A HISTORICAL ACCOUNT OF PROGRESS MADE IN CASSAVA VARIETAL IMPROVEMENT IN CHINA

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ABSTRACT

Cassava varietal improvement in China has historically been conducted by collecting and evaluating local varieties, by introducing and testing of cassava germplasm from abroad, followed by the establishment of a cassava cross-breeding program. Considerable progresses has been made in the following areas:

a) Collection and evaluation of the local varieties, SC205 and SC201 and their extension over a wide range of growing conditions, so as to expand their growing range and planting area
b) Setting up a cassava germplasm bank to conduct cross-breeding of cassava
c) Establishing a nation-wide cassava regional trial network, which forms an integral part of the breeding program, in order to develop improved varieties, test and demonstrate as well as extent new higher-yielding cassava varieties
d) Selection of many promising clones
e) Release of some improved varieties.

The cassava breeding program in China was started in the 1960s when several good local varieties were collected, evaluated and released. It was shown that cassava can be planted in the region south of Qinling Huaihe and the Yangtse river basin, in those areas having a mean annual temperature above 18^{o}C and a frost-free period of more than 8 months of the year. Since the 1970s marked progress has been made by adopting an integrated system of germplasm introduction and breeding, with the major objectives of high yield, high starch content and resistance to wind. A nation-wide cassava trial network was established to form part of this integrated breeding system to produce improved varieties, test, select and demonstrate as well as extend these new varieties. Some of these improved varieties, such as SC6068, SC124, SC8002, SC8013, Nanzhi-188, GR891 and GR911, have been released. They are now grown in an area of about 50,000 ha and outyield the local clones by about 20%, increasing farmers' income by more than 3.4 million yuan.

In recent years the cassava breeding program in China has been capable of annually producing more than 3000 hybrid seeds from 80-100 cross combinations, as well as evaluating 2000-3000 hybrid seeds introduced from CIAT/Colombia and the Thai-CIAT program. More than 500 promising clones have been selected, of which OMR33-10-4, ZM8641 and ZM9057 will be further tested and examined for release. In addition, many promising clones, such as CMR34-11-4, OMR36-63-6, OMR37-103-1, OMR37-14-9, CMR38-163-4, SM2323-6 and ZM9244, which are characterized by high yield and high dry matter content, can be used in the future in the cassava varietal improvement program in China.

INTRODUCTION

Cassava is the fifth most important crop in southern China, following rice, sweetpotato, sugarcane and maize. It is used mainly as animal feed and for starch manufacturing which both play an important role in the upland agricultural economy. Cassava has been cultivated in China for over 180 years. Presently the production area is

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about 400,000 ha. There are only two major local varieties: SC205 and SC201. However, good progress has been made in developing other high-yield and high-starch cassava varieties, and several improved varieties have recently been released in southern China.

HISTORICAL REVIEW

It is still unknown when cassava was first introduced into China, but most reports indicate that cassava was first introduced from southeast Asia into China in about 1820. Up to 1840, cassava was grown mainly by slash-and-burn cultivation or as a backyard crop. After 1851, cassava was widely grown in the eastern areas of Guangdong province and cassava-based products were sold at the local markets. Cassava stems were then taken to Hainan island and Guangxi province and spread throughout most regions of south China. Now, cassava has become the fifth most important crop, used mainly as animal feed and as raw material for industrial processing.

The earliest research on cassava cultivation was carried out at the Guangdong Agriculture and Sericulture Experimental Farm, where local cassava varieties were collected and evaluated, for two crop cycles, and roots analyzed for their nutritive value during 1914 to 1919. From 1940 to 1944, the collection and evaluation of local cassava varieties was continued by Li You Kai in Guangxi province, where HCN content and its distribution in cassava plants was determined (Li You Kai, 1943). The book entitled "Research on Cassava Toxins" was published. However, a systematic and intensive investigation about cassava cultivation was first conducted in 1958 with the objective of stimulating China's cassava production. Twelf local varieties were collected and some good ones were recommended and released, such as "Yinshanhongpi" and "Nanyangqingpi". Cassava breeding and agronomy research was later conducted by Li You Kai, Liang Guang Chang and Wun Jian at other research institutes in Guangdong, Guangxi and Hainan provinces. Based on trials conducted in 1958-1964, Wun Jian *et al.* (1964) pointed out that in China cassava could be planted in the Yangtze river basin in those areas where the mean annual temperature was above 18^{o}C and where there was a frost-free period of more than eight months of the year. The suitable area was about 1,200,000 km^2 (Liang Guang Chang, 1982). Also, some local varieties with high yield and wide adaptability, such as SC205 and SC201, were evaluated and released.

After 1980, several research institutes, such as CATAS, UCRI and GSCRI, established their cassava breeding programs. With good international cooperation, cassava breeding and agronomy research were systematically conducted, and good progress has been made.

PRESENT SITUATION AND PROGRESS

Cassava varietal improvement in China has historically been conducted by introducing and testing of cassava germplasm, collecting and evaluating local varieties, followed by cassava cross-breeding.

1. Collection and introduction of cassava germplasm and establishment of a cassava germplasm bank for cross-breeding

In China the number of local cassava varieties was minimal before 1996. Many cassava varieties that were planted at a large scale had been introduced from abroad. Some local clonal progenies, which had evolved through natural or artifical selection from natural crosses, also existed but these were quite limited and scattered, with less than 20 accessions in total. Therefore, cassava germplasm in China can mainly be attributed to direct introductions or to cross-breeding of local with introduced germplasm. Over the years, China has introduced more than 30 accessions of cassava from CIAT/Colombia or from the Thai-CIAT program (**Table 1**) and a number of cross parents from CIAT's breeding materials have also been evaluated and are now being conserved. A cassava germplasm bank has been set up at CATAS, which presently has more than 120 accessions; their major characteristics have been evaluated, and these are being catalogued and documented. This fills in the gaps in the fields of cassava science and technology in China, forms the foundation for cassava breeding, and is a source of genetic diversity for selecting cross parents. Presently, the cassava programs in China are capable of annually producing more than 3000 hybrid seeds from 80-100 cross combinations, as well as evaluating 2000-3000 hybrid seeds introduced from CIAT/Colombia and the Thai-CIAT program. These are very important to cassava varietal improvement in China.

Table 1. Cassava germplasm introduced to CATAS from 1982 to 1999.

Accessions	Year of introduction	Origins	Utilization
Rayong1	1982	CIAT	Cross parent
MCol 22	1982	CIAT	up parent
CM1585-13	1982	CIAT	up parent
MCol 1468	1982	CIAT	up parent
CM1372-15	1986	CIAT	up parent
CM2399-4	1986	CIAT	up parent
CM1568-2	1986	CIAT	up parent
CM26-07-15	1986	CIAT	up parent
CM4054-40	1986	CIAT	up parent
CM7530-3	1986	CIAT	up parent
MCUB32	1997	CIAT	Propagation and testing
MBRA900	1997	CIAT	Propagation and testing
SG104-264	1997	CIAT	Propagation and testing
CM5253-1	1997	CIAT	Propagation and testing
Rayong 5	1999	Rayong/Thailand	Propagation and testing
Rayong 60	1999	Rayong/Thailand	Propagation and testing
Rayong 72	1999	Rayong/Thailand	Propagation and testing
KU 50	1999	Rayong/Thailand	Propagation and testing

2. Establishing a national cassava trial network, forming an integrated breeding system of improved varieties, testing and demonstration as well as extension of cassava

In China, a national cassava network has been set up, of which CATAS and GSCRI are mainly in charge of cassava sciences and technologies research work, such as cassava breeding, agronomic research and extension. Some experiment stations in Guangdong (Zhanzhang and Zhaoqing districts), Guangxi (Nanning and Liuzhou districts), Hainan (Beisha, Tunchang and Dingan counties) and Yunnan (Honghe district) have been conducting regional trials and production tests. Over the years, more than 100 promising clones have been evaluated in regional trials and about 15 good clones have been tested in the network. Those found to have high yield and wide adaptability, such as OMR33-10-4, ZM9057, ZM8641, ZM8639 and ZM9242 have been selected for propagation and will be released as new varieties when they are approved. Now, CATAS has become the center of the national cassava research program and a national cassava trial network has been established, thus forming an integrated breeding system of varietal improvement, evaluation, demonstration and dissemination of new cassava varieties in China.

3. Multiplication and dissemination of improved varieties

Several improved varieties have been selected and released. Based on previous varietal improvement work, the first improved variety, namely SC6068, with high starch and low HCN content was bred and released for human food and animal feed by CATAS in 1980. This variety was widely distributed in southern China, but with a limited area of about 6000 ha in total (**Table 2**), mainly planted on Guangdong, Hainan and Fujian provinces. It is an early maturing variety, which can be harvested in 7-8 months after planting. However, its fresh root yield is about 15-20 t/ha, while its root dry matter and starch contents reaches 40 and 30%, respectively. In 1992, another new variety, SC124, with high yield and resistance to cold was recommended by CATAS. This variety has been released in most cassava planting areas in south China, mainly in Guangxi and Yunnan provinces, with a total extension area of about 30,000 ha (**Table 2**). In 1994, two new improved varieties, SC8002 and SC8013 from CATAS, were released in south China. Of these, SC8002 was mainly released in Guangdong province with an extension area of about 6000 ha, while SC8013 was released in the coastal regions of Hainan, Guangdong and Guangxi provinces with an extension area of about 5000 ha. However, SC8013 has become a major variety in those regions affected by typhoons, due to its good wind resistance.

In 1998, two new varieties, named GR891 and GR911, selected from CIAT's breeding materials, were selected and released by GSCRI. They were mainly released in Beihai, Nanning and Liuzhou districts of Guangxi province with a total area of 100 ha each until now. However, they will become important varieties for commercial cassava production in Guangxi, due to their good performance in terms of high yield and high starch content.

In addition, the South China Institute of Botany in Guangzhou recommended two varieties, named Nanzhi-188 and Nanzhi-199, selected from CIAT germplasm introduced as tissue culture in 1984.

Table 2. Improved cassava varieties released in China, their yield characteristics and the area grown in 1999.

Varieties	Fresh root yield (t/ha)	Dry root yield (t/ha)	Root dry matter content (%)	Area grown (ha)
SC6068	20.6	8.3	40.5	6,000
SC124	32.5	19.2	37.6	30,000
SC8002	28.7	10.5	36.7	6,000
SC8013	29.5	11.6	39.2	5,000
Nanzhi-188	22.5	8.7	38.5	200
GR891	23.2	9.1	39.2	100
GR911	28.9	10.3	35.5	100
SC205	28.6	10.6	37.0	-

Promising clones in the pipeline for further testing

Over the years, 2500 cross parents were introduced and evaluated in China, in the form of 120,000 true seeds, of which 70,000 seeds from CIAT/Colombia and 50,000 from the Thai-CIAT program. More than 40,000 F_1 seeddlings were obtained. After evaluation and step by step selection, many promising clones have been identified in addition to those improved varieties mentioned above (**Table 3**). Of these, OMR33-10-4, ZM9057 and ZM8641 have been evaluated on farmers' fields and may soon be approved for release (**Table 4**). They have been planted on a small scale in many locations.

Table 3. Yield characteristics of some promising clones.

Clones	Fresh root yield (t/ha)	Dry root yield (t/ha)	Root dry matter content (%)
ZM9036	31.3	12.4	39.5
ZM9242	31.1	11.5	37.1
ZM9244	32.1	11.7	36.6
ZM92157	29.4	10.1	34.5
OMR36-36-6	35.0	14.7	41.9
OMR36-63-6	25.8	11.1	43.2
OMR36-40-9	27.5	11.7	42.7
OMR36-40-12	30.8	12.1	39.4
CMR35-70-6	31.3	12.1	38.7
CMR35-70-1	28.7	12.4	43.1
OMR36-40-13	27.1	11.7	43.1

Table 4. Clones which are being considered for release in the near future in comparison with two check varieties[1)].

Clones	Fresh root yield (t/ha)	Dry root yield (t/ha)	Root dry matter content (%)
OMR33-10-4	31.4	12.3	39.3
ZM9057	30.9	11.8	38.2
ZM8641	28.3	10.9	38.4
SC205 (check)	24.07	9.2	37.4
SC201 (check)	21.50	7.8	36.1

[1)]Data are average values from eight Regional Trials.

DEVELOPMENT POTENTIAL AND STRATEGIES

Development Potential

Cassava is a very important food and animal feed crop. It can be planted in the southern part of China in those areas with a mean annual temperature above 18^{o}C and a frost-free period of more than eight months of the year. The suitable area is about 1.2 million km^2, including Guangdong, Guangxi and Hainan provinces, as well as the southern parts of Yunnan, Fujian, Jiangxi, Hunan and Sichuan provinces. Therefore, it is very important and necessary for cassava breeders to select new varieties that are suitable for these different regions. Although several improved varieties have been selected and released, they were found to be not all suitable for the various cassava production areas. In addition, their root dry matter content and starch content had not significantly increased. Thus, cassava varietal improvement needs to be continued in order to meet the requirements of intensive and commercial cultivation. Greater attention should be paid to cassava breeding programs, as there is indeed a very bright future for cassava cultivation in China.

Development Strategies

The following strategies have been formulated to enhance cassava varietal improvement and dissemination in China:

- The main objective of cassava varietal improvement in China remains the selection of new varieties which are characterized by high yield, high starch content, strong wind-resistance and early maturity.
- CATAS might be considered as the center of cassava varietal improvement in China, working together with other research institutes, production units and cooperating stations to form a national cassava network. All units have to be united together to conduct cassava research, so as to form an integrated breeding system for improving varieties, testing, demonstrating and disseminating new cassava varieties in China.
- A recommended management system would be the combination of "research institutes + companies + farmers" in order to speed up the dissemination and transfer of improved varieties and new technologies.

- Set up a cassava biotechnology laboratory to develop new breeding technologies to facilitate the breeding for early maturity and starch quality.
- Use as a guiding principle the need to combine cassava breeding with germplasm introductions.

This is a very important strategy for cassava varietal improvement in China. Cross-breeding is the best way to achieve yield improvements in China, while germplasm introduction is the best way to widen the genetic base needed to make progress in cassava breeding. It is very difficult for breeders to make any breakthrough by using only the very limited native genetic resources. Therefore, a combination of native germplasm with those coming from abroad, so as to produce better cross parents, should be most successful. From **Tables 5** and **6**, we can see that many elite clones of CATAS were selected from the hybrids between native materials with those introduced from CIAT/Colombia or the Thai-CIAT program. The materials from abroad have shown over the years a high selection efficiency and a very high root dry matter content. Those from the Thai-CIAT program have shown the best performance, both in terms of root yield and root dry matter content.

Table 5. Average yield characteristics of new clones according to their origin in comparison with those of SC205.

Origin of germplasm	No. of clones	Fresh root yield (t/ha)	Dry root yield (t/ha)	Root dry matter content (%)
CATAS	394	22.3	7.7	34.6
CIAT/Colombia	55	18.1	6.2	34.2
Thai-CIAT	165	20.5	7.7	38.7
SC205 (check)		20.5	7.3	35.7

Table 6. Results of the Preliminary Yield Trials (PYT) and Advanced Yield Trials (AYT) conducted at CATAS in 1998.

Trail	Origin/ name of clones	No. of tested clones	No. of selections	Fresh root yield (t/ha)	Dry root yield (t/ha)	Root dry matter content (%)	Harvest index
PYT	CATAS	33	18	25.4	9.8	38.5	0.65
	Thai-CIAT	28	15	25.5	10.8	42.5	0.63
	CIAT/Colombia	8	4	25.9	10.7	41.3	0.57
	SC205			22.0	8.6	39.1	
AYT	CATAS	28	17	28.0	10.4	37.0	
	Thai-CIAT	16	8	24.4	9.8	40.7	
	SC205			22.1	8.6	39.2	

Strengthen international cooperation

The exchange of cassava germplasm and experiences with other cassava-growing countries, through active international cooperation and training courses, will further strengthen the breeding effort and enhance the development of new varieties and technologies.

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