selected because of the moderating temperature effect from Lake Okeechobee. The wisdom in selecting the site has been proven every 3 to 5 years south Florida experiences freezing temperatures. Often freezes occur as close as 3 to 10 km from Lake Okeechobee and damage commercial sugarcane, but temperatures usually remain above freezing at Canal Point. The cool night temperatures (below 16°C) in November and December are beneficial because they naturally emasculate sugarcane flowers, thereby simplifying the identification of female tassels used in biparental crosses.

The Sugarcane Field Station was originally created to supply true seed for the Louisiana sugarcane industry. The first agreement covering this arrangement was made in 1924 between USDA, and the Agricultural and Mechanical College of Louisiana State University. Since about 1960, the Canal Point station has been developing cultivars with CP prefixes for Florida under a three-party cooperative agreement among USDA-ARS, the University of Florida, Institute of Food and Agricultural Sciences, and the Florida Sugar Cane League.

The Sugarcane Field Station expanded with the Florida sugarcane industry in the 1960s. The 1960-61 crop in Florida was harvested on 19,800 hectares and the 1964-65 crop on 88,990 hectares. The dramatic expansion resulted in sugarcane being planted on land farther from Lake Okeechobee, thereby loosing its protection from winter freezes. Prior to the 1960s, most of the sugarcane production was attributed to U.S. Sugar Corporation, a private company located in Clewiston, Florida, on land with moderating temperatures near Lake Okeechobee. U.S. Sugar Corporation had the only program at that time that developed sugarcane cultivars for Florida. These cultivars, with the CL prefix, were developed to produce on organic soils near Lake Okeechobee. CL 41-223 was one highly successful cultivar developed by US Sugar Corporation.

Due to the industry expansion, USDA added a cultivar development program for Florida to its station mission at Canal Point and modernized the facility. A plastic-covered crossing house was built (1959), which was followed by major construction and modernization in the mid-1960s: new pathology and seedling greenhouses (1965), vehicle sheds (1967), laboratories and offices (1968), and another greenhouse with attached head house (1970). Since then, a photoperiod house, a new crossing house, and a shop were added and...
a former residence was converted into the administrative building for the station.

Hurricanes are always a threat in South Florida and hurricanes in 1926, 1928, and 1932 left 60 cm of standing water on the station grounds. The two most damaging hurricanes occurred in 1947, with the first dropping 46 cm of water and the second, about a month later on October 12th, braking a dyke that allowed 1.8 m of water to inundate the World Collection of Sugarcane then maintained at Canal Point. Fields at the station were under water for several months and station personnel used boats to go into the fields and dive into the water to cut stalks of sugarcane and save the collection. In 2004, Hurricanes Frances and Jeanne struck only 3 weeks apart and caused about $200,000 in property damage, substantial damage to outside research, but (at the time of this writing) only minor damage was estimated to 2004 seed production.

Pathogen introductions of smut (caused by Ustilago scitaminea) in 1978 (Todd, 1978) and rust (caused by Puccinia melanocephala) in 1979 (Dean et al., 1979) caused the loss of susceptible commercial cultivars and added substantial pressure to the breeding program. Screening programs for these and other new diseases were implemented. A leaf scald (caused by Xanthomonas albilineans) outbreak in the early 1990s caused the loss of approximately 20% of the clones in the cultivar development program in spite of a preventive screening program prior to the outbreak. However, no major commercial yield losses were recorded due to leaf scald.

The organic soils in the Everglades Agricultural Area and the role of phosphorus enrichment on the Florida Everglades have affected both the industry and the station’s research (Glaz, 1995). Phosphorus levels throughout much of the undisturbed Everglades are less than 20 ppb. Ecologists have been concerned with possible phosphorus enrichment to the natural Everglades resulting from release of phosphorus from oxidation of organic soils and fertilizer runoff in the Everglades Agricultural Area. Efforts by growers to reduce phosphorus fertilizer and restrict water discharged from their farms to public canals (best management practices to control phosphorus export) have resulted in substantial reductions in phosphorus export. As a consequence of reduced water discharged from farms aimed at controlling phosphorus export, water tables on growers’ farms are often higher than is considered optimum for sugarcane.

A major change in the Florida sugarcane industry was its 100% conversion to machine harvesting about 10 years ago. This has caused more emphasis on selection for erect cane cultivars. Mechanized planting methods are being developed by growers and may require research to address new disease problems associated with poorer quality seedcane.

**Impact**

The impact of the Sugarcane Field Station is illustrated by its output of true seed, more than 40 CP-cultivars released in Florida in the last...
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**Sugarcane grown in lysimeters at different water tables**

30 years, and the hectares of these cultivars grown in the sugarcane industries it serves. In the 2003-2004 crossing season, the station produced 552,781 seeds for Florida, 816,955 seeds for the USDA-ARS Sugarcane Production Unit in Houma, Louisiana, and 111,924 seeds for the Texas Agricultural Experiment Station, of the Texas A&M University System, Weslaco, Texas sugarcane cultivar development programs. In the 1950s, 95% of the sugarcane hectarage in Louisiana was planted in CP-cultivars. During the 1970s, cultivars with the L prefix of the Louisiana State University program gained in hectarage and the CP-cultivar hectarage decreased to 70% in Louisiana. Presently, LCP 85-384 occupies 88% of the commercial hectarage; this cultivar was developed from a cross made at Canal Point and selected by Louisiana State University (LSU), and developed cooperatively between LSU, USDA-ARS, Houma and the American Sugar Cane League.

In Florida, CP-cultivars occupied 14% of the hectarage in 1970, but increased to 90% in 2003 (Glaz and Vonderwell, 2003). The Texas industry is essentially 100% CP cultivars. Canal Point germplasm is also used extensively outside of the United States (Tew, 2003), particularly in Argentina (25% of total hectares), Belize (16%), El Salvador (50%), Guatemala (65%), Honduras (47%), Mexico (15%), Morocco (54%), Nicaragua (75%), Senegal (9%) and Venezuela (9%).

**Outline of CP-cultivar development program**

The cultivar development program is a cooperative program (Table 1) that includes the USDA-ARS, the University of Florida, IFAS, and the Florida Sugar Cane League. Each stage of the program is supervised by an individual scientist: Dr. Jimmy D. Miller (recently retired, Research Geneticist, USDA-ARS)—made crosses; Dr. Serge Edmé, Research Geneticist, USDA-ARS—Seedlings (80,000); Dr. Peter Tai (recently retired Research Geneticist, USDA-ARS)—Stage I (12-15,000 clones) and Stage II (1300-1500 clones); Dr. Robert Gilbert, Agronomist, University of Florida—Stage III (131 clones); Mr. Barry Glaz, Research Agronomist, USDA-ARS—Stage IV (16 clones); the Florida Sugar Cane League manages the seedcane increase program (usually about 10 clones) on cooperating grower farms; and Dr. Jack C. Comstock, Research Plant Pathologist, USDA-ARS—disease screening throughout the program. The CP breeding program has always been participatory in nature. Stage III, Stage IV, and expansions are planted and managed by growers who also serve on the committee that recommends dropping, advancing, and releasing of clones. Growers who do not participate in the program purchase new cultivars from the expansion plots grown in the fields of growers who provide land for Stage III and Stage IV tests.

**Research staff**

Research of Sugarcane Field Station scientists focuses on ways to improve the cultivar development program and to sustain and enhance sugarcane production while maintaining the fragile south Florida ecosystem. A description of each scientist’s research is presented.

**Jimmy D. Miller**, Research Leader and Research Geneticist, retired in April 2004 after 34 years at the station. He was responsible for crossing for Florida, and cooperated with scientists from Louisiana and Texas to conduct crosses for their programs. His research was on day length modification in flower synchronization and broadening sugarcane's genetic base (Miller and Tai, 1991). His role as Research Leader emphasized research of the station's scientists to improve and maintain the cultivar development program for the Florida sugarcane industry. Forty-five Florida cultivars resulted from crosses of Miller.

**Peter Tai**, Research Geneticist, was responsible for the Seedling stage, Stage I, and Stage II of the cultivar development program for most of his 27 years at the station. Dr. Tai retired in September 30, 2004. He also screened clones for cold tolerance and developed cold-tolerant populations (Tai and Miller, 1996). He identified two cultivars, CP 78-1628 and CP 89-2143, that have considerable tolerance to frost as young plants based on an electrolyte leakage technique he
modified for sugarcane (Tai et al., 2004). Tai has worked extensively with the World Collection of Sugarcane and Related Grasses at the USDA-ARS Subtropical Horticultural Research Station at Miami, Florida to preserve and characterize this germplasm which resulted in the development of a core collection of *Saccharum spontaneum* clones (Tai and Miller, 2001). He self-pollinated 235 accessions of wild sugarcane in the collection producing seed for long-term storage at the USDA-ARS National Seed Storage Laboratory in Fort Collins, Colorado (Tai et al., 1994). With a pollen storage technique he developed, *S. spontaneum* clones that flower in September were crossed with sugarcane cultivars and *S. officinarum* clones that flower in December (Tai, 1988). Populations from these crosses are used in molecular research.

**Serge Edmê**, Research Geneticist, manages the Seedling Stage in the cultivar development program and conducts molecular research. His approaches rely on the ability of microsatellite (SSR) and amplified fragment length polymorphism (AFLP) markers to elucidate the genetic control of yield potential and help generate a PCR-based map of the sugarcane genome. The genome and QTL mapping populations were derived from three interspecific crosses made by Tai that included *S. officinarum* and *S. spontaneum* clones, and cultivars. Genome size in these hybrid populations ranged from 1474-4298 Mbp (Edmê et al., 2004), which is about 1.5 times that of corn (*Zea mays*) and 10 times that of rice (*Oryza sativa*). Use of single-dose markers, which have been used for mapping polyploids, is also being explored. The candidate gene approach, by way of the cDNA-AFLP technique, is used for identification of genes governing tolerance to cold, drought, and flood/high water table, which are three of the main environmental stresses sugarcane is exposed to in Florida. A review of the Canal Point sugarcane breeding program spanning a 33-year period (1968-2000) revealed that 69% of the total gain in sugar yield was attributed to breeding (Edmê et al., 2005).

**Barry Glaz**, Research Agronomist, manages Stage IV of the cultivar selection program and conducts agronomic research to identify and develop crop-production and genetic strategies that improve the sustainability of sugarcane in the Florida Everglades. Exposure to a summer water-table depth of less than 15 cm compared with 38 cm resulted in no losses for some cultivars and up to 25% yield loss for one cultivar (Glaz et al., 2002). Water-table depths from 16 to 50 cm, substantially affected sugar yields of a genotype with no constitutive stalk aerenchyma. Yields of a second genotype with constitutive stalk aerenchyma were not affected by periodic floods or water-table depth (Glaz et al., 2004a). Flooding and water-table depth generally did not affect sugarcane CO₂ exchange rates, except for sporadic enhancement by a 16 cm water-table depth with periodic flooding (Glaz et al., 2004b).

**Jack Comstock**, Research Plant Pathologist, has emphasized screening sugarcane clones for resistance to ratoon stunt, leaf scald, smut, rust, eye spot, and mosaic to assist in developing high yielding CP-cultivars with adequate resistance. He has evaluated the incidence of ratoon stunt in grower fields and evaluated the importance of genetic resistance on its spread (Comstock et al., 1996; Comstock et al. 1997). He has developed and refined pathogen detection and screening techniques and detected and reported new diseases (or pathogenic races) in Florida: rust races, dry top rot, sugarcane yellow leaf virus (SCYLV), sugarcane bacilliform virus, and purple spot. The effects of ratoon stunt, leaf scald, yellow leaf, rust, and bacilliform virus on yield were determined. He has determined the presence of SCYLV in grower fields and the cultivar development program. Comstock has characterized several populations for their reaction to rust, SCYLV, and ratoon stunt and in cooperation with Edmê and others is developing molecular markers associated with resistance.

**Dolen Morris**, Research Soil Scientist, studies microbial processes of soil subsidence in high organic matter soils. Several methods were compared for their ability to provide rapid and accurate measurements of organic matter degradation. A method that uses radio-
carbon isotopes provided the best indicator of organic matter losses due to microbial activity in Everglades' organic soils (Morris et al., 2004a). A water-table depth of 15 cm for 2 weeks following a 1-week flood resulted in oxidation potentials that were similar to those measured during flood periods (Morris et al., 2004b). Tillage to 38 cm soil depth resulted in an average of 1.7 times more potential for soil loss compared with no tillage (Morris et al., 2004c). Some sugarcane cultivars had greater soluble carbohydrates in the root zone than others, and there were greater soluble carbohydrates around the roots at higher water-table depths, suggesting that sugarcane's adaptation to high water table involves efficiency of carbohydrate storage by the plant. Sugarcane tolerance to high water tables also included increased root mass and length and reduced root diameter near the soil surface (Morris and Tai, 2004 and Morris et al., 2004d).

Robert Gilbert, Agronomist at the University of Florida IFAS, Everglades Education and Research Center, Belle Glade, manages Stage III of the cultivar development program, the first replicated off-station testing. Gilbert conducts research on agronomic evaluation of commercial CP cultivars and transgenic CP lines. Gilbert and associates have determined the year effect (Gilbert et al., 2004a) and yield curves of the major commercial cultivars and made harvest recommendations to growers (Gilbert et al., 2004b). Cultivar CP 89-2143 was found to have superior sucrose content throughout the 5-month harvest season. Disease resistance, yield, and agronomic characteristics of transgenic sugarcane clones with inserts of the sugarcane mosaic virus coat protein gene were evaluated and a wide amount of somaclonal variation (9-fold difference in sucrose yield) among the clones was found due to either the tissue culture or transformation process. The large variability in yield characteristics and disease resistance encountered demonstrates the necessity of thorough field evaluation of transgenic sugarcane.

Conclusion

The USDA-ARS Sugarcane Field Station has contributed to the U. S. mainland sugarcane industry through production of true seed for the cultivar development programs in Florida, Louisiana, and Texas, and broadening of the genetic base of the current sugarcane cultivars using germplasm enhancement. Research of current and past scientists has contributed to an increased knowledge in sugarcane genetics, breeding, pathology, agronomy, and oxidation of the organic soils of Florida. In the future, Canal Point scientists hope to develop the use of marker-assisted selection in Florida to improve efficiency in the cultivar development program.

References


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**Table 1. USDA-ARS Sugarcane Field Station CP-Variety Development Program**

* Checks in Stages III and IV: CP 72-2086 (all locations), CP 78-1628 (sand soils), and CP 89-2143 (organic soils)