

OVERVIEW OF SUGARCANE BREEDING IN MAINLAND CHINA

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Abstract

THIS PAPER briefly reviews the history of sugarcane breeding in mainland China, major sugarcane research institutes in different provinces, and the development and adoption of new varieties in the past 10 years. It also highlights important benefits and progress in introducing sugarcane varieties from overseas and Taiwan, China. Progress in utilising basic germplasm for sugarcane improvement in mainland China is also briefly reviewed. Challenges facing sugarcane breeding in China and potential ways to address these are proposed.

Introduction

China is currently the 3rd largest sugarcane producing country in the world, following Brazil and India. Sugarcane is mainly grown in south-western China. In the 2007–08 season, 1.47 million hectares of sugarcane was grown in China and produced 13.19 million tonnes of sugar.

Improvement of sugarcane varieties has played a critical role in the Chinese sugarcane industry. The central and local governments have therefore given a high priority to the program of sugarcane breeding, and sugarcane improvement through breeding has made considerable progress in recent years.

History of cane breeding in mainland China

Chinese people have cultivated sugarcane for more than 2000 years. In the early days, (before 1930) of sugar production in mainland China, the principal varieties were Bamboo Cane and Lu Cane, which were *Saccharum sinense Roxb* (Chen *et al.*, 2003).

From 1932 to 1934, POJ2725, POJ2878 and POJ2883 were introduced from the Philippines, and Badila from Australia, but only POJ2878 and POJ2725 became major varieties for sugar production. F134 and Co419 (originally from India) were introduced to the mainland from Taiwan in 1947. F134 became the most popular variety in the sugarcane growing areas in mainland China until early 1980 (Peng *et al.*, 1990).

In 1953, a sugarcane breeding station was established in Yachen Sanya (formerly known as Yaxian county), Hainan Island. It is located in a tropical region (18°27'N) and sugarcane can flower in the field (Figure 1). Sugarcane seeds from this station were sent to sugarcane research institutes in different provinces (Table 1). This station can make 1200 crosses from 1600 flowers every year. Besides this station, Ruili hybrid station can provide about 100 crosses. The number of seedlings is

about 0.8 million over the country each year.



Fig. 1—(a) Parental plots in the sugarcane breeding station in Yachen, Sanya Hainan province; (b) Crossing house at the same sugarcane breeding station.

Table 1—The main sugarcane research institutes in different provinces in mainland China

Institute Name	Location	Abbreviated Chinese name and prefix of varieties selected at each location
Guangzhou Sugarcane Industry Research Institute (GSIRI)	Guangzhou, Guangdong	YueTang – YT YueGan – YG
Sugarcane Breeding Station, GSIRI	Yacheng, Hainan	YaCheng – YC
Guangxi Sugarcane Research Institute, Guangxi Academy of Agricultural Science (GAAS)	Nanning, Guangxi	GuiTang – GT
Sugarcane Synthetic Research Institute, Fujian Agriculture and Forestry University (FAFU)	Fuzhou, Fujian	Funong – FN
Sugarcane Research Institute, Fujian Academy of Agricultural Science (FAAS)	Zhangzhou, Fujian	Mintang – MT
Sugarcane Research Institute, Yunnan Academy of Agricultural Science (YAAS)	Kaiyun, Yunnan and Ruilli, Yunnan	Yunzhe – YZ YunRui – YR
Sugarcane Research Institute	Gangzhou, Jiangxi	Gangzhe – GZ
Sugarcane Industry Research Institute	Zhizong, Sichuan	Chuantang – CT
Economic Crop Research Institute, Guangdong Academy of Agricultural Science (GAAS)	Guangdong, Guangzhou	Yuenong – YN

Since the 1950s to 1999, more than 100 sugarcane varieties have been bred and released for commercial sugarcane production in mainland China. Of these GT11 (CP49-50 × Co419), YT57-423 (F108 × F134), YT63-237 (Co419 × CP33-310) and MT70-611 (CP49-50 × F134) have become dominant varieties for a period in different provinces (Lin *et al.*, 2004; Tan and He, 2004).

From 1999 to 2009, 42 new sugarcane varieties have been released for commercial sugarcane production (Table 2).

Table 2—New varieties released in recent 10 years and their parents.

Variety name	Female parent	Male parent	Identified by	Released year
GT91-116 (GT19)	ROC1	YC85-55	National	2005
GT93-103 (GT23)	ROC1	YC71-374	National	2005
GT94-116 (GT24)	GT71-5	YC84-153	National	2005
GT96-44 (GT25)	CP72-1210	YC71-374	National	2005
GT96-211 (GT26)	Pindar	GT11	National	2007
GT86-267 (GT16)	YT59-65	Ya72-399	National	1999
GT84-332 (GT15)	HN56-12	Neijian59-782	National	1999
GT89-5 (GT17)	GT11	YC62-40	National	1999
GT94-119 (GT21)	GZ75-65	YC71-374	National	2005
GT90-95 (GT18)	CP65-357	F172	Guangxi	2001
YT89-240 (YT48)	CP72-1210	GT11	National	2005
YT91-976 (YT49)	YN73-204	CP67-412	National	2005
YT91-1102 (YT51)	YN73-204	YT84-3	National	2007
YT93-159	YN73-204	CP72-1210	Guangdong	2001
YT85-177	YT57-423	CP57-614+CP72-1312	National	1999
YT96-835 (YT49)	Co419	ROC10	National	2007
YT96-86 (YT50)	YT85-177	Zang74-141	National	2007
FN91-3623	CP72-1210	GT11	National	2002
FN91-4621	CP72-1210	Zang74-141	National	2002
FN91-4710	CP72-1210	Ke5	Fujian	2004
FN94-0403	CP72-1210	MT69-263	National	2005
FN98-1103	Cp72-1210	Zang74-141	National	2009
FN95-1702	CP72-1210	YN73-204	National	2005
FN83-36	CP49-50	FN57-18	National	1999
FN81-745	YT59-65	CP36-105	National	1999
MT88-103	Co1001	YC82-96	National	1999
MT92-649	ROC1	Co1001	National	2005
MT86-2121	Q641	CP49-50	National	2005
MT92-505	Co1001	CP73-1547	national	2007
MT99-596	Co1001	YC73-226	National	2009
YZ85-151	Gang64-137	Chuang57-416	National	1999
YZ92-19	Gang64-137	CP67-412	National	2005
YZ89-351	YC82-96	GT11	National	2005
YZ94-375	CP72-1210	YC73-512	National	2007
YZ99-596	Co419	YC85-881	National	2009

* Variety identified by National means that the variety can be planted in main production provinces. Identified by one province means can only be grown in this province; before extending in other provinces, further testing may need to be done in those provinces.

Cane production and cane yield and quality have been improved very quickly in mainland China in the past 50 years. Cane production in mainland China has risen from 12.4 Mt in 1961 to over 97.5 Mt in 2008, while the harvested area has increased from less than 0.3 Mha to more than 1.5 Mha (Figure 2). Over the same period, cane yield has increased by about 40%, from under 50 t/ha to over 70 t/ha, representing an increase of 40% or an average 0.43 t/ha/year over 47 years. The average sucrose content, over this same period, has increased from under 13% to more than 14.5%,

with some varieties now providing an average over 16% (from October to April) (Figure 3 and Table 3). Success in the improvement of sucrose content is attributed at least partly to the use of introduced varieties with high sucrose, such as CP and ROC varieties, as parents.

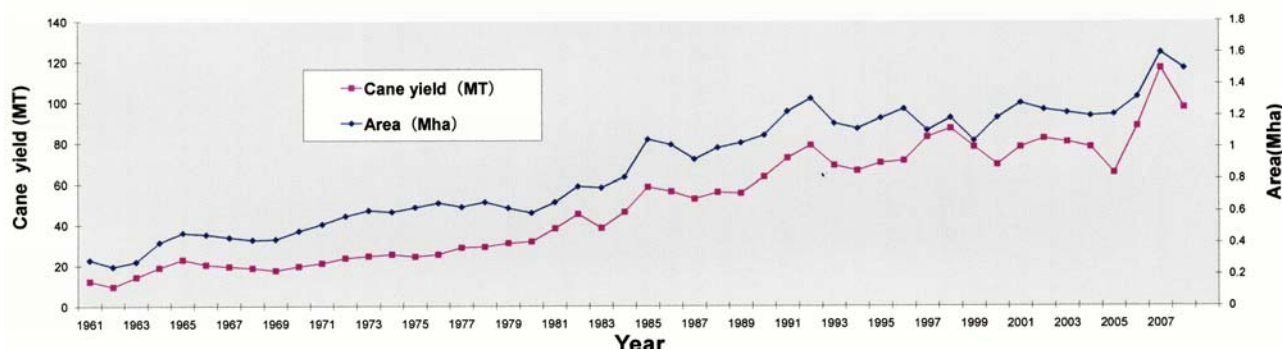


Fig. 2—Cane yield and area in mainland China 1961–2008.

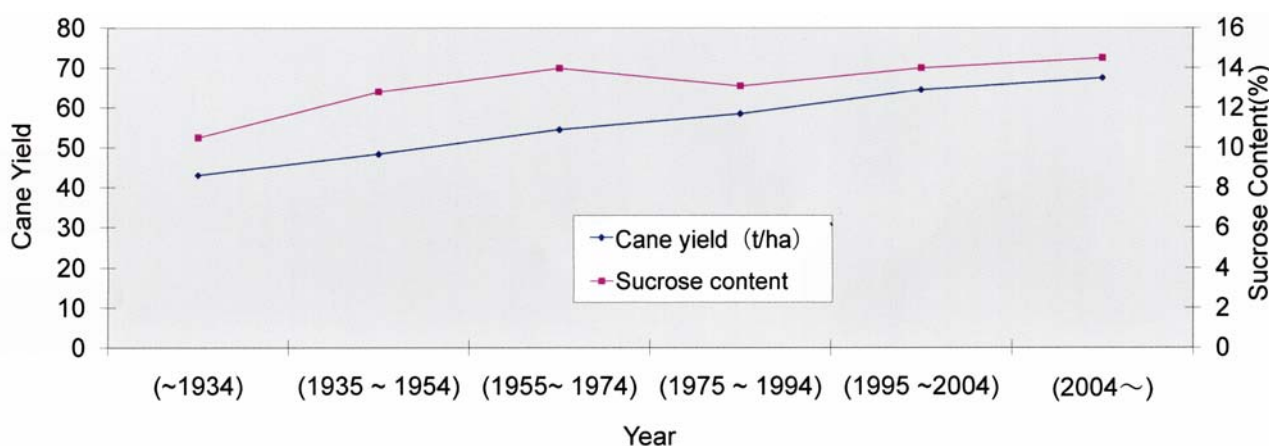


Fig. 3—Cane yield and sucrose content of sugar in mainland China.

Table 3—Cane yield and sucrose content of new varieties in the sixth series of national evaluation trials.

Varieties	Cane (t/ha)	Mean sucrose content (%)	
		Means of February	Means of November–March
RB76-5418	123.92	15.33	14.14
FN02-3924	108.73	17.08	16.28
FN99-20169	124.96	16.18	15.48
GN99-591	117.05	15.87	15.38
GT98-296	116.15	16.50	14.84
GY6	128.23	15.29	14.56
MT95-261	122.57	15.57	14.26
MT96-6016	124.36	15.76	15.1
YT16	137.99	15.28	14.6
YT18	110.53	16.78	15.92
YZ99-91	108.62	16.53	15.5
CK1 (ROC16)	108.67	15.44	14.76
CK2 (ROC22)	116.21	15.60	14.44

Sugarcane varieties introduced and used in mainland China

A large number of overseas sugarcane varieties have been introduced into mainland China since 1978, such as the CP series of USA, Q series of Australia, PR series of Puerto Rico, RB series

of Brazil and ROC series of Taiwan, China. After quarantine, most of them have been used as parental clones in the breeding program.

The CP and ROC series (Wu *et al.*, 2008), in particular, CP72-1210, CP84-1148, ROC1 and ROC10, were used most frequently.

Some introduced varieties were suitable for commercial production in some cane growing areas and adopted directly as varieties. After assessment trials, such clones have been released as commercial varieties.

The most important of these have been ROC10, ROC16 and ROC22 bred by Taiwan Sugarcane Research Institute in China, and introduced to mainland China in 1980–2000.

The planting area of these three clones has expanded continuously due to their high cane yield, high sucrose content and adaptation to a range of environmental conditions.

In the 2006–2007 season, these three clones accounted for 70 percent of the total planting area of mainland China.

Basic hybridisation program in mainland China

China is rich in sugarcane germplasm resources. Since the 1980s, Chinese sugarcane breeders have collected a large number of wild cane resources from different provinces and maintained most of these in the National Sugarcane Germplasm Nursery, Kaiyuan City, Yunnan province (Table 4).

Among them, *S. spontaneum* and *E. arundinaceus* are more prominent than other wild species.

Table 4—Genetic resources maintained in National Sugarcane Germplasm Nursery, Kaiyuan, Yunnan

Genus	Species	Number
<i>Saccharum</i>	<i>S. officinarum</i>	36
	<i>S. barberi</i>	8
	<i>S. sinense</i>	21
	<i>S. robustum</i>	6
	<i>S. spontaneum</i>	663
	<i>Landrace</i>	69
	<i>Commercial varieties</i>	1158
<i>Erianthus</i>	<i>E. Arundinaceus</i>	153
	<i>E. fulvus</i>	4
	<i>E. rockii</i>	9
<i>Narenga</i>	<i>N. porphyrocoma</i>	13
	<i>N. fallax</i>	2
<i>Miscanthus</i>	<i>M. floridulus</i>	10
	<i>M. sinensis</i>	3
<i>Imperata</i>	<i>I. cylindrica</i>	2
Total		2163

As soon as the Sugarcane Breeding program was set up on Hainan Island, in 1953, Chinese sugarcane breeders began working on a basic hybridisation program by crossing the local *S. spontaneum* with *Badila* (*S. officinarum*).

This effort produced two high performing F1 hybrids; YC 58-43 and YC 58-47 (Deng *et al.*, 2004), which in turn have produced 5 and 9 commercial varieties, respectively (Figure 4).

In recent years, Chinese sugarcane breeders have used *E. arundinaceus* to cross with *S. officinarum* in order to introduce the characteristics of resistance to disease and vigour in *E. arundinaceus* into sugarcane. Some promising clones have been bred from the cross between *Erianthus* and *Saccharum* (Figure 5).

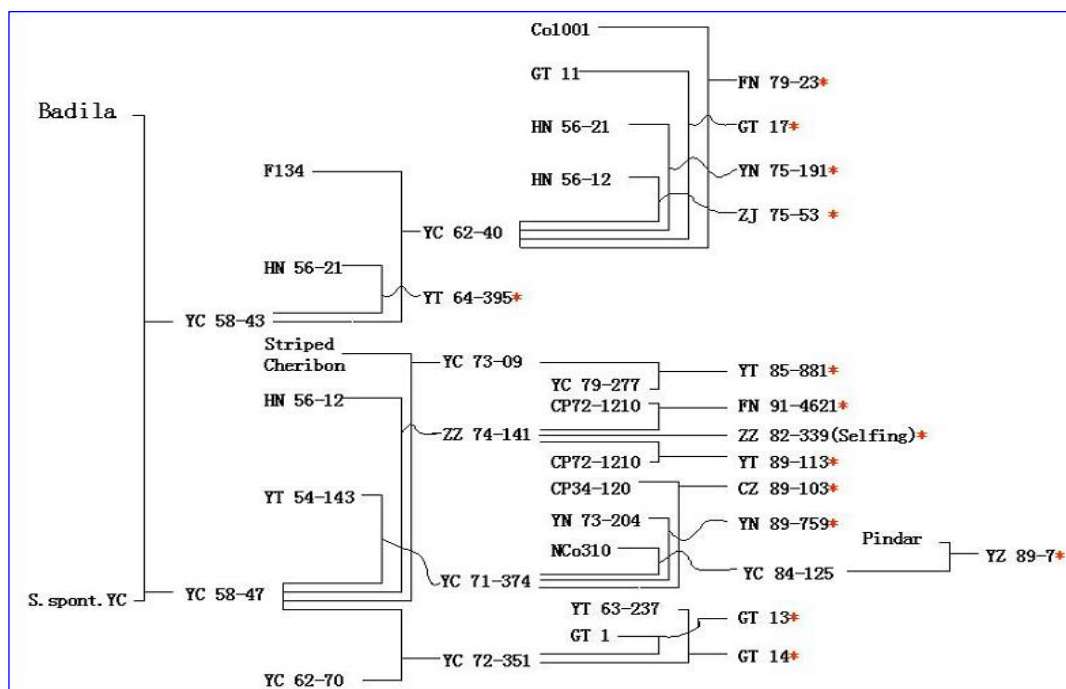


Fig. 4—Pedigrees of *S. spont. YC* Derivative Varieties (Note: Those marked with ‘*’ are released varieties).



Badila E. *Arundinaceus* Badila F1 E. *arun.* FI BC1 BC2
 Fig. 5—*Saccharum officinarum*, *Erianthus arundinaceus* and their hybrids.

Selection program in mainland China

The selection programs conducted in China are almost the same in all research institutes in mainland China. Clones are first tested in an experiment station at an institute for 5–6 years.

This is followed by testing at multiple sites outside the original institute for 4–5 years. An example of such a program, conducted in Fujian province, is shown in Table 5.

In addition to selection schemes operated by each individual institute, in 1996, China began a new project to evaluate sugarcane varieties in a nationally coordinated series of trials.

The project was named the National Sugarcane Variety Cooperative Regional Test (NSVCRT), and was coordinated by Fujian Agriculture and Forestry University and supported by Crop Variety Examination and Approval Committee, Ministry of Agriculture in China.

Seven series of regional tests have been carried out and more than 110 varieties were assessed in the tests, of which 55 varieties have been approved and released.

Table 5—Sugarcane selection scheme in Sugarcane Synthetic Research Institute, Fujian Agriculture and Forestry University (FAFU).

Year and stage	Site	Population size	Experimental design and selection criteria
Y1 Single seedling	FAFU	200 crosses, 80 000 seedlings	Seedlings planted with 33 cm between plants and 100 cm between rows. Selection: vigour, stalk number, diameter, height and Brix
Y2 First clonal trial	FAFU	4000 – 5000 clones	Augmented design, 2.5 m long, 1.2 m row spacing, with commercial variety in every 30 rows. Selected in November. Plant cane only. Selection criteria are similar to Y1.
Y3 Second clonal trial	FAFU	300–500 clones	Augmented design, 3 row plots, 8 m long, 1.2 m row spacing, with commercial variety every 20 rows. Selection in plant cane. Visual screening for smut and mosaic resistance, juice analysis, estimating cane and sugar yield.
Y4 Preparation trial	FAFU	30–50 clones	RCB, 3-row plots, 3 replicates, 8 m long, 1.2 m row spacing. Selection in plant cane only, testing stalk numbers, diameter, height and yield, sucrose analysis, disease screening for smut and mosaic.
Y5-6 Comparative trial	FAFU	10–20 clones	5-row plots, 3 replicates, selection on 2 plant crops and one ratoon crop. Selection criteria same as in preparation trial.
Y7-9 Regional trial	8–12 sites	10–14 clones	5–6 row plots, 3–5 replications. Selection in 2 plant cane crops and one ratoon crop. Selection criteria same as in comparative trial.
Y9-11 Demonstration	8–12 sites	5–8 clones	10–20 row plot, unreplicated, 2 plant crops and one ratoon crop. Yield estimate and sucrose analysis
Y11-12 Approval	Approval	1–2 varieties	Approval by the National Sugarcane Variety Examination and Approval Committee for release

Issues in sugarcane breeding in mainland China

An issue of concern in China is that currently the planting areas of three ROC varieties accounted for 70% of the total sugarcane area in mainland China and exceeded 90% in Guangxi. The growing areas of new varieties bred in mainland China only accounted for 30%. Adaptability and yield stability of these newly bred varieties are commonly poorer than that of ROC series varieties. However, many of them have higher sucrose or higher TCH than the ROC series varieties.

It is considered greater progress will be made by increasing the scale of sugarcane breeding in China, which is limited by financial input by the Ministry of Agriculture and the Ministry of Finance of Chinese Government. Substantial financial support from the government for the long term should provide a golden chance for sugarcane improvement.

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REGARD SUR L'AMÉLIORATION GÉNÉTIQUE DE LA CANNE À SUCRE EN CHINE CONTINENTALE

Par

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**MOTS CLÉS: Amélioration Génétique,
Production du Sucre, Canne à Sucre, Chine.**

Résumé

CET ARTICLE passe en revue brièvement l'histoire de l'hybridation de la canne à sucre en Chine continentale, les principales institutions de recherche dans les différentes provinces, le développement ainsi que l'adoption des nouvelles variétés de canne à sucre durant ces 10 dernières années. Il met en exergue les avantages et les progrès accomplis en introduisant des variétés de canne à sucre de l'étranger et de Taiwan, Chine. Le progrès accompli avec le matériel génétique de base est aussi brièvement examiné. Les défis auxquels l'amélioration génétique de la canne à sucre est confrontée, et les moyens potentiels de les aborder sont proposés.

VISIÓN GENERAL SOBRE MEJORAMIENTO DE CAÑA EN CHINA CONTINENTAL

Por

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**PALABRAS CLAVES: Mejoramiento Genético, Producción de Azúcar,
Caña de azúcar en China.**

Resumen

ESTE artículo revisa rápidamente la historia del mejoramiento de caña en China continental, los principales institutos de investigación en las diferentes provincias y el desarrollo y adopción de Variedades en los últimos 10 años. También se destaca los importantes beneficios y progresos al introducir variedades desde otros países y Taiwan. Los progresos logrados al usar el germoplasma básico de China son también brevemente revisados. Futuros retos y caminos potenciales para trabajar en mejoramiento de caña en China también son analizados.