CHINESE SORGHUM GENETIC RESOURCES[1]

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Lu Qingshan *(Sorghum Research Institute, Liaoning Academy of Agricultural Sciences, Shenyang, China 110161) and* **Jeffery A. Dahlberg** *(Research Director, National Grain Sorghum Producers, P.O. Box 5307, Lubbock, TX 79424).* CHINESE SORGHUM GENETIC RESOURCES. *Economic Botany 55(3):401–425, 2001. In its long period of evolution and cultivation, Chinese sorghums have formed a rich genetic base in which unique characteristics have evolved. These resources and their characteristics have been identified and partially utilized within China's breeding programs. Records and data have been compiled and updated into the* Annuals of Chinese Sorghum Varieties, Catalogue of Chinese Sorghum Variety Resources. *These evaluations and recorded information provide a solid base from which further studies and utilization of this important source of genetic diversity can take place in the future.*

Key Words: sorghum; China; germplasm; evaluation; history.

Sorghum [*Sorghum bicolor* (L.) Moench], which is widely planted throughout the country, has had a long agricultural history in China. In the process of cultivation, a rich array of Chinese sorghum landraces formed because of different environmental and ecological conditions and through both natural and artificial selection.

The first historical writings on sorghum in China were found in the *Records of Natural Science* by Zhang, which was written sometime in the third century A.D. (see Zhang n.d.). It is unknown whether the 'Sichuan broomcorn millet' mentioned in Zhang's work is what we call sorghum today. It has been suggested that no definitive records of sorghum existed until the Yuan Dynasty. For example, Zhen Wang (1313) described the shape characteristics of sorghum: "Its stem is over 3.3 m tall with its ear as big as broom and its kernels as black as pitch." Li Shizhen (1548) of the Ming Dynasty, described sorghum in his *Compendium of Material Medica* as "Sichuan broomcorn millet is called sorghum today with its reed-like shape, its ear as big as broom, its kernel as big as pepper seed which is reddish black. The grains of sorghum, which are yellowish red, are solid. There are two kinds of grains: sticky ones that can be used as bait to brew wine and unsticky ones which can be used to make gruel or pudding." These scholars described not only characters of sorghum but also its types and uses (Li 1548; Wang 1313; Zhang n.d.).

Further descriptions of sorghum were written by scholars of the Qing Dynasty in the 17th century. They wrote that sorghum kernels: "have different colors: yellow, green, white and red"; "sorghum is drought resistant"; and, "Sichuan broomcorn millet has four ears on one stem." At the end of the 19th century, Yunsheng Guo (1896), a scholar of the Qing Dynasty wrote in his work entitled *Simple Book for Saving Famine* "sorghum with black kernels are wind and rain resistant, water and drought resistant as well"; "sorghum with white kernels have seeds that can be used as grains and stems that can be used to produce sugar"; "Sorghum with red kernels is alkali resistant, thus it can be planted on alkaline land"; and, "Kuai Sorghum, which is also named Qiyecao, grows only seven leaves and is 1.67 m tall." These descriptions about different types of sorghum indicate that farmers constantly created sorghum cultivating varieties through farmer selection in the field.

In the early 20th century, sorghum was one of the major cereals in China. Its planting area once accounted for 16–26% of the total area under cultivation. Sorghum was the third most important crop behind rice (*Oryza sativa* L., *Oryza glaberrima* Steud.) and wheat (*Triticum* sp.). It was cultivated in nearly all parts of the country, but was concentrated in a large region north to

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TABLE 1. DISTRIBUTION OF CHINESE SORGHUM GERM PLASM RESOURCES THROUGHOUT THE COUNTRY (QIAO 1992).

Province	No.	Province	No.	Province	No
Shanxi	1261	Shandong	1199	Henan	1068
Liaoning	842	Inner Mongolia	820	Hebei	830
Sichuan	695	Heilongjiang	615	Jilin	460
Shanxi	283	Hubei	277	Anhui	270
Jiangshu	252	Hunan	128	Yunnan	120
Ganshu	113	Beijing	110	Xinjiang	94
Other regions	1004				

the Yellow River. At the same time, different local varieties came into being; however, these valuable resources of sorghum varieties were scattered among farmer's fields and were not found in any systematic collection (Qiao and Zhenshan 1980a).

COLLECTION AND CONSERVATION EFFORTS SINCE THE 20TH CENTURY

Few agricultural science, research, and teaching units made collections, conserved, and did research on sorghum varietal resources. The former central farming experimental site in Jilin Province, the Gangu agricultural testing station, was the main research institute for sorghum. From the 1920s to the 1930s, the collection, evaluation, and study of varieties was carried out by Beijing, Ding County, Taigu, the Jinan and Kaifeng experimental station, and agricultural schools of Jinling University. For example, the farming experimental station of Hill Princess collected, recorded, registered, and conserved 228 sorghum varieties from northeast Manchuria in 1927. The central farming experimental station also did research on sorghum stem-borer resistance and blooming characteristics, and imported and planted some foreign germplasm. In 1940, the farm belonging to the Jinchaji border region collected and identified local varieties. Their results indicated that the multieared sorghums imported from Africa had high yield, good adaptability, relatively good drought resistance, and were popularized in the border region in 1942 (Qiao 1992).

With the establishment of the People's Republic of China, research work on sorghum began in earnest. In 1951, evaluation of selected local varieties was launched throughout the country. Scientists and research personnel collected sorghum varieties from different regions and identified excellent varieties that were adapted to local cultivating conditions. These germplasm sources were increased and released. Some examples of these varieties were Daluobang, Xiaohuangke of Liaoning, Hongbangzi of Jilin, Zhuyeqing of Hebei, sweet sorghum of Shandong, Luyiwaitou of Henan, Xiheliu of Anhui, Dahongpao of Jiangshu, Aizinuo of Hubei, and Jinghehong of Xinjiang (Qiao and Wang 1984).

In 1956, the first large scale collection of local varieties was carried out throughout the country. Sixteen thousand, eight hundred forty-two accessions were collected from the main production areas of sorghum. These included 6306 accessions from northeast Manchuria and 10 536 accessions from northern, northwest, and middle China. In 1978, short-term investigations and collection of sorghum germplasm were carried

TABLE 2. DISTRIBUTION OF IMPROVED BREEDING MATERIAL FROM VARIOUS PROVINCES (QIAO 1992).

Regions	Total no.	Improved varieties	A/B-lines	R-lines	Others
China	762	199	136	297	130
Heilongjiang	430	67	70	158	108
Inner Mongolia	88	8	50	30	0
Jilin	56	31	8	9	8
Liaoning	51	15	6	24	6
Hebei	46	3	8	27	8

TABLE 3. DISTRIBUTION OF THE REGISTERED PLANT GENETIC RESOURCES THROUGHOUT CHINA (QIAO 1992).

Record	Total	Local cv.	Improved total #1	A-lines	B-lines	R-lines	# of provinces
RVRCK	1048	962	86	46	11	18	23
CVRCK	6549	6334	215	69	36	74	27
CVRCKC	2817	2356	461	94	90	187	28
Total	10 414	9652	762	209	137	279	—

RVRCK—Records of Varietal Resources in Chinese Kaoliang.
CVRCK—Contents of Varietal Resources in Chinese Kaoliang.
CVRCKC—Contents of Varietal Resources in Chinese Kaoliang (continuation).

out in eight provinces: Hunan, Zhejiang, Jiangxi, Fujian, Yunnan, Guizhou, Guangdong, and Guangxi. Over 300 local sorghum entries were inventoried. From 1979 to 1984, another complementary collection of sorghum varietal resources was conducted throughout the country and over 2000 accessions were collected. In addition, some local varieties were gathered from crop breeding programs in Xizhang, Xinjiang Shennongjia of Hubei, Yangtz River, Three Gorges Region, and Hainan. By 1984, most local varieties of sorghum, that had been scattered amongst farmer's fields, had been collected in several scientific and research institutes. Except Qinghai, the other 30 provinces, municipalities, and autonomous regions within China had located and conserved several local varieties of sorghum. This conservation effort throughout the country not only effectively preserved these valuable germ-plasm resources, but also laid the foundation for the research and enhancement of sorghum genetic resources (Qiao and Wang 1984).

Based on germplasm conservation efforts, sorghum agricultural science and research units were developed to enhance, conserve, and utilize local varieties. In 1978, three provinces of the northeast began removing duplicates within the collections based on common names, started evaluation of germplasm based on major expression of agronomic traits, and identified characteristics that would be useful in breeding programs. From this, 384 sorghums were selected and the data published in *Records of Chinese Sorghum Varieties, Volume 1* (Qiao and Zhenshan 1980b). In 1981, another group of 664 representative sorghum varieties were selected from collections from 21 provinces representing major sorghum producing areas in China and *Records of Chinese Sorghum Varieties, Volume 2* (Qiao and Zhenshan 1983) was published. In 1983, research data accumulated over several years identified 7597 local sorghum varieties (with some improved varieties and strains) from 27 provinces and municipalities that had been collected, conserved, and identified before the end of 1981. This data was published in the *Directory of Chinese Sorghum Variety Resources* (Qiao 1984). From 1985 to 1990, another 2817 germ-plasm sources were collected to supplement the collection and this information was reported in the *Directory Continuation of Chinese Sorghum Variety Resource* (Qiao 1992). These 10 414 Chinese sorghum germ-plasm resources that were collected, evaluated, and conserved from 1956 to 1989, were then registered in the Gene Library of Natural Seed Crop Resources located in the Chinese Academy of Agricultural Sciences, Beijing (Qiao and Wang 1984).

These plant genetic resources include 9652 local varieties plus improved varieties and strains that originated from 28 provinces, municipal, and autonomous regions. These were further sorted according to use: 9895 sorghum accessions were classified as food types, 394 accessions were classified as varieties for fodder or crafts use, and 125 varieties were classified for use in sugar production (Qiao and Wang 1984).

Chinese sorghum varieties are used primarily in the north and northeast of the country (Table 1). Provinces that have over 1000 varieties include Shanxi, Shandong and Henan. The 726 breeding varieties (strains) that have been registered include 199 improved varieties and strains, 136 male sterile lines (A-lines) and their B-lines, 197 restorer lines (R-lines), and 130 other varieties. The distribution of these improved lines and the areas in which they were produced are given in Table 2. A breakdown of where material has been registered in China is

TABLE 4. SELECTED SOURCES OF TALL SORGHUMS FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Ht (cm)	Origin	Conservation unit
8852	Dahuangke	450	Suxian County Anhui	Suxian County Institute of Agricultural Sciences (SCIAS)
6935	White sorghum	447	Zaoyang Hubei	Hubei Academy of Agricultural Sciences (HAAS)
5596	sorghum	436	Huangxian County Shandong	Shandong Academy of Agricultural Sciences (SAAS)
641	Guandongqing	435	Leting Hebei	Tangshan Institute of Agricultural Sciences (TIAS)
6995	Tiezu sorghum	434	Dangyang Hubei	HAAS
10382	long broom-shaped sorghum	434	Xunyi Shanxi	Baoji Institute of Agricultural Sciences (BIAS)
577	White sorghum	430	Laiyang Shandong	SAAS
1684	Xiquebai	430	Xinglong Hebei	TIAS
7669	White sorghum	429	Yutian Hebei	TIAS
1042	Wolf tail	428	Yangqu Shanxi	Shanxi Academy of Agricultural Sciences (SxAAS)

presented in Table 3. The varieties come from 24, 27, and 28 provinces, municipalities, and autonomous regions, respectively.

Table 3 indicates that systematic collection within the country has increased the number of accessions within the collection and has covered many of the provinces within the main sorghum production areas. Conservation efforts in recent years have concentrated on improved varieties from these various regions. The *Directory of Chinese Sorghum Variety Resources* also includes records on several specialty sorghum, such as; steriles 'Zhang 2A', 'Yongnuo 2A', and 'Zhezhou A' (glutinous sorghums); sterile sweet sorghum 'Zhetian 1A'; the sterile tetraploid sorghum 'Tx622A' and its B-lines 'Tx622B'; and the tetraploid sorghum restorer lines '3B–15', '378R', and '623R' (Qiao 1984; Qiao and Wang 1984).

All sorghum genetic resources that have been collected are stored at the Chinese Agricultural Science Academy National Seed Bank (CASANSB) for long-term preservation. Samples are placed in sealed envelopes and stored at low temperatures. The purity of the conserved seeds is approximately 100%, with most seed samples containing less than 2% foreign matter, and germination of over 85%. Using these techniques, it is estimated that conservation of this germplasm can be as long as 30 years. Data bank management is handled by the computer management group within the CASANSB.

There are two ways that agricultural science academies from different provinces, municipalities and autonomous regions preserve local sorghum genetic resources. (1) Genetic resources of a given province (municipality or autonomous region) are periodically regenerated and conserved by local or regional agricultural science research institutes (ASRI). These tend to represent different ecological conditions within the province. At the same time, provincial agricultural science academies receive and complete a complete backup of these plant genetic resources. (2) Sorghum accessions from regional or provinces are consolidated and maintained by their respective agricultural science academies. For example, germplasm collected from Shandong and Henan are conserved by their regional agricultural science academy, accessions from Anhui are conserved by the Research Institute of Agricultural Science of Shuxian County, Anhui, and accessions from Jiangshu are conserved in the Research Institute of Agricultural Science of Xuzhou, Jiangshu. Regeneration varies from 3–10 years due to different economic and environmental conditions and facilities. With frequent regeneration, however, care must be taken to maintain the purity of the accession, which may change due to genetic drift (such as caused by differential rates for seed death in storage) or improper technical procedures. China has created a system that allows for the duplication of the collection from both a regional and national level and thus ensure the safety of its collection for the future.

IDENTIFICATION OF TRAITS WITHIN THE SORGHUM COLLECTION

Since sorghum germplasm has been collected, every scientific research institution of agriculture has carried out initial identification of these accessions. Since the Sixth Five-Year plan, trait evaluation has been conducted based on national standards. Evaluations have also been coordinated with other research facilities. Data have included agronomic and nutritional characteristics, and abiotic and biotic stress screenings. Agronomic traits are comprised of the color of the coleoptile and seedling, plant height, stem thickness, the color of the mid-rib, ear type, ear shape, ear length, ear stem length, the color of glumes and kernel, panicle weight, 1000-seed weight, growth and development stage, and number of tillers. Nutritional characteristics consist of coarse protein, lysine, tannin content, and cutin percentage. Evaluation of abiotic and biotic resistance include stalk lodging, head smut, drought and water-lodging, barrenness, saline-alkali soil, cold resistance, aphid resistance, and stem-borer resistance. Most Chinese germplasm are distributed in temperate and frigid temperate zones.

AGRONOMIC TRAITS

There are distinct differences between the local varieties found in China and those sorghums typically found in the tropics (e.g., African and Indian). Average day to maturity of Chinese germplasm was 113 days and most can be classified as medium maturity. Sweet stem 'Dawantou' (Tulufan, Xinjiang) requires 190 days to mature, while the second longest, black-husk sorghum (Mengbai, Yunnan), takes 171 days. Approximately 900 accessions require less than 100 days to mature, those with the shortest only

TABLE 5. SELECTED SOURCES OF SHORT SORGHUMS FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Ht (cm)	Origin	Conservation unit
8485	Stieby sorghum	63	Huinan Jilin	Jilin Academy of Agricultural Sciences (JAAS)
7872	Wanjinai	76	Yangqu Shanxi	SxAAS
9983	Penghuhong	78	Taiwan	Liaoning Academy of Agricultural Sciences (LAAS)
957	Aihong sorghum	80	Manasi Xinjiang	Xinjiang Academy of Agricultural Sciences (XAAS)
479	Xiaobaiai sorghum	85	Akesu Xinjiang	XAAS
2392	Bangluosan	88	Datong Shanxi	SxAAS
2851	Zheihai 27	91	Zhe lengue Neimenggu	Zhe league Institute Agricultural Sciences (ZIAS)
796	Yazigou	92	Hezhe Shandong	SAAS
8070	Fubo sorghum	93	Licheng Shanxi	SxAAS

TABLE 6. SELECTED SOURCES OF GERM PLASM THAT HAVE LONG PANICLES FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Ht (cm)	Origin	Conservation unit
372	Yaozi sorghum	80.0	Yanshou Heilongjiang	Heilongjiang Academy of Agricultural Sciences (HjAAS)
10222	short sorghum	80.0	Yizhang Hunan	Hunan Academy of Agricultural Sciences (HnAAS)
2179	Yuanjiaozi	79.5	Wuxiang Shanxi	SxAAS
3290	Honghuangke	72.0	Chaoyang Liaoning	Chaoyang Institute of Agricultural Sciences (CIAS)
10220	short stem sorghum	72.0	Shuangpai Hunan	HnAAS
7431	Hangkejiaozi	70.9	Yushe Shanxi	SxAAS
10221	short sorghum	70.0	Linwu Hunan	HnAAS
7432	Huangtiaozhoujia o	68.8	Xiyang Shanxi	SxAAS
7428	wolf tail	67.3	Xiyang Shanxi	SxAAS
1105	Haidianhong	64.7	Haidian Beijing	Pingzi Institute of China Academy of Agricultural Sciences (PICAAS)

requiring 80 days ('Bangluosan' (Datong, Shanxi)).

Most local varieties are photoperiod insensitive and are not sensitive to temperature. Maturity decreases only a few days under short days (less than 10 hours). They belong to a middle-reacting type. In general, early-maturing varieties in high latitudes are slow in reacting to temperature and day length, their maturity stage only decreases about five days under 10 hours of light. Some examples of these are 'Wudalang' (Xuanhua, Hebei), 'Bangchuihong' (Tianzheng, Shanxi), 'Ailaoer' (Xinghua, Jiangshu), and 'Xiaohuangke' (Benxi, Liaoning). On the other hand, some varieties found at low latitudes are sensitive to temperature and day length such as the local varieties 'Hainan of Xinjiang Horse Tail' sorghum (Zhenxiong, Yunnan), 'Wanba' sorghum (Mengbai, Yunnan), and 'Fangbai' sorghum (Chengxian County, Hunan) and under condition of long days and fairly low temperature, maturity of these may vary by as much as 40 days. Characteristic of these photoperiodsensitive accessions are seedling creep and internode elongation delay. Seedling creep has been described as sorghum that creeps along the surface of the soil and is typically occurs under long days and low temperatures (L. Qingshan pers. comm.). These are also typical characteristics of photoperiod-sensitive sorghums grown in temperate areas of the world. Many of the accessions brought in from Africa and India are photoperiod sensitive and will not flower when planted in Beijing and Shenyang. Maturity expression of the Chinese accessions suggest that photoperiod insensitivity is dominant throughout the germplasm.

Chinese accessions are universally tall and big, with an average plant height of 271.7 cm. The accession 'Dahuangke' (Suxian County, Anhui) is the tallest at 450 cm. Thirty-eight percent of the collection is made up of short-statured (>100 cm) plants, for example, sticky sorghum (Huinan, Jilin) at 63 cm, 'Penghuhong' (Aiwan) at 78 cm, and short and red sorghum (Manasi, Xinjiang) at 80 cm. Average stem thickness is 1.46 cm. The thickest is 60-day 'Zaohuang' sorghum (Nanzhang, Hubei) at 3.7 cm. Most accessions have dry stems. Local varieties are thick and tall due to long-term, unconscious selection by farmers for sorghums that could be used as building material and for firewood. Accessions tend to be of good seed quality (Wang and Yinghua 1982), with thick, tough

TABLE 7. PANICLE WEIGHTS OF SELECTED SOURCES OF GERM PLASM FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Seed wt (g)	Origin	Conservation unit
9942	Dawantou	163.5	Shanshan Xinjiang	Hami Institute of Agricultural Sciences (HIAS)
7289	white sorghum	160.0	Hami Xinjiang	Tulufan Institute of Agricultural Sciences (TfIAS)
959	Aiwantou	160.0	Tupkesun Xinjiang	TfIAS
881	Miaogangdawantou	155.0	Tulufan Xinjiang	TfIAS
9955	Pengke	152.7	Jiashi Xinjiang	HIAS
7288	white sorghum	145.0	Shufu Xinjiang	TfIAS
9966	Aiwantou	142.0	Shanshan Xinjiang	HIAS
3537	black husk	141.0	Luda Liaoning	XIAS
2069	Hongerguan	140.0	Linfen Shanxi	PICAAS
756	Hekeer sorghum	140.0	Shufu Xinjiang	XAAS
529	Badanmu	140.0	Shanshan Xinjiang	TfIAS

stems that have little, if any tillering. The major leaf vein is predominately white or yellow and there are several accessions that are quite waxy.

Tall and large stems are restrictive factors to improvements in yield because they influence such things as planting density and lodging. Therefore, research efforts are underway to produce short-statured sorghums for the development of hybrids for use in the country.

Panicle shape and type varies considerably. Sorghum germplasm from the north tends to be semicompact, with spindle and cylindrical shapes. As one moves from the north to the south, the panicles gradually becomes semiloose to loose. Panicle shape becomes more clubbed, broom-like, and sprankle-topped. Sprankle-topped is similar in panicle shape to broomcorn; however, sprankle-top sorghums tend to have no obvious internodes and rachis branches come from a single node and are of various lengths. In the southern region, loose broom-like and sprankle-top varieties predominate. Panicle length varies from 20–25 cm in compact heads to 35–40 cm in loose-headed panicles. One variety, 'Yaozi' sorghum (Yanshou, Shanxi), has a panicle measuring up to 80 cm in length.

Productivity, as measured by a single panicle, is fairly high with an average grain weight per panicle of 50.3 g. Fifty three accessions have single panicle weights of over 110 g and some of these include Pingza (Pingliang, Gansu) at 174.0 g, Aiwantou (Tuokexun, Xingjiang) and white sorghum (Hami, Xinjiang) at 160.0 g, Badanmu (Shanshan, Xinjiang), Miangandawantou (Tulufan, Xinjiang), Hekeerhe white sorghum (Shufu, Xinjiang), Hongerguan (Linfen, Shanxi), black husk (Dalian, Liaoning) at over 140.0 g. These accession come primarily from Xinjiang. Small-headed sorghums include small sweet stem (Zhushan, Hubei) and Qianjinlong (Chengde, Hebei) at 8–9.0 g and sticky sorghum (Bishan, Sichuan), which has the lowest weight at 6.1 g.

Average seed number of a single panicle varies from 2200 to 2500 seeds per panicle, with some accessions having over 4000 seeds. The average 1000-seed weight is 24.0 g. One hundred thirty accessions have 1000-seed weights exceeding 35.0 g and some examples include 'Dahongpao' (Ziyan, Shandong) at 51.0 g, No. 632 sorghum (Hami, Xinjiang) at 52.5 g, and cow tail sorghum (Yicheng, Shanxi) at 53.6 g. In general, grains tends to be smaller in size to

TABLE 8. THOUSAND-SEED WEIGHTS OF SELECTED SOURCES OF GERM PLASM FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	1000-seed wt. (g)	Origin	Conservation unit
4465	Huangke	56.2	Boli Heilongjiang	Hejiang Institute of Agricultural Sciences (HgIAS)
7893	Niuwciba sorghum	53.6	Yicheng Shanxi	SxAAS
9937	632	52.5	Hami Xinjiang	HIAS
5559	Liuzi sorghum	52.0	Xintai Shandong	SAAS
4852	Hongliuzi	51.7	Boxian Anhui	Suxian County Institute of Agricultural Sciences (SCIAS)
5081	Dahongpao	51.0	Ziyang Shandong	SAAS
5087	Dahongpao	49.0	Sishui Shandong	SAAS
584	white sorghum	48.0	Shule Xinjiang	XAAS
7116	Tiexin sorghum	46.6	Jiangjin Sichuan	Yongchuan Institute of Agricultural Sciences (YIAS)
10323	Tieshalian	44.6	Wuxian Shanxi	SxAAS

the south of the Yangtz, while larger sized grains are found in the arid regions of the Xinjiang, Liaoning, and Shanxi provinces.

Brown, red, yellow, and white are the main phenotypic seed colors with white seed color accounting for 34% of the total collection. As one moves south in the country, the number of deep-colored seed accessions becomes smaller and smaller. Glume color varies from black, purple, brown, red, yellow, and white. Red glume color is found in 3070 accessions, accounting for 29.5% of the total collection, while black glumes make up another 28.7% of the collection (2988 accessions). Black glumed accessions are found primarily in the spring growing regions, while purple glumed sorghums are mainly distributed in southern China. Approximately 75% of the germplasm threshes easily, however, as one moves from north to south, threshability decreases.

NUTRITIONAL TRAITS

Chinese sorghums are primarily used as food and, consequently, grain quality tends to be excellent. Among 1048 accessions found in the book of *Annals of Chinese Sorghum Variety,* 400 accessions were rated as delicious. Recent analytical result looking at the nutritional composition of grain found that the average protein content was 11.3% (averaged over 8404 samples), the content of lysine to protein was 2.4% (averaged over 8171 samples), and tannin content was 0.8% (averaged over 7173 samples). There are 64 accessions whose protein content exceed 15.0% and 61 varieties whose lysine to protein content exceed 4.0%. Examples of these include 'Xinlian 80' (Xinzhou, ShanXi) (lys content = 4.76%) and 'Dabalian' (Inner Mongulia) (4.20%). The grain shape of these high lysine content varieties is normal and they seem to have adapted to the surrounding environments. Their grain traits are superior to the high lysine content varieties from Ethiopia (Sun, Weixian, and Yili 1992, 1996).

ABIOTIC AND BIOTIC RESISTANCE

Many accession have good tolerance/resistance to drought, cold, saline and alkaline soils, and low fertility. Resistance to pest and diseases such as head smut (*Sphacelotheca reiliana* (Kühn) Langdon & Fullerton), sugar cane aphid (*Melanaphis sacchari* (Zehntner)), and Europe-

TABLE 9. EARLY MATURING SOURCES OF GERM PLASM FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Growth period (d)	Origin	Conservation unit
2392	Bangluosan	80	Datong Shanxi	SxAAS
9029	Shangqiuhong	81	Shangqiu Henan	Shanqiu Institute of Agricultural Sciences (SIAS)
6983	sorghum	81	Wufeng Hubei	HAAS
7932	white sorghum	84	Tianzhen Shanxi	SxAAS
7616	Laomuzhu taitou	84	Beijing	Institute of Variety Resources of Chinese Academy of Agricultural Sciences (IVRCAAS)
7820	Erehuang	84	Yanggao Shanxi	SxAAS
7931	white sorghum	85	Hunyuan Shanxi	SxAAS
7933	white sorghum	85	Tianzheng Shanxi	SxAAS
9028	Laoyazuo	85	Xixian Henan	Henan Academy of Agricultural Sciences (HeAAS)
8164	black sorghum	85	Shanyin Shanxi	SxAAS

an corn-borer (*Ostrinia furnacalis*) varies among the accessions.

Drought Resistance. From repeated trials on seedling drought stress, 229 out of 6877 accessions were selected as having good seedling drought tolerance. Under sever stress, the survival rate of these accession was still above 70% even after three to four repeated inducements of drought. Some of the best accessions were 'Ernuxin' (Yuci, Shanxi) and 'Dahongsheyan' (Zhao league, Neimeng). In further research, approximately 6% out of a total of 1000 accessions had coefficient of drought resistance that exceeded 0.5. These plants were subject to drought stress throughout the life cycle and in some cases production, based on single panicles, was reduced by less that one-half. Accessions that showed good tolerance to drought and high production were 'Pingdingguan', 'Duansanchi' (Yikezhao league, Neimeng), 'Shangting ear' (Changzhi, Shanxi), 'Heilong' sterile 11A and 30A (Haerbin, Heilongjiang).

Cold Hardiness (Appendix, Table A). Research on germination of seeds under low temperatures revealed several accessions that had high germination rates and two of the best accession were 'Pingtingxiang' (Shuangcheng, Heilongjiang) and 'Heikebang' (Hulan, Heilongjiang). Cold hardiness of more than 9000 sorghum accessions was tested at the seedling stage in both field plots and in climate boxes. Accessions were evaluated for their relative rate of germination, exponential ratio of germination, and dry weight ratio.

Two hundred and eight accessions were rated as a 1 in cold tolerance and examples of these are red-husked sorghum (Gaoping, Shanxi), 'Dahongke' (Keshan, Heilongjiang), and 'Tiaozhenmizi' (Jinzhou, Liaoning). The cold hardiness of more than 1000 sorghum accessions was evaluated at the milk stage under field conditions (late autumn). Evaluations were based on the dry weight of grain, the ratio of dry weight accumulated per day, and 1000-seed weight. Results showed that three accessions, 'Heisaomiao' (Xinjin, Laoning), 'Changsuihuangkebai' (Chaoyang, Liaoning), and Dasheyang (Hejing, Heilongjiang) had rating of over 2.0. Several accessions within the collection have shown promise in terms of cold tolerance at various growth stages (Gong 1980; Liguo et al. 1992; Zhao 1985).

Saline-Alkali Soil. Six hundred and forty-four sorghum accessions were tested in saline-alkali

TABLE 10. LATE MATURING SOURCES OF GERM PLASM FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Growth period (d)	Origin	Conservation unit
10019	Chibai sorghum	191	Mojiang Yunnan	Yunnan Academy of Agricultural Sciences (YAAS)
1013	Tiangan dawantou	190	Tulufan Xijiang	TfIAS
913	Heike sorghum	171	Mengzi Yunnan	LAAS
10261	Datian sorghum	171	Shiquan Shanxi	BIAS
742	Qingwaxi	170	Shanshan Xinjiang	TfIAS
881	Miangan dawantou	170	Tulufan Xinjiang	TfIAS
10281	Tiangan sorghum	169	Shiquan Shanxi	BIAS
10267	Honglida tian sorghum	167	Pingli Shanxi	BIAS
10280	sweet-stalked sorghum	167	Pingli Shanxi	BIAS
666	Hongkefan sorghum	163	Xinping Yunnan	LAAS

soils (chlorine content (Cl^-) of 2%) in 1980. Testing included germination, chlorosis of seedling tissue, and seedling death. The accessions 'Diaoshaji' (Xinhua, Jiangshu), 'Hongwobai' (Chengde, Hebei), and 'Dujiaohu' (Xintai, Shandong) had germination rates of over 60%, seedling chlorosis ratings of less than 5%, and seedling death of less than 4% when tested on these soils. Accessions were also tested for their response to germination under saline conditions (2.5% NaCl). Over 6500 accessions were screened from 1985 to 1990. Salt resistance ratings were calculated based on the ratio of germination between the salt treatment versus the control. Results showed that there were 528 accessions that rated as a grade 1 (0–20%). Over 6500 sorghums were tested for resistance to high salt solutions at the seedling stage, both at trials by the sea or in greenhouse work. Plants were exposed to salt solutions (1.8%, $NaCl^{+}CaCl_2$, 7:3) in pots at the three-leafed stage. Ratings were based on a ratio of dry leaf material to dry plant material. Only three accessions were rated as a 1.0 and 19 were rated as 2.0. In general, sorghum germplasm does not tolerate salt at the seedling stage (Zhang 1992).

Fertility Problems. The diversity of responses to poor soil fertility among Chinese germplasm varied greatly. Low fertility fields, which had low organic matter (0.82%), low hydrolytic N nitrogen (38.25 mg kg^{-1}), low quick-acting phosphorus (2.30 mg kg), and low quick-acting potassium (94.85 mg kg^{-1}) were used to screen 9883 accessions. Approximately 5.9% (592) of the accessions showed delays in anthesis of between 0–7 days, but otherwise matured normally. Yields decreased by as little as 0.5% in many of these accessions. The best material was 'Bayueqi' (Chaoyang, Liaoning), 'Mugewo' (Xiaoyi, Shanxi), and 'Xiao bailian' (Zhe league, Neimeng). These varieties are predominately early maturing varieties, which are short-statured and thin and are generally found in poor soils of northeast, northwest, and northern China.

Plant and Pest Diseases. Head smut (*Sporisorium reilianum*), sugar-cane aphid [*Melanaphis sacchari* (Zehntner)], and stem-borers are the main disease and insect problems facing sorghum production in China (Wang and Fugang 1993).

Zhiguang Wang (1982) identified resistance sources to head smut in 1016 Chinese accessions

TABLE 11. SOURCES OF GERM PLASM WITH HIGH PROTEIN CONTENT FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Protein (%)	Origin	Conservation unit
4276	Laozhuadeng	17.10	Bayan, Heilongjiang	HjAAS
1602	Huangnian gaoliang	16.64	Qinhuangdao, Hebei	TIAS
1625	Heikebai	16.60	Pingquan, Hebei	TIAS
6750	Heilaopo fanbaiyan	16.58	Dengxian, Henan	IVRCAAS
4175	Pingdingxiang	16.40	Bayan, Heilongjiang	HjAAS
7798	Luogaoliang sorghum	16.33	Xushui, Hebei	TIAS
8221	Xiaohong sorghum	16.33	Chifeng, Neimenggu	Chifeng Institute of Agricultural Sciences (CfIAS)
10338	Changzihongke tiaozhoumizi	16.30	Huinan, Jilin	JAAS
10404	Sansangaoliang	16.30	Dingbian, Shanxi	BIAS
1026	Saozhougoliang	16.30	Wushu, Xinjiang	XAAS

coming from 23 provinces and autonomous region throughout the country. Four accessions showed no infection, while 322 accessions showed a high rate of infection. Between 1986 and 1990, nine thousand accessions were artificially inoculated with head smut. From these studies, classification of resistance (Xiude et al. 1994) could be broken down into three categories: introduced foreign sorghum varieties such as nine-headed bird (Xihua, Hebei) and 'Bakicha' (Fuxin, Liaoning); new breeding lines such as 'Feng 9' (Fengyan, Shanxi), 'Jiging line 10' and '13'; local varieties 'Baiyuli' (Anxiang, Hunan).

Approximately 5000 varieties were screened by artificial inoculation for aphid tolerance. Only a small percentage (0.3%) of the accessions showed some form of resistance. One accession, 5–27, showed resistance after repeated inoculation. It is a R-line that has been recently developed in one of our breeding programs. Its source of resistance is from 'TAM428', an improved American variety.

Five thousand accessions were artificially infested with corn-borer larvae. Results indicated that about 0.2% of the accessions tested had some form of resistance to corn-borer. Accessions showing resistance were 'Xiao' sorghum (Xiaoyi, Shanxi), red-husked sorghum (Xiyan, Shanxi), 'Bodigao' (Fuxin, Liaoning), and white sorghum (Chengwu, Shandong). Thirty-five hundred accessions were also screened for resistance to head smut, aphids, and corn-borer. Though none of the accessions had resistance to all three of these biotic stresses, two accessions, 'Huangluosan' (Zhucheng, Shandong) and 'Sanma' sorghum (Liangshan, Shan dong), were resistant to head smut and one of the insect diseases.

Qingshan et al. (1989) identified 38 accessions that seemed to have sorghum downy mildew (*Peronosclerospora sorghi* (Weston and Uppal) C. G. Shaw) resistance. Further research, however, indicated that these sources of resistance did not hold up under further screenings.

SELECTED SOURCES OF GERMPLASM VARIABILITY

Since the 1970s, China began an intensive program of selection for unique and superior characteristics within their germplasm resources. Identification of superior agronomic traits, improved nutritional composition, and resistance to

TABLE 12. SOURCES OF GERM PLASM WITH LYSINE CONTENT ABOVE 4.5% FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Lysine (%)	Origin	Conservation unit
8960	Aigan gaoliang	4.76	Guangfeng, Jiangxi	Jiujiang Institute of Agricultural Sciences (JIAS)
10209	Xiangnanai	4.76	Youxian, Hunan	HnAAS
732	Xinliang 80	4.76	Xinxian, Shanxi	SAAS
2581	Dabailian	4.73	Naiman, Neimenggu	Zhemeng Institute of Agricultural Sciences (ZmIAS)
10357	Make sorghum	4.71	Hengfeng, Jiangxi	JIAS
9080	Shiyong gaoliang	4.65	Zaoyang, Hubei	HAAS
10084	Hongmian gaoliang	4.58	Ninghe, Tianjin	Tianjin Academy of Agricultural Sciences (TAAS)
10157	Hong gaoliang	4.56	Shuangpai, Hunan	HnAAS
2578	Dabailian	4.54	Keerqin, Neimenggu	ZmIAS
8901	Aigan gaoliang	4.54	Longnan, Jiangxi	JIAS

both abiotic and biotic stresses have been registered in "Chinese Sorghum Variety Resources" and several outstanding sources of germplasm have been identified.

AGRONOMIC TRAITS

Tall Plant Accessions. One hundred ten accessions have plant heights that exceed 400 cm. The tallest is 'Dahuangke' from the Suxian County, Anhui at 450 cm. Table 4 lists some of the tallest accessions within the collection.

Short Plant Accessions. There are 49 varieties whose plant height are less than 100 cm. The shortest variety is sticky sorghum (Huinan, Jilin) at 63 and Table 5 lists several sources of short germplasm.

Panicle Shape, Length, and Weights. Panicle shape varies from compact to broomcorn to umbrella shape. Panicle length of compact panicles varied between 20–25 cm, with a few accessions surpassing 35 cm. Loose shaped panicles varied in length between 35–50 cm with some of the broomcorns and umbrella shape measuring over 50 cm (Table 6). The accessions with the longest panicle are 'Yaozi' sorghum (Yanshou, Heilongjiang) and short sorghum (Yizhang, Humam) at 80 cm. Over 31.7% of the collection has panicle lengths exceeding 30 cm, while only 97 or 0.9% of the collection has panicles over 50 cm. Table 6 lists some of the germplasm with long panicles. There were 113 accessions in which panicle weight exceeded 100.0 g, representing 1.1% of the total collection. 'Dawantou' (Shanshan, Xinjiang) weighed 163.5 g (Table 7). Sorghum accessions from the Xinjiang region tended to have higher panicle weights, providing 9 out of the 11 accessions with panicle weights exceeding or equal to 140 g.

Kernel Weights. One hundred forty-six accessions had 1000-seed weight exceeding or equaling 35 g. The heaviest was 'Huangqiao' (Boli, Heilongjiang) with a 1000-seed weight of 56.2 g (Table 8).

Time to Maturity. Nearly 900 accessions (8.6% of the total collection) require less than 100 days to mature with 'Bangluosan' (Datong, Shanxi) requiring only 80 days and 'Shangquhong' (Shangqiu, Henan), the summer-sowing improved variety bred recently, requiring 81 days (Table 9). There are 37 local varieties (0.4% of the total collection) in which days to maturity exceed 150. The longest is 'Chibai'

TABLE 13. LOW TANNIN SOURCES OF GERM PLASM FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Tannin (%)	Origin	Conservation unit
1059	Beijingbai	0.02	Beijing	IVRCAAS
1075	Beiping Heikebai	0.02	Beijing	IVRCAAS
1081	Baidazimao	0.03	Changping, Beijing	IVRCAAS
1885	Xiaohong gaoliang	0.03	Lishi, Shanxi	SxAAS
94	Niuxinbai	0.03	Yixian, Liaoning	Jinzhou Institute of Agricultural Sciences (JzIAS)
10154	Xinglong gaoliang	0.03	Xinglong, Hunan	Yongshun County Institute of Agricultural Sciences (YCIAS)
10081	Baigaoliang	0.03	Baodi, Tianjin	TAAS
9967	Aiwantou	0.03	Shanshan, Xinjian	HIAS
9955	Pengke	0.03	Jiashi, Xinjiang	HIAS
8383	Huangcaobai	0.03	Kalaqin, Neimenggu	CfIAS

sorghum (Mojiang, Yunnan) that matures in 191 days (Table 10).

NUTRITIONAL TRAITS

High Protein Content. Chinese sorghum is mainly used as human food and consequently, indirect selection has led to improved taste and grains with higher protein content. One thousand and fifty accessions were found to have grain protein contents of over 13%, accounting for 10.1% of the collection. 'Laozhaodeng' (Bayan, Heilongjiang) has the highest protein content at 17.1% (Table 11).

High Lysine. Lysine content was measured as lysine concentration per 100-grain total protein. Within the collection, 209 accessions had lysine levels of 3.5% or higher. Three accessions, 'Aigai' sorghum (Guangfen, Jiangxi), 'Xiangnanai' (Younian, HuNan) and 'Xiliang 80' (Xinxian, Shanxi), had lysine reading of 4.76% (Table 12).

Low Tannin. The tannin content within the collection ranged between 0.02 to 3.29%, and there are 30 accessions with tannin contents below 0.30%. Two accessions, 'Beijingbai' (Beijing) and 'Beiping Heikebai' (Beijing) and had tannin contents of 0.02% (Table 13).

RESISTANT TRAITS

Head Smut Resistance. Few accessions within the collection have resistance to head smut (*Sporisorium reiliana*). Less than 0.36% of the National collection has shown any resistance to the disease. (Table 14).

Insect Resistance (Appendix, Table B). Very few, if any sorghum accessions within the National Collection have resistance to aphids. Of the 5000 Chinese sorghums tested, only a few were found to show some aphid resistance. Under artificially infested conditions, one cultivar 5-27 showed resistance. It is a restorer line bred in the 1980s, and its resistance source can be traced back to the introduced variety, TAM428. A few sorghum accessions show some resistance to aphids, reaching the second-grade standard (Table 15).

Few accessions have been reported to have resistance to the corn-borer (Appendix, Table C). Using both natural and the artificial inoculation, 5000 accessions have been screened and only 0.2% were found to offer a certain level of resistance (Wang and Fugang 1993). Only 'Heikedaluochui' (Pingyuan, Shandong) and

TABLE 14. HEAD SMUT (*SPORISORIUM REILIANA*) SOURCES OF GERM PLASMA FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Incidence (%)	Origin	Conservation unit
792	Liantangai	0	Guiyang, Hunan	LAAS
552	Dongshanhong gaoliang	0	Bama, Guangxi	LAAS
1504	Duosui gaoliang	0	Luanxian, Hebei	TIAS
3050	Bakecha	0	Fuxin, Liaoning	JzIAS
6055	Fenzhi gaoliang	0	Luyi, Henan	HeAAS
5981	Jiulouniao	0	Xihua, Henan	HeAAS
3427	Yangdali	0	Xingcheng, Liaoning	JzIAS
2148	Fenjiu	0	Fenyang, Shanxi	IVRCAAS
3775	Jigongxi 10	0	Gongzuling, Jilin	JAAS
1094	Jingxuan yihao	0	Beijing	IVRCAAS

Heikeluoziwei (Fangcheng, Henan) were rated as a grade-1 variety (Table 16).

Resistance to Drought Stress (Appendix, Table D). The country is continuing its testing of the whole collection for drought resistance. Niu and Xuemeng (1980–1983) screened 1009 local varieties for drought resistance and found 62 accessions that were rated as a grade 1 (Niu and Xuemeng 1984a,b).

The Institute of Crop Variety Resource, Chinese Academy of Agricultural Sciences tested the drought-resistance of 3500 accessions at seedling stage between 1985–1986. Result indicated that 56 accessions had survival rates of 70% or greater after four drought induced stages (Table 17).

Resistance to Water-logged Soils (Appendix, Table E). Wang et al. (1983) evaluated 435 sorghums for their resistance to water logging, using water-soaking methods at both the seedling and elongation stages. Data was collected on the number of yellow leaves, the average accumulation of dry matter weight per day, and 1000-kernel weight.

From these ratings, a water-logging resistance score was developed where; A = most resistant, B = resistant, C = moderate resistance, D = little resistance, and E = death. Twenty accessions were rated as class A (Table 18).

Tolerance to Poor Soils. Tiantang et al. (1984) screened 1009 accessions under poor soil conditions. Poor soils were defined as those that have had their topsoil removed and contained 0.022–0.035% potassium (K) in the 0–30 cm layer of soil that remained. Data was collected on days to flowering, stature of the plant, degradation of the inflorescence, and plant death. Five levels of tolerance were developed from these ratings. A rating of 1 was given to plants in which flowering was delayed by 20–30%, but the panicles matured normally. A rating of 5 was given to plants that did not head out and in many cases withered and died. Xuemeng et al. (1982) also conducted research on 3438 additional accessions. According to both research findings, 374 accessions were rated as class-1 tolerant (Table 19).

Tolerance to Saline-Alkali Soil (Appendix, Table F). Accessions that have been identified as salt tolerant have been moved into national

TABLE 15. APHID RESISTANCE SOURCES OF GERM PLASM FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Resistant grade	Origin	Conservation unit
8432	5-27	1	Shenyang, Liaoning	LAAS
8485	Niangaoliang	2	Huinan, Jilin	JAAS
8916	Daluochui gaoliang	2	Zhanhua, Shandong	SAAS
2269	Jinsuigaoliang	2	Xingxian, Shanxi	SxAAS
6192	Hongkesanma	2	Luyi, Henan	HeAAS

TABLE 16. STEM-BORER RESISTANCE SOURCES OF GERM PLASM FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Resistant grade	Origin	Conservation unit
5858	Heikeda luochui	1	Pingyuan, Shandong	SAAS
6745	Heikeluo ziwei	2	Fangcheng, Henan	HeAAS
1750	Erguandong	2	Yuci, Shanxi	SxAAS
1878	Xiaogaoliang	2	Xiaoyi, Shanxi	SxAAS
2040	Hongkegaoliang	2	Xiyang, Shanxi	SxAAS
3449	Jinsui hongliang	2	Kalaqin, Liaoning	Chaoyang Institute of Water and Soil Conservation (CIWSC)
3565	Heikebangzhi	2	Heishan, Liaoning	JzIAS
3647	Baodigao	2	Fuxin, Liaoning	JzIAS
6709	Heikehuang luosan	2	Baofeng, Henan	HeAAS
7159	Nuogaoliang	2	Cengong, Guizhou	Bijie Institute of Agricultural Sciences (BjIAS)

breeding programs and through improved varieties greatly increased the area under production for sorghum within China. Wang et al. (1983) screened 546 accessions for salt tolerance. The saline-alkali soil in the treated plots contained a salt content of 0.516% and Cl^- levels of 0.246% in the first 0–15 cm of the soil.

Sixteen accessions had ratings of 1. This rating consisted of plant emergence over 60%, yellowing of leaves at the seedling stages below 5%, and seedling death below 4% (Appendix, Table G).

The Institute of Crop Variety Resources, the Chinese Academy of Agricultural Science (1982–1989) evaluated 3692 for salt tolerance at the seedling stage in 1985–1986. Zhang (1992) screened 2085 accessions at both the seedling and bud stage. Selected accessions whose salt-tolerance ratings were 1 are listed in Table 20.

Tolerance to Cold. In the main area of sorghum production in the north, low temperature and cold can damage sorghum crops. Chinese germplasm has shown greater levels of tolerance to cold stress than introduced sorghums. These accessions have germinated under low temperatures, emerged and grown normally. Wenjuan (1980) identified 20 accessions out of 400 that had high rates of germination under 5–6°C. Shijun et al. (1981) further evaluated 115 accessions at 4°, 6°, and 8°C. They found one accessions that had 80.1–100% germination at 4°C, 13 accessions were found at 6°C, and 23 accessions were found at 8°C. Yutian (1985) screened 1275 accessions at the seedling stage and found 259 accessions with excellent cold tolerance. Liguo, Shufen, and Fude (1992) evaluated 1292 and 857 sorghum varieties at both the seedling and grain filling stage and found seven accessions at the seedling stage and eight at the grain filling stage with class-2 levels of resistance. A partial list of the best material is listed in Table 21.

UTILIZATION OF GENETIC RESOURCES

DIRECT UTILIZATION

Utilization and selection within local accessions has provided the most economical and efficient use of exotic germplasm within the National breeding programs. In 1951, the identification of excellent local accessions began throughout the country. Both researchers and farmers evaluated and selected high yielding ac-

TABLE 17. SELECTED SOURCES OF GERM PLASM WITH REPORTED DROUGHT RESISTANCE FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM. RATINGS INCLUDE WORK FROM BOTH NU TIANTANG ET AL. (1984) AND FROM THE INSTITUTE OF CROP VARIETY RESOURCES (QINGSHAN 1999).

National accession #	Variety name	Resistant grade/% viability	Origin	Conservation unit
536	Pingdingguan	1	Qinglong, Hebei	TIAS
931	Duansanchi	1	Yigezhaomeng, Neimenggu	Neimenggu Academy of Agricultural Sciences (NAAS)
340	Aigaoliang	1	Kaiyuan, Liaoning	Tieling Institute of Agricultural Sciences (TiIAS)
484	Xiaobagaoliang	1	Luannan, Hebei	TIAS
997	Nuogaoliang	73.8	Yuanjiang, Yunnan	LAAS
1368	Bailigaoliang	81.3	Pingquan, Hebei	TIAS
2599	Dahongsheyan	85.7	Chifeng, Neimenggu	Zhaomeng Institute of Agricultural Sciences (ZgIAS)
1089	Denglonghong	93.5	Yanqin, Beijing	IVRCAAS
2918	Huangchaoxiao baigaoliang	100.0	Ningcheng, Neimenggu	ZgIAS
7393	Sanmanian	100.0	Chengde, Hebei	TIAS

cessions that were directly utilized into production. These selections and use of these accessions depended heavily on regional selections. They were used to increase production and yield per unit area in the mid to late 1950s increased by approximately 10% when compared to the 1940s. At the same time, these accessions became the foundation for new varieties and sources of heterosis. Some of the important germplasm sources and the provinces in which they are found are listed in Table 22.

After superior accessions were identified and selected, some scientific Research Units of Agriculture began a systematic program of development for improved sorghum varieties. For example, Xiongyue Agricultural Research Institution of Liaoning Province released 'Xiongyue 334' and 'Xiongyue 360', the Hejiang Agricultural Research Institution of Province produced 'Hejing Red 1', and the Chifeng Experimental Farm of Neimenggu released 'Zhaonong 303'. Using traditional plant breeding methods other varieties such as 'Xiongyue 253', 'Yuejin 4', 'Jingliang 9–2', 'Hu2', 'Hu4', 'Hu22', 'Pingyuan Red', 'All Red 1', 'Zhaonang 300' and 'Brached Bog Ear' were released.

During the late 1950s to the early 1960s, the Liaoning Academy of Agricultural released 119 new varieties and the Jinzhou Agriculture Research Institution produced 'Jingliang 5'. In 1956, heterosis studies began. At first, local varieties were used as restorer lines in research activities. As an example, hybrids developed by the Heredity Research Institution of the Chinese Academy of Sciences were made by using local varieties such as 'Baodizu' the male parent of 'Yiza 1', and Luyiwaitou as the male for 'Yiza 2' and 'Yiza 7'. The Atomic Energy Research Institution of the Chinese Academy of Sciences used the local variety 'Aizikang' to develop 'Yuanza 2'.

The maturity of these hybrids is 110–120 days. Their heights are over 200 cm with the tallest being 295 cm. Because of these attributes, lodging and unstable yield have limited their utilization. Starting in the early 1970s, mid to short plant height became a priority within breeding programs throughout the country.

From these programs, 'Jinza 5' was the first hybrid that was short-statured. The male parent was an excellent local variety called 'Sanchisan' (Shanxi, Feng Yang). 'Zhengza 3' is a widely adapted hybrid now grown in the spring and

TABLE 18. SELECTED GERM PLASM SOURCES SHOWING RESISTANCE TO WATER-LOGGED SOILS FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Resitant grade	Origin	Conservation unit
465	Dayong gaoliang	A	Dayong, Hunan	LAAS
553	Longtou cungaoliang	A	Kunming, Yunnan	LAAS
549	Daluochui	A	Ganyu, Jiangsu	Xuzhou Institute of Agricultural Sciences (XzIAS)
614	Laoguazuo	A	Kaifeng, Henan	HeAAS
627	Diaoaoji	A	Xinghua, Jiangsu	XzIAS
718	Chenggong gaoliang	A	Chenggong, Yunnan	LAAS
869	Niangaoliang	A	Guangde, Anhui	SCIAS
891	Ziliuzi	A	Tongshan, Jiangsu	XzIAS
920	Heigengtou	A	Muyang, Jiangsu	XzIAS
1022	Heiketian gaoliang	A	Huaiyuan, Anhui	SCIAS

A = most resistant, B = resistant, C = moderate resistance, D = little resistance, and E = death.

summer growing seasons and its male parent was 'Daqingjie' (Henan, Mingquan). The diverse nature of the female parents in all these hybrids made for excellent heterosis and the use of superior local varieties as males gave these hybrids wide adaptability and acceptance. Acceptance of hybrids has also led to an increase of yield from below 100 kg mu^{-1} to over 200 kg mu^{-1} (1 ha = 15 mu).

At present, China uses sorghum hybrids widely, however, the utilization of outstanding local varieties is still used by farmers of the country and is an important component within the agricultural production system of our developing economy. In 1989, Sichuan Rice-Sorghum Institution of Academy of Agricultural Sciences selected a glutinous sorghum 'Qingkeyang' from local varieties for use in the development of an alcoholic beverage. This sorghum is grown on more than 130 000 ha (2 000 000 mu) in the southwest. The Shenyang Academy of Agricultural Sciences, through direct selection, developed 'Shenyang Bayeqi' from the local variety 'Bayeqi'. It is now planted in 666 666 ha. 'Taikang' sorghum, which was selected from local varieties by the Henan Grain Crops Research Institution of Academy of Farming and Forestry Sciences, is widely used in wine making and the stalks are used for building material.

Direct utilization of local varieties is a simple and effective tool used in sorghum production. It is one of the most important ways of using sorghum genetic resources. Continued growth and development within the country required the use of improve local accessions. One of the difficulties in developing and utilizing hybrids has been the lack of good restorers and maintainers within our National Collection. Only 14% of the accessions tested so far restore in A_1 male-sterile cytoplasm. Testing has also indicated that only 9% are maintainers, while only 9% and 5% restore and maintain in A_2. If fertility and others agronomic characters, such as the plant height, the length of growing period, seed quality, and resistance to abiotic and biotic stresses are comprehensively surveyed, the use of local varieties as a hybrid parents becomes difficult. Therefore, until further research can be carried out, the direct use of local landraces and varieties will continue to play an important role in our society.

INDIRECT UTILIZATION

One of the most important ways of using sorghum genetic resources is in their use as parents

TABLE 19. TOLERANCE TO POOR SOILS OF SELECTED SOURCES OF GERM PLASM FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Resistant grade	Origin	Conservation unit
640	Guandonghong	1	Fenyang, Shanxi	SxAAS
462	Dahuangke	1	Yanggao, Shanxi	SxAAS
703	Maihuang	1	Tongshan, Jiangsu	XzIAS
740	Longnan 403	1	Gangu, Gansu	Gansu Academy of Agricultural Sciences (GAAS)
397	Erhongshushu	1	Yongcheng, Henan	HeAAS
518	Changbojian	1	Tangyin, Henan	HeAAS
5096	Daliuzishushu	1	Yishui, Shandong	SAAS
248	Huangkexiao baigaoliang	1	Chaoyang, Liaoning	CIWSC
2500	Xiaohonggaoliang	1	Kalaqin, Neimenggu	ZgIAS
106	Shuangxinhong	1	Wuchang, Heilongjiang	HjAAS

in population development from which improved lines can then be selected. Research in this area began late in China and has not been widely utilized. In 1957, Liaoning Province Academy of Agricultural Sciences used the local variety 'Huangxingong' and the foreign sorghum 'Dula' to develop a population from which sorghum 119 was selected. The Jiuzhan Agricultural Research Institution of Jilin Province selected 'Jiuliang 5' from a population derived from 'Red Ear' and 'Hammer'. Both these sorghums have been used widely throughout the country.

In 1956, Zuguanren introduced the male sterile line Tx3197A into China and began a research project on hybrid vigor. At the same time, he also began indirect utilization of sorghum germ-plasm resources. The history of utilizing sorghum hybrid vigor is more than 30 years old and has been one of primarily using introduced male-sterile lines with local landraces as restorers.

Before the middle 1970s, direct use of local landraces that could restore male-sterile landraces predominated sorghum breeding methodology. In the mid-1970s, crossing of local varieties with foreign varieties and selection of improved inbred lines was adopted. The main crosses were developed from Chinese sorghums and Hegaris, Kafirs, Feteritas or Taibengna. For instance, Chinese sorghum 'Hu4' and the Hegari 'Jiutuoniao' were crossed and from this the restorer 'Jihui 7384' was selected. This was then crossed with Heilong 11A to produce the hybrid named 'Tongza 2' which was widely used in China. 'Jinza 5' was a selection from Tx3197A and the Chinese sorghum 'Jinfu 1', which had been developed through mutation (radioactive) breeding. All these hybrids became important in the spring-sowing and late-maturing growing regions.

According to incomplete statistics, before the 1980s, among the 90 lines being used as restorers, 70% were made up from local landraces, 24% from improved inbred lines, 4% from mutation breeding programs, and 2% from foreign introductions. After the 1980s, 30 lines were being used as restorers with local landraces accounting for 3.3%, improved inbred lines 73.4% and foreign introductions making up 23.3% of the restores in use (see Table 23).

TABLE 20. PARTIAL LIST OF SORGHUMS TOLERANT TO SALINE-AIKALI SOILS FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999, ZHANG 1992).

National accession #	Variety name	Resistant grade	Origin	Conservation unit
696	Hongwobai	1	Chengde, Hebei	TIAS
627	Diaoaoji	1	Zinghua, Jiangsu	XzIAS
877	Chubogeng	1	Peixian, Jiangsu	XzIAS
942	Hanshushu	1	Fengtai, Anhui	XzIAS
783	Dujiaohu	1	Xintai, Shandong	SAAS
651	Jiangshan lusu	1	Jiangshan, Zhejiang	LAAS
712	Lusu	1	Tujiang, Jiangxi	LAAS
757	Peitoulia	1	Qinyang, Henan	HeAAS
970	Aizigaoliang	1	Hengyan, Hunan	LAAS
761	Gadegaoliang	1	Xihe, Gansu	GAAS

FOREIGN INTRODUCTIONS

In the 19th century, Chinese germplasm began to spread throughout the world. In 1853, Amber and Chinese sweet sorghums were introduced into the United States for sugar production. In 1856, it was planted in Colombia, Washington and its seed was distributed to farmers to plant. It was used to produce syrup and sugar. Much of the sweet and forage sorghums developed in the U.S. can trace their heritage back to Amber sorghum. Quinby and Martin (1954) evaluated short-stalked sorghum varieties that were introduced from China. Data indicated that the northeast China sorghum Black shell was a 1-dwarf (Dw_1Dw_1 Dw_2Dw_2 Dw_3Dw_3 dw_4dw_4 (Quinby and Karper 1954)) and Shandong sorghum Black shell was 2-dwarf (Dw_1Dw_1 Dw_2Dw_2 dw_3dw_3 dw_4dw_4) genotype.

The former USSR also introduced sorghum varieties from China in the 1930s. They used these accessions to breed Chinese Amber sugar 813 which was planted in vast area of Armenia in 1947. This material was thought to have a great future in arid regions.

In 1976 Sherev (from Fude 1986) regarded cold tolerance of Chinese germplasm as the best. The high degree of cold tolerance within the hybrid 'TeHuBB 6' is derived from Chinese sorghum short 1428. From 1974 to 1976, CIMMYT identified cold tolerant accessions in which Chinese accessions were rated as excellent sources of resistance during vegetative growth stages and marginal after reproductive growth started. For example, 'Yutingbai' was rated as a 1 during its early growth stages, but was rated as a 5 later in its life cycle. Sherev also analyzed lysine content of more than 500 sorghum accessions and found that that the content of Chinese Brown Grains sorghum 481 reached 4.2%. He believed it to be a reliable resource of high lysine. At the same time he pointed out that the grain yield of hybrids using Chinese germplasm was high. The Texas Agricultural Experiment Station and the United States Department of Agriculture, Agricultural Research Service USA have used Kaoliang 119 for both experimental purposes and in RFLP studies on taxonomy (Yang et al. 1996). The Research Station of the Australian Hermitage has incorporated cold tolerance into some of their hybrids for planting in high elevations (B. Henzel, Dept. of Primary Industries, Hermitage Research Station, Australia, pers. comm.).

Since the 1980s, the exchange of sorghum germplasm resources has gradually increased along with the accelerated pace of China's opening and reform and through the strengthening of international technical exchange and cooperation (Qingshan 1985b, 1992, 1993a,b; White et al. 1994; Yue et al. 1993). Chinese germplasm has spread throughout the world for evaluation, selection and breeding purposes (Qingshan 1985a, 1990).

SUMMARY AND CONCLUSIONS

Sorghum has a long cultivated history in China. Its diversified uses and its widespread plantings have formed a broad and rich genetic resource. Since the founding of the People's Republic of China, there have been three extensive and planned collections of local landraces throughout the country. From these expeditions, 12 836 accessions have been assembled and 10 414 of these have been registered as genetic

TABLE 21. PARTIAL LIST OF SORGHUMS TOLERANT TO COLD STRESS FOUND WITHIN THE CHINESE NATIONAL COLLECTION OF SORGHUM (QINGSHAN 1999).

National accession #	Variety name	Resistant grade	Origin	Conservation unit
342	Jinliang 9-2	2	Jinzhou, Liaoning	XIAS
4179	Baigaoliang	2	Lanxi	Suihua Institute of Agricultural Sciences (ShIAS)
110	Pingdingxiang	2	Shuangcheng, Heilongjiang	HjAAS
7806	Erniuxin	2	Shouyan, Shanxi	SxAAS
7915	Baiyuangaoliang	2	Yingxian, Shanxi	SxAAS
4533	Heikebang	2	Hulang, Heilongjiang	HjAAS
8435	Shuangli	2	Fuxin, Liaoning	LAAS
4175	Pingdingxiang	2	Bayan, Heilongjiang	HjAAS
4091	Dasheyan	2	Hulan, Heilongjiang	HjAAS
314	Heikebai	2	Chaoyang, Liaoning	CIWSC

resources and are currently being preserved in the National Genetic Germplasm Resources Bank. Extensive evaluations of these accessions have identified several important sources of germplasm for agronomic uses and abiotic and biotic resistance/tolerance. From these, the following Table (24) has been developed to summarize the collection.

During the course of sorghum production, it is both economical and efficient to make use of local varieties directly. It has become one of the most important tools of utilization in regards to our national sorghum collection. From different areas, approximately 50 superior landraces have been selected, such as 'Duluobang', 'Hongbangzi', 'Hongkebangzi', 'Erniuxin', 'Guandongqing', 'Luyiwaitou', 'Zhuyeqing', Fragrant sorghum, short old men, 'Sanchisan', 'Xiheliu', 'Yantingxianfeng', 'Sandu', 'Hongnuo', 'Jingxiu', 'Pingluouawa', and 'Zhilimisui'. Through selection, about 10 varieties were bred and introduced into production with the result that the yield per unit area was raised by 10%.

Through recurrent phenotypic selection, local landraces have played an important role in improving varieties released from research facilities. For example, Jinza 5, a selection from a cross that included the landrace Sanchisan, was one of the predominant varieties used in late season planting regions and improved yields by up to 20%. Local landraces have also been used to develop R-lines that have been successfully used in hybrid development. Prior to 1980, local landraces made up 70% of the R-lines used in China, while improved inbred lines accounted for 22% of the total number of R-lines in use. At the same time, Chinese sorghum genetic resource had been widely evaluated in foreign countries and successful utilization of this germplasm has been achieved.

In its long period of evolution and cultivation, Chinese sorghums have formed a rich genetic base in which unique characteristics have evolved. These resources and their characteristics have been identified and partially utilized within China's breeding programs. Records and data have been compiled and updated into the *Records of Sorghum Varieties in China* (Chao, Chuizhen, and Fengjin 1998) and *Sorghum* (Qingshan 1999). These evaluations and recorded information provide a solid base from which further studies and utilization of this important

TABLE 22. SOME OF THE IMPORTANT GERM PLASM SOURCES AND THE PROVINCES IN WHICH THEY ARE FOUND IN CHINA (QINGSHAN 1999).

Province or region	Accession name
Liaoning	Daluobang (Gaixian)
	Xiaohuangke (Gaizhou)
	Huitouqing (Haicheng)
	Guandongqing (Jinzhou)
	Yangdali (Yixian)
	Aiqingke (Shenyang)
	Baidali (Kaiyuan)
	Haiyanghuang (Tieling)
Jilin	Hongbangzi (Yanji)
	Huboxiang (Siping)
	Hubocuo
	Heikebangzi (Huaide)
Heilongjiang	Hongkebangzi (Echeng)
	Dabaye (Mudanjiang)
	Erwaibo (Shaqi)
Neimenggu Autonomous Region	Erniuxin Duanshanchi (Yimeng)
	Stalk Yellow
Hebei	Northeast Green (Leting)
	Flat Hat (Ginglong)
	Gianjinnian (Jixian County)
	Wudalang (Xuanhua)
	Waibozhang (Zhangjiakou)
Shandong	Zhuyeqing (Zhouping)
	sweet sorghum (Rushan)
	Sanbianse (Teng Xian County)
Shanxi	Sanchisan (Fengyan)
	Lishi Yellow (Lishi)
Jiangsu	Big Red Ribe (Bixian County)
	Black Willow (Fuyang)
Hu Dei	Damaonuo Glutinous (Mianyan)
Sichuan	Lantingxianfeng (Mian yan)
Guizhou	short stalk sorghum (Bijie)
	Sandu sorghum (Sandu)
Yunnan	Red Glutinous (Shaotong)
	Glutinous Sorghum (Li jiang)
The Guangxi Zhuang Autonomous Region	Jinxiu Sorghum (Jinxiu)
	Hexian sorghum (Hexian County)
Ganshu	Hongbaerqi (Ningxian)
	short Greybeard (Zhuanglang)
Shanxi	white sorghum (Shuide)
Ningxia Autonomous Region	Wawa (Pingluo)
Xinjiang Autonomous Region	Erect Codon (Tulufan)
	Jinghe Sorghum (Jing he)

TABLE 23. TYPES OF GERM PLASM RESOURCES USED AS R-LINES IN DEVELOPMENT OF CHINESE HYBRIDS (WANG AND QINGSHAN 1985).

			Type of R-line (%)			
Date	Combination #	R-lines	Local cv.	Inbred	Radiation	Foreign
pre-1980s	152	90	63	22	3	2
post-1980s	35	30	1	22	0	7

TABLE 24. SUMMARY OF NATIONAL COLLECTION FOR SELECTED SCREENING OF AGRONOMIC, BIOTIC, AND ABIOTIC CHARACTERISTICS (QIAO 1992, WANG AND SHOUEN 1983).

Agronomic descriptor	Notes	# Accessions identified
Tallest plant height	Height exceeds 400 cm with tallest being 450	110
Shortest plant height	Heights are below 100 cm with shortest being 63	49
Panicle length	Length of longest grain-type is 40 cm, while broomcorn exceeds 80	
Panicle weight	Exceeds 100 g with heaviest weighing 165.5	113
1000-seed weight	Exceeds 35 g with heaviest weighing 56.2	146
Short maturing types	Days to maturity is less than 100 d and the shortest is 80	900
Late maturing types	Days to maturity exceeds 150 days with longest 191	37
High protein content	Protein content exceeds 13% with highest being 17.1	1050
High lysine content	Content per 100 g of protein exceeds 3.5% with highest being 4.76	209
Low tannin content	Tannin content below 0.03% with the lowest being 0.02	30
Head smut resistance	Resistance to *Sporisorium reiliana.*	37
Aphid resistance	Reached grade-2 level resistance	5
Stem-borer resistance	Reached grade-1 level resistance	2
Drought resistance	Reached grade-1 level resistance	62
Water-logging resistance	Reached grade-1 level resistance	20
Poor soil tolerance	Reached grade-1 level resistance	374
Salt tolerance	Reached grade-1 level resistance	16
Cold tolerance	Reached grade-1 level resistance	15

source of genetic diversity can take place in the future.

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APPENDIX

TABLE A. CLASSIFICATION STANDARD OF COLD RESISTANCE.

Stage	Rating	Emergence rate (5)	Index ratio of E.R.	Ratio of seedling dry wt
Seedling	1	81–100	<2.00	>0.26
	2	61–80	2.01–2.30	0.21–0.25
	3	41–60	2.31–2.60	0.16–0.20
	4	21–40	2.61–2.90	0.10–0.15
	5	0–20	>2.91	<0.09
	Rating	Dry wt ratio of grain in ear		
Filling	1	>0.91		
	2	0.81–0.90		
	3	0.61–0.80		
	4	0.41–0.60		
	5	<0.40		

* All ratios are determinative value (stress) comparing with normal value (CK).

TABLE B. GRADING OF APHID RESISTANCE.

Rating	One plant	One leaf
1 = Highly resistance	1–60	1–40
2 = R.	61–300	41–200
3 = Mid-susceptible	301–600	201–400
4 = S.	601–1000	401–700
5 = H. S.	>1000	>700

TABLE C. GRADING OF STEM-BORER RESISTANCE.

Grading	Range of weighted average
1 = HR	<0.18
2 = R	0.19–0.30
3 = MS	0.31–0.42
4 = S	0.43–0.54
5 = HS	>0.54

Weighted average is the range of several damage measurements, some of which include number of damaged plants, number of insect entry holes, and diameter of holes.

TABLE D. RATINGS FOR DROUGHT.

Grading	% Grain yield reduction compared to check	Index of drought tolerance
1	<50	>0.50
2	51–70	0.30–0.49
3	71–80	0.22–0.29
4	>80	0.01–0.21
5	No grain yield	0

TABLE E. WATER-LOGGING GRADE.

Rating	A. Rate of yellow leaf in seedling (%)	B. Accu-mulation of dry mass weight/day (g)	C. Weight/ 1000 grains (g)
1 = HR	<5	<0.03	<0.9
2 = R	6–30	<0.12	1.0–1.2
3 = MR	31–50	<0.13	1.2–1.4
4 = S	51–90	<0.23	1.4–1.5
5 = HS	>90	<0.30	>1.6

A: Seedling stage means 5–6 leaf stage.
B: Middle stage means 10–11 leaf stage.
C: Last stage means maturing period.
All values mean measured value (stress) compared to normal value (CK).

TABLE F. SALT CONCENTRATIONS OF TEST PLOTS.

Treatment	Depth (cm)	Salt	$CO3^{-3}$	$HCO3^{-2}$	Cl^{-1}	SO_4^{-2}
Stress	0–15	0.5155	no	0.0542	0.246	0.0399
Normal (CK)	0–15	0.1735	no	0.10	0.016	0.0399

TABLE G. SALT-RESISTANCE GRADING CRITERIA AT SEEDLING (4–5 LEAF) STAGE.

Rating	Rate of emergence (%)	Rate of yellow leaf (%)	Rate of dried seedling (%)
1 = HR	>60	<5	<4
2 = R	40–59	5.1–10.0	4.1–5.0
3 = MR	25–39	10.1–15.0	5.1–10.0
4 = S	20–24	15.1–25.0	10.1–15.0
5 = HS	<19	>25.1	>15.1