Current Trends in Corn Production and the Seed Corn Industry in China

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To breed a crop effectively, you must understand the current agricultural system plus try to anticipate the situation expected in 10 or more years. Understanding the history of breeding and germplasm pools is important to devise a strategy.

History of Hybrid Seed Corn in China

Corn has been grown in China for centuries (Meng et al., 2006). Double Cross hybrids were widely adopted in China in about 1960 versus 1938 in the USA, but single crosses were widely adopted more quickly in about 1971 versus 1960 (Li Jiansheng, China Agriculture University; Lamkey and Edwards, 1999). Currently, over 95% of the corn planted in China uses hybrid seed. The remainder is typically in remote and/or high altitude environments. Significant activities in developing inbreds in China started in the 1940's. Many temperate materials from the USA were used early in these programs. Breeding was done by national, provincial, city, and town institutes, academies, and universities. Winter nurseries were utilized in southern China, especially Hainan, since the 1970's. In the past, all inbreds developed in China through public programs were considered "public inbreds", but after 1999, inbreds could be protected by PVP.

The history regarding developer, genetic background, date of development of older inbreds is not well documented. Teng et al. (2004) at China Agriculture University, using molecular markers, have grouped inbreds into Reid, Lancaster, Luda, and Tangsipingtou pools (Figure 1). Newer inbreds developed from Pioneer hybrids are grouped into Pioneer A and B pools. Suwan inbreds from Thailand have had been used in southern China and introgressed into temperate germplasm.

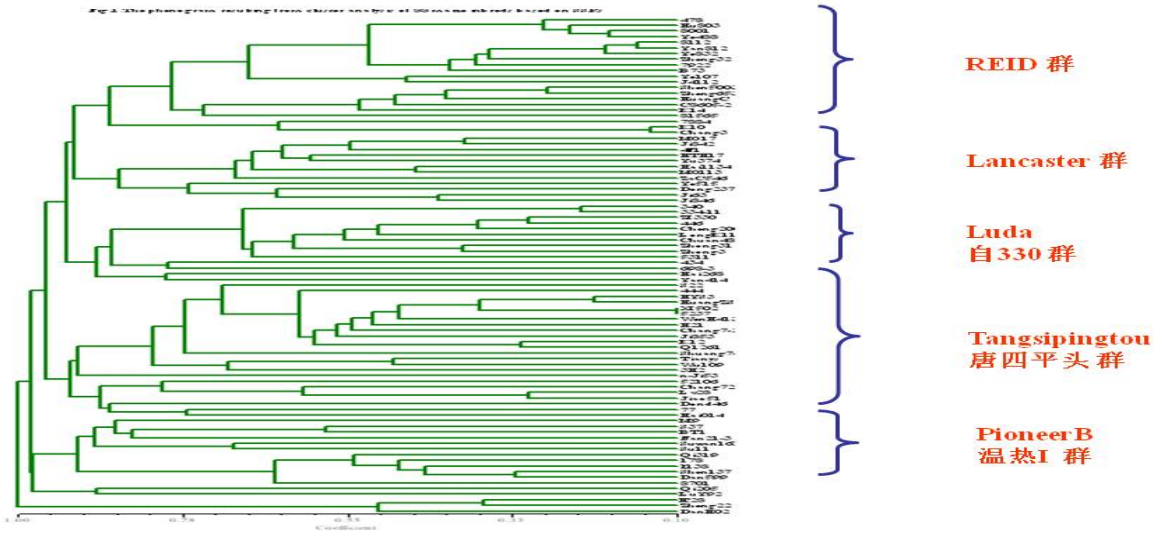

Figure 1. Cluster analysis of 84 Chinese inbreds, Teng et al., 2004.

Consolidation and privatization of the seed corn industry has been occurring for over 10 years. International seed companies can not sell seed of major field crops directly in China. Typically, joint ventures have been established with a China Partner who owns 51% of the assets. Pioneer first established a research station in Liaoning in 1997 and has formed joint ventures in China in 2002 and 2006. Monsanto established a JV in 2001. Syngenta established a JV with SanBei in 2008.

Historically, hybrid seed corn prices were very low which provided little incentive to invest in research and businesses. Now, prices are high enough on new, elite hybrids to encourage investments, but prices vary broadly for different hybrids.

Commercialization of corn hybrids in China requires approval through official Provincial or National Testing programs. Approval typically takes 3 years.

Geographic Production areas

There are 4 major production areas in China: Spring, Summer, Subtropical, and Tropical. These areas produce about 42, 32, 15, and 3 % of China's total corn production, respectively. Spring Corn planting and harvest dates are very similar to dates for the USA cornbelt. Hybrids as early as MG1 and 2 are planted in the northern areas of the spring corn area. In the summer corn regions, corn can be hand planted into the growing wheat crop in May or may be planted after the wheat is harvested in Late June. A crop of both corn and wheat is produced each year. Corn production is nearly impossible in dry western areas without irrigation. See Figures 2 – 5.

Production and Yields in China.

Through year 2000, the annual increase in corn yields were very comparable between the China (121 Kg/Ha) and the USA (129 Kg/Ha), but the average was much lower in China (5000 Kg/Ha) versus the USA (9000 Kg/Ha). See Figures 6 and 7.

China is second globally in corn production, harvesting 28.1 million Ha. in 2007 (69.3 million acres) versus the USA with 35.0 million Ha. (86.5 million acres). Area planted has increased in both countries, but the rate of yield improvement is lower in China (Figure 8). China produced 3 times more than Brazil which is #3 (Figure 9), (FAO, 2009).

There is major concern in China that yields in corn, rice, and wheat may not have increased since approximately 2000 (Figure 10. USDA, 2009, FAS).

There are many areas in China where corn is planted in extremely small and/or poor areas. Yields may be very low in these areas. Examples are corn planted up a steep ravine in a strip a few meters wide, hillside planting on slopes greater than 40 degrees, and high altitude corn planting by subsistence farmers. These systems would not be physically or economically possible in the USA. Also, farmers often plant corn in the poorer fields with better fields used for high value crops such as vegetables or rice. Including these lower yield production areas can explain some of the lower national yields in China.

Figure 2. Syngenta Corn PD System in China 2008

Figure 3. Corn maturity areas in China.

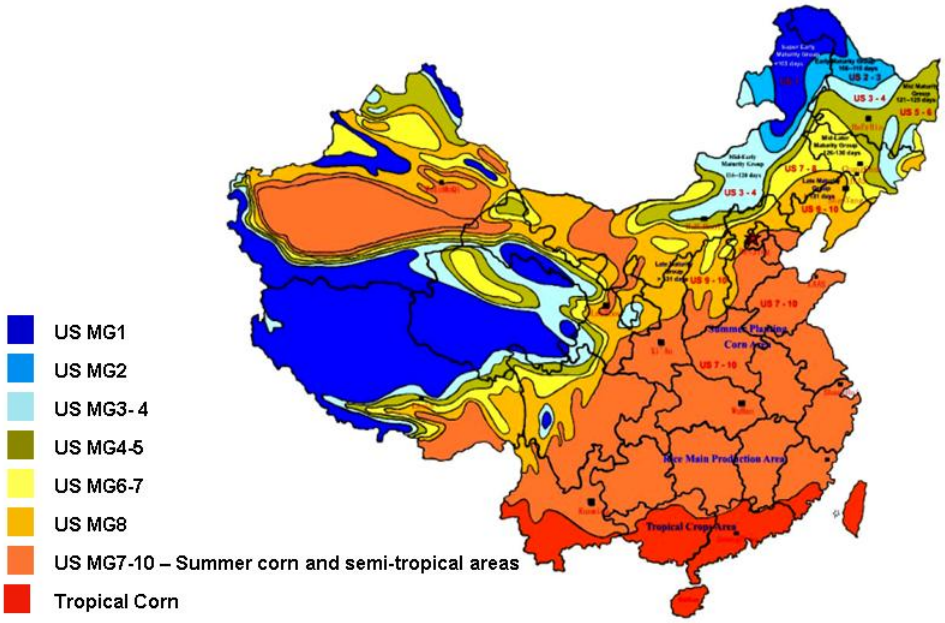

Figure 4. Major and Minor Corn Growing areas in China

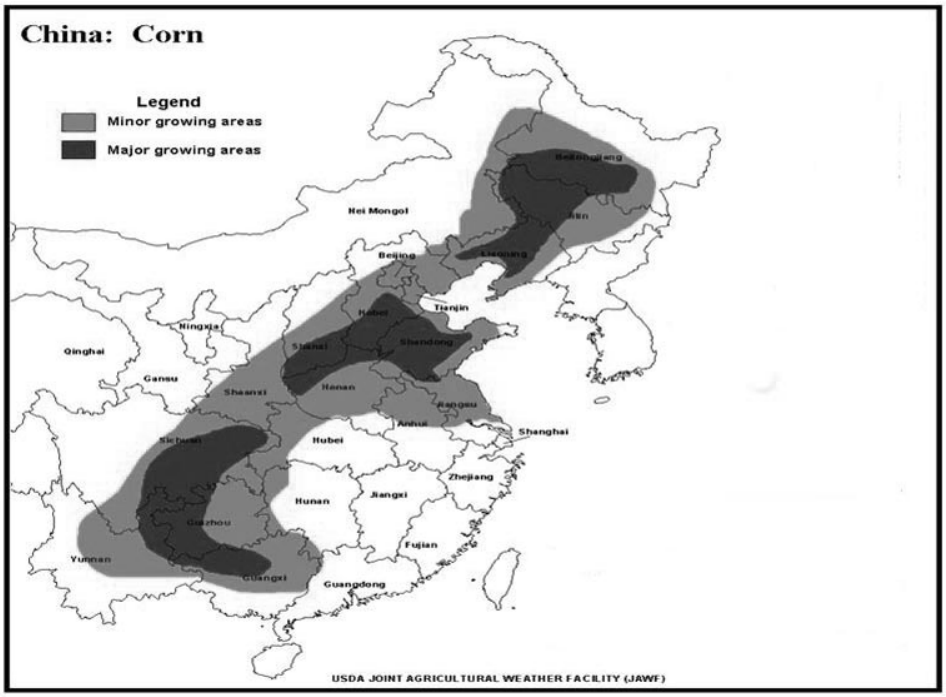

Figure 5. Rainfall map of China. Scribd. 2009

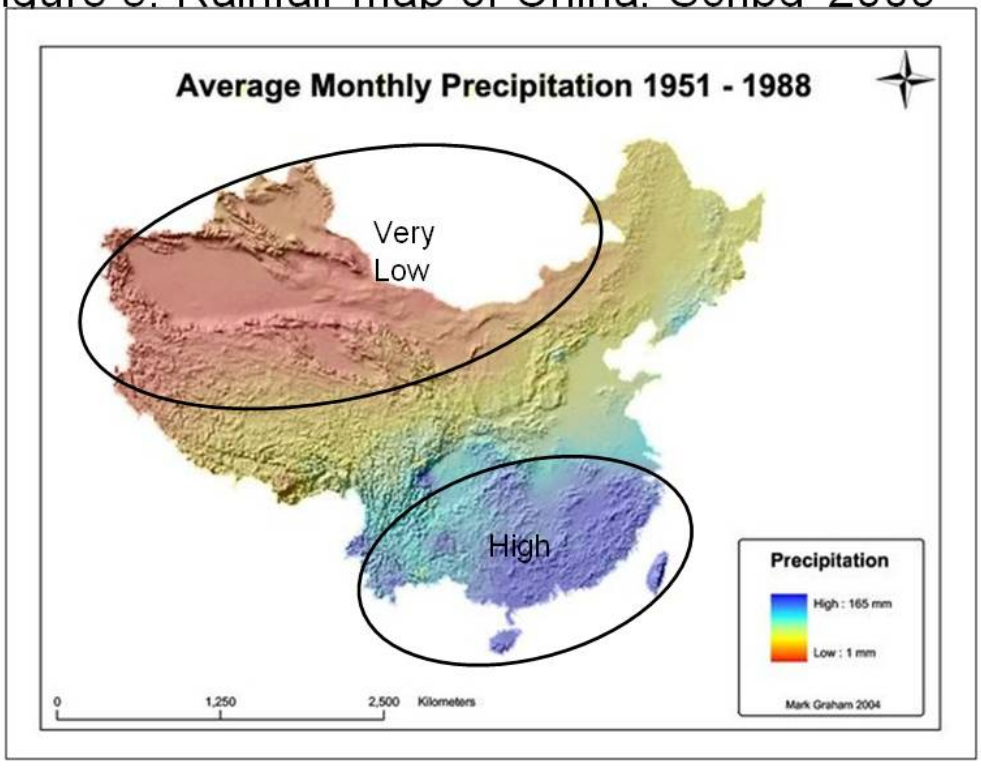

Figure 6. Historical Corn Yields in China
Graph from Li Jiansheng, China Agriculture University

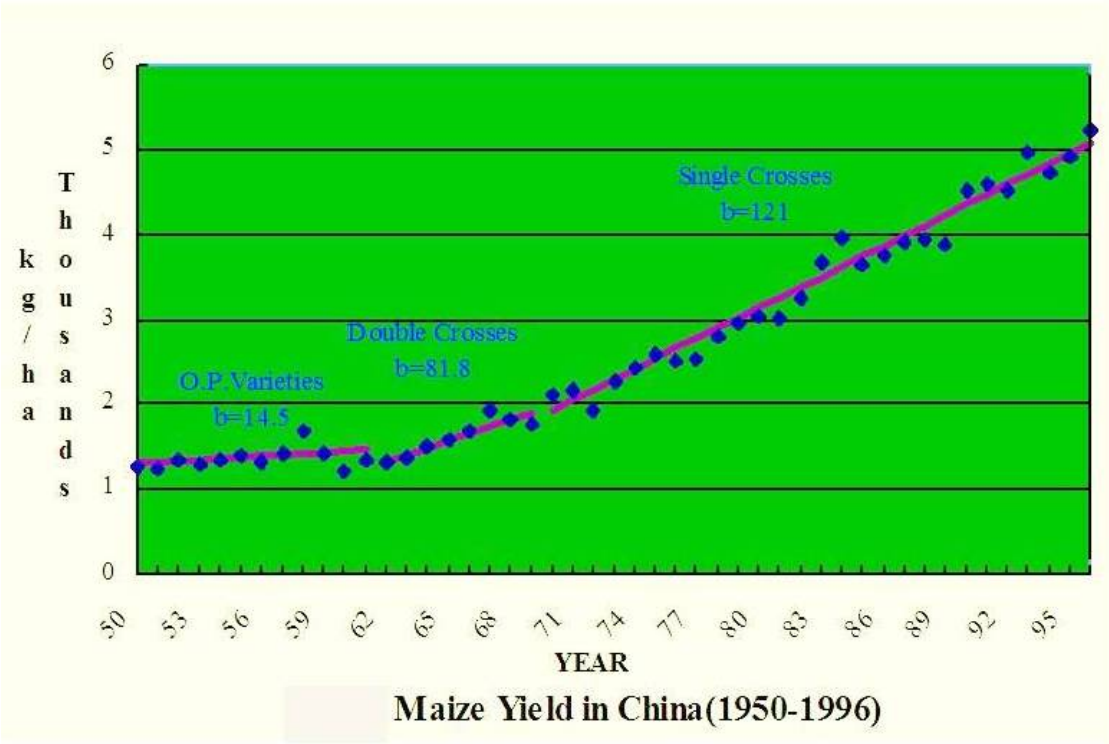

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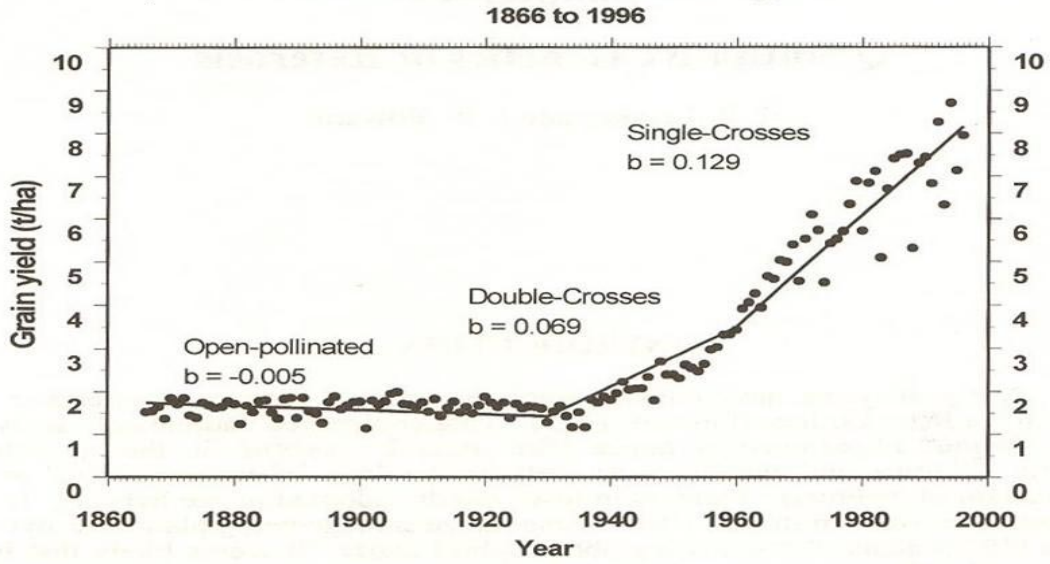
Figure 7. **U.S. Corn Yields and Cultivar Types**



Average U. S. maize yields from 1866 to 1996. Regression lines were splined together at 1930 and 1960, which corresponds roughly to when double-cross and single-cross hybrids started to become important. Regression coefficients are in t ha^{-1} yr^{-1}. Data are from the USDA, National Agricultural Statistics Service.

Seed companies in China

In China, a network of public county seed companies supplied seed in the past (Meng et al., 2006). Many have now evolved into private seed businesses. Mergers have occurred to leverage research, production, and sales activities. Much information is readily available on the internet.

Pioneer and Monsanto both have several research stations. Syngenta now has corn research stations in Heilongjiang, Jilin, Beijing, Henan, Guangxi, and Hainan (Figure 2). Seed Corn sales for international companies must be done through the Chinese JV partner. However, inbreds can also be licensed for use by other Chinese companies.

Corn Production and Management

Fields are typically small with most farmers having a few acres of land. Corn planting and harvest has been typically been done by hand. In many areas, especially the northeast Spring Corn area, ear harvest is done in early October with grain moistures up to 35%. In many areas, the ears may be dried along road sides for several days. Ears are stored in small cribs to dry. Shelling is done when the grain is at moistures that can be stored safely.

Plant densities are lower than in the USA: 45 to 55,000 plants/hectare are common whereas 75,000 plants/hectare or more (30,500 plants/acre) is common in the USA. Densities are increasing in recent years as farmers recognize that some newer hybrids may produce higher yields when planted at high densities. Currently, less than 50 % of the corn seed is treated. To minimize the risk of bad stand establishment, most farmers plant 2 or 3 seeds per hill. Extra plants are removed at early growth stages to get to the desired density.

Herbicides are used, but there is still great reliance on cultivation and hand weeding. Fertilizers, especially Nitrogen, are often sidedressed by hand in early vegetative stages. Nationwide, for all crops, Nitrogen, Phosphate, and Potash usage has increased by a factor of 1.7, 2.1, and 5.6 respectively in the last 20 years (USDA, 2009). Imports of potash exceed annual production internally (Jasinski, 2009) and are impacting global prices for potash. There is concern in China that conversion of fertilization into increased yields is lower than desired.

Irrigation – Approximately 45% all farm land in China is irrigated. Of that, approximately 55% is flood irrigated (USDA, 2009). Much of the corn in the summer corn area is irrigated. Excluding the summer corn area, most of the irrigation is used for higher value crops such as rice and vegetables. However, corn is irrigated in western areas with lower rainfall.

Drought is considered to be one of the greatest factors limiting yield in corn (Meng et al., 2006). The competition between cities, industry, and agriculture for water is recognized as a major challenge in China. Canals are being completed to bring water from southern China to northern China.

Stover Removal - In almost all areas of China, corn stalks are removed from the field at harvest time. This stover may be used for livestock feed or bedding, but is often used as a low grade fuel for heating rural houses. The long term impact of stover removal could have major impacts on soil quality in China. However, diseases may be reduced by stover removal, especially in areas of China with near-monoculture production of corn year after year.

Silage Corn – There has been nearly a ten-fold increase in milk production in China in the last ten years (USDA, 2009). Silage production has increased greatly in conjunction with milk production. Inner Mongolia, Heilongjiang, and Hebei produce 37% of the nation's total milk and supply much of the milk consumed in Beijing.

Diseases and Insects - Gray leaf spot, *Cercospora zeae-maydis,* is common through much of China. Northern Corn Leaf blight, *Setosphaeria turcica* (Luttrell) K. J. Leonard and E. G. Suggs, can do much damage in northeast China. Head Smut, *Sphacelotheca reiliana* (Kuhn) G. P. Clinton**,** can cause 100% yield reductions on very susceptible hybrids in some environments in northeast China. Various stalk rots and damage from the Asian Corn Borer, *Ostrinia furnacalis,* can cause extensive stalk lodging and yield reduction.

Mechanization in Corn Production - Simple corn planters have become more common in China in the last five years. Because of the difficult work, there has been a major increase in mechanization of soybeans, rice, and wheat harvest in that period. Four row ear harvesting systems are now being used in corn harvest. Some of these ear harvesters are quite similar in concept to the machines used in NAFTA for seed corn harvest. The first major adoption of these ear harvesters was in the summer corn area where rapid corn harvest was critical to allow wheat to be replanted quickly.

Usage of Corn Grain

Currently about 75% of corn grain is used for livestock feed. People still consume corn meal directly, but this is in stark comparison to 60 years ago when over 70% of corn grain was used for direct human consumption.

There has been a 4 fold increase in meat production in the last 20 years (USDA, 2009). In 2007, the USA was #2 globally in pork production, but China produced over six times more. Since 2000, **Corn Use** has exceeded **Corn Production** in China. In the period 1993 to 2005, use increased at 3.1% per year while production increased .8% per year (Table 1). This increase in production is due as much to the increase in production area as to the increasing performance of the hybrids during that period (Figure 8). China still exported more corn than it imported as recently as 2004-05, but ending stocks have been decreasing. To produce this quantity of meat, China currently imports approximately 75% of the soybeans used.

There are ethanol plants in China that utilize corn grain. Plans for additional plants producing ethanol for fuel were put on hold in the fall of 2006 when the international price for corn grain jumped. There is much alcohol from corn used for human consumption. Corn is also milled for corn meal, starch, and other industrial uses.

Internal Movement of Corn Grain – Approximately 30% of the corn is produced in northeast China (Liaoning, Jilin, Heilongjiang, and eastern parts of Inner Mongolia), while 6.9% of the hogs are in that area (USDA 2009). Corn grain is moved by train and/or ship to corn deficit areas of China.

Table 1. China Corn Supply and Use

http://www.fas.usda.gov/grain/circular/2004/05-04/graintoc.htm

Thousand metric tons

	Beginning stocks	Production	Imports	Feed Use	Total Dom. Use	Exports	Ending stocks
1993/1994	84,534	102,700	-	66,000	92,900	11,594	82,740
1994/1995	82,740	99,280	4,287	71,000	97,000	1,333	87,974
1995/1996	87,974	112,000	1,476	75,000	101,200	157	100,093
1996/1997	100,093	127,470	75	79,000	105,750	3,892	117,996
1997/1998	117,996	104,309	287	82,500	109,500	6,173	106,919
1998/1999	106,919	132,954	262	86,500	113,920	3,338	122,877
1999/2000	122,877	128,086	71	89,500	117,300	9,935	123,799
Average 1993 to 2000		**115,257**			**105,367**		
2000/2001	123,799	106,000	89	92,000	120,240	7,276	102,372
2001/2002	102,372	114,088	39	94,000	123,100	8,611	84,788
2002/2003	84,788	121,300	29	96,000	125,900	15,244	64,973
2003/2004	64,973	114,000	100	98,000	128,600	8,000	42,473
2004/2005	42,473	115,000	200	100,000	131,600	4,000	22,073
Average 2000 to 2005		**114,078**			**125,888**		

Figure 8. Corn Production Area(Bars) and Yields (line) in China (solid red) and USA (blue) - FAOSTAT

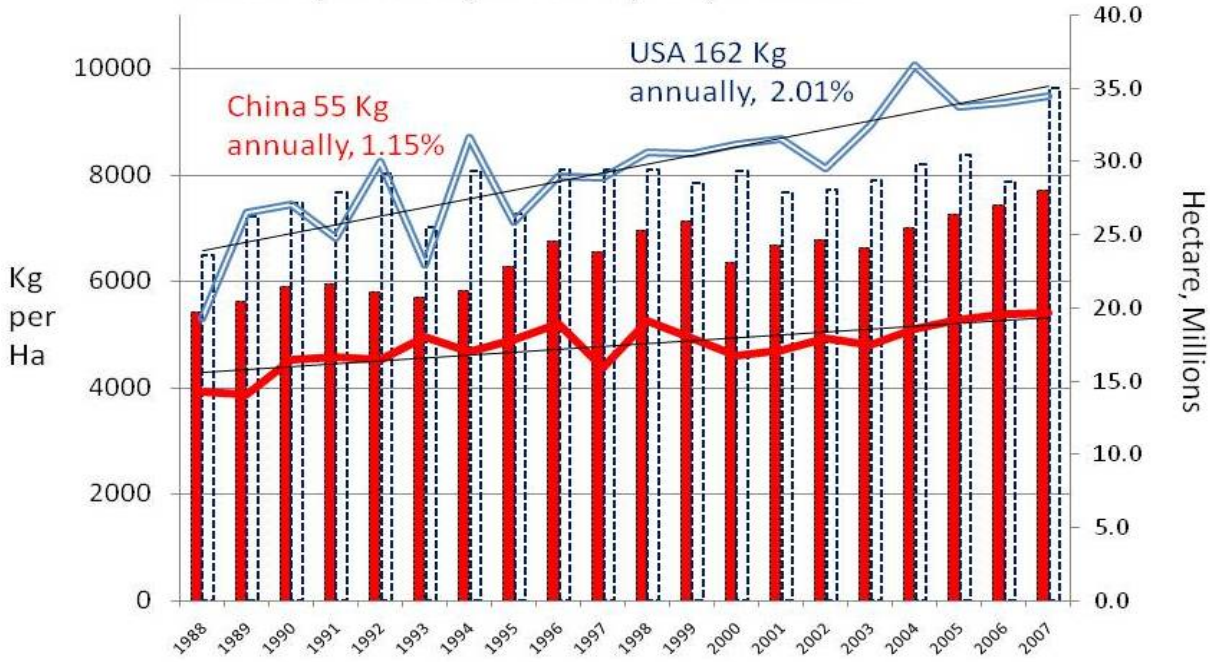
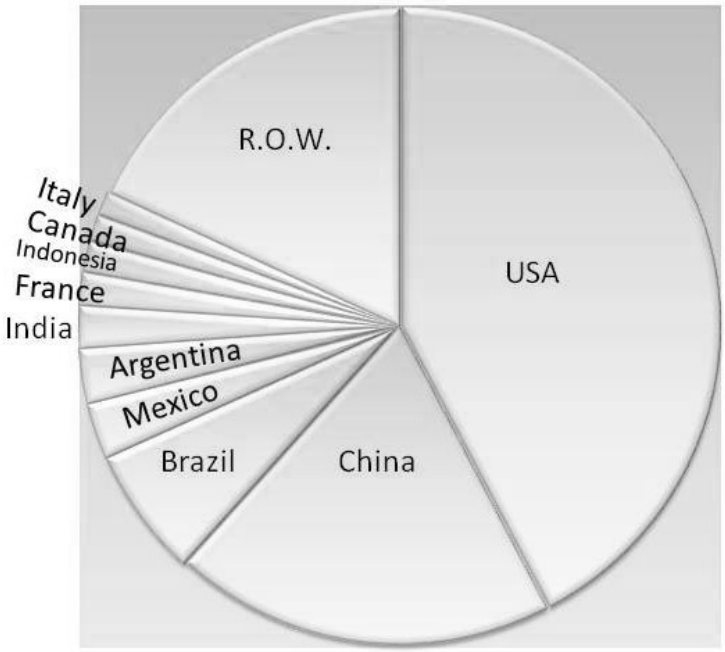


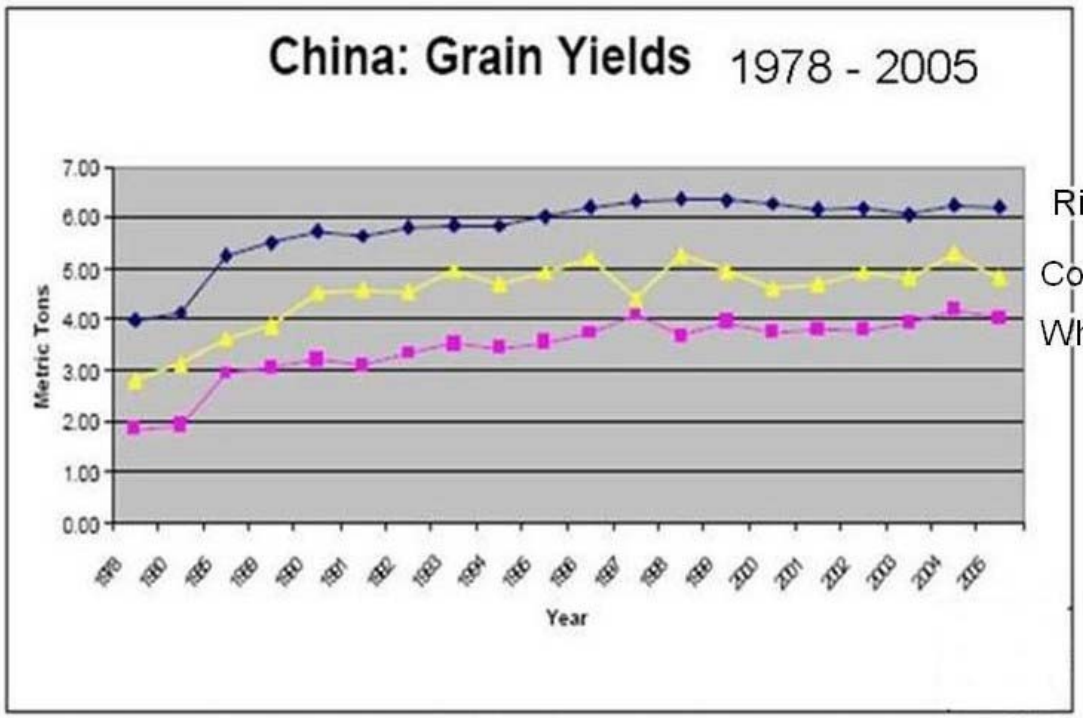
Figure 9. Global Maize Production – Top 10 countries vs.the Rest of the World. FAOSTAT



Global Total – 784.79 Million Tonnes

United States	332.09
China	151.97
Brazil	51.59
Mexico	22.50
Argentina	21.76
India	16.78
France	13.11
Indonesia	12.38
Canada	10.55
Italy	9.89
ROW	142.16

Figure 10. Yields of Rice, Wheat, and Corn in China



Data from National Statistical Bureau. Data for 2004 and 2005 are estimates by FAS Beijing

Education in China

There are approximately as many people who are working on corn breeding in China as in the rest of the world combined (Henry Lu, Syngenta Seeds China). Historically, many plant breeders in China had little formal education in plant breeding. However, now many plant breeding students graduate with a MS degree annually. PhD degrees are also granted in plant breeding in China. As in the USA, education in Biotechnology is very common in China, but there are many graduates with education in Plant Breeding.

Prior to about 1995, many students who had studied abroad delayed returning to China, in some cases permanently. In the last 10 years, with the strong economy in China, numerous professionals with valuable education and experiences are returning to work in China.

A record 5.6 million students received a college degree in China in 2008 (The Economist, 2009). Based on information from the US Department of Education (2009), this is nearly as high a percentage relative to population as in the USA.

Chinese students start studying English in primary schools. College entrance exams strongly emphasize knowledge of English. English is the international language of business in China.

There are few farmers in China with greater than a high school level education (Meng et al., 2006). In the USA, 25% of farmers have college degree (USDA, 2009).

Intellectual Property in the Seed Corn Industry

As the seed industry has evolved recently, laws for protection of germplasm have been created.

Seed Import / Export

Laws regarding vegetable and flower are greatly different from those for major field crops. For example, hybrid vegetable seed produced in western China is able to be shipped for sale globally.

For importation into China, corn seed must be tested for specified pathogens and freedom from GMO's. Corn seed MAY NOT be shipped from the USA to China, or vice versa, but seed produced in countries such as Chile, France, the Philippines, and India can be shipped to China. The process of getting import permit, testing, and shipping can often take over 3 months.

Hybrid corn seed can be exported from China, but does not occur in great volumes. To export inbreds, the Chinese Ministry of Agriculture must approve each one individually to assure that none are/or contain Chinese germplasm.

Chinese PVP is based on the 1978 Act of the UPOV (International Union for the Protection of New Varieties of Plants) Convention. Protection by using patents is not possible in China. On April 23, 1999, China became the 39th member of UPOV. Information in English can be found at the UPOV and Chinese PVP websites. Protection through PVP is available for both hybrids and inbreds. An inbred does not have to be protected to get protection for a hybrid produced using that inbred. Foreign inbreds may be granted protection by Chinese PVP.

Chinese PVP provides protection from unauthorized use of protected inbreds by others in producing commercial hybrids. Utilizing Chinese PVP laws, protection of inbreds and hybrids has been enforced (Zhang, 2007). However, based on the provisions of the 1978 UPOV act, even protected lines can be used by others to develop new inbreds.

Based on the 1411th meeting of the Judicial Committee of the Supreme People's Court effective February 1, 2007 (The Supreme People's Court (China), 2007), it appears that: molecular markers can be used in enforcement; and that protection against repeated crossing is prohibited. This may provide protection against others creating a close version of a protected inbred.

Much of the hybrid seed production of temperate hybrids is done in the western desert areas of China. These areas with high solar radiation and irrigation produce high quality seed. Better control over germplasm security in these areas is possible due to the isolation and low density of human population (Figure 11).

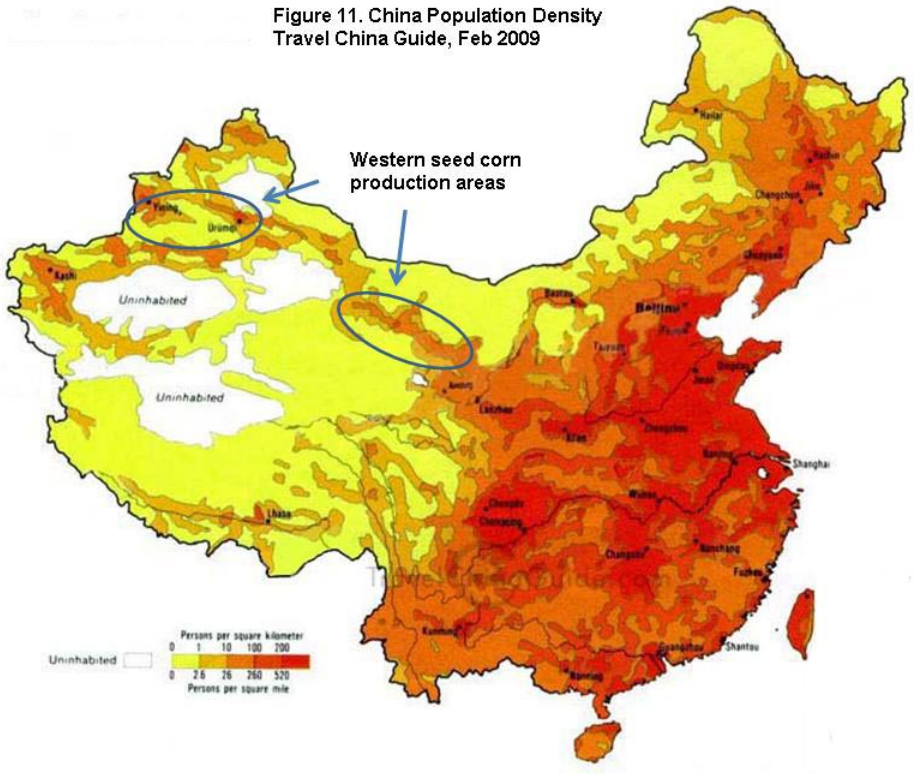


Figure 11. China Population Density
Travel China Guide, Feb 2009

Biotechnology and GMO's

There is much research and field testing of various GMO plants in China.
"China has so far approved transgenic cotton, potato, pimiento and morning glory seeds, but only transgenic cotton seeds have proven popular with farmers" (Wu, 2008).
Cotton, Tomato, Poplar, Petunia, Papaya, Sweet Pepper are grown on 3.8 Million Ha in China (James, 2007). Transgenic cotton is grown in China on nearly 70 % of the cotton area.

The capabilities of biotech research groups in China are already being utilized. "China (Mainland) already has 80% of the biotech cotton area under a locally developed Bt gene" (National Institute for Biotechnology and Genetic Engineering, 2007).

So far, transgenic rice and corn have not proceeded past regulated field trials.
There are numerous collaborations, joint ventures, etc. established by international groups with Chinese partners. Syngenta is in the process of building major global biotech research center in Beijing.

Challenges for the Future

China needs to identify and reduce the impediments of improving crop yields. Meng et al. (2006) identify many of these issues.

Enhanced IP controls to reduce risks of germplasm exposure could entice more investment into breeding in China for both Chinese as well as international companies.

The ability to export germplasm developed in China will help Chinese breeding programs to have a more global impact. Currently that is difficult even if the new germplasm does not contain any Chinese germplasm.

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