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The Potential Impact of Advanced Maize Genomic Technology on Corn Cultivation in Northern China

Introduction

China is the most populous country in the world, with a current population of approximately 1.32 billion.[1] China has a very rapidly growing economy. With a growth rate (GDP) of 11.7% for 2007[2] and an estimated GDP of 9-10.7% for 2008, China's economy is one of the fastest growing in the world[3,4]. The income for both China's farmers as well as its city-dwellers is rising. For 2008, annual per capita disposable income is projected to increase by 7.3% in rural areas and by 11.1% in urban regions[3].

With more money to spend, Chinese people are buying greater quantities of and more expensive types of goods including food. And in regard to food, they are consuming greater quantities of meat, previously considered almost a luxury[5]. According to a report in *Biofuels Digest*, the per capita meat consumption in China has increased 112% from 1995 to 2007[6]. It is estimated that for every 1% increase in take-home pay, average Chinese household meat consumption rises 2%[7]. The price of pork, one of the most popular meats eaten in China, has increased 62-98% during the last quarter of 2007, compared with the same quarter in 2006. One of the factors that was responsible for the rise in the cost of pork was a 25% rise in the cost of animal feed (corn or "maize") compared to two years ago[8]. Rising food prices are becoming an important cause of China's rising inflation rate in 2008[9].

Currently, China is the second largest consumer of maize in the world. It is also the second largest producer, after the United States. Maize is used primarily in China as an animal feedstock. It is also used as a source for food and industrial products such as sweeteners, starch, and industrial alcohol. Only 7% of the maize crop is sold directly for human consumption. Approximately 2.6, 6.5, and 7.6 pounds of feed are required to produce one pound of chicken, pork, and beef, respectively[9],. More meat being consumed results in an increased demand for more meat production and in turn an increased demand for maize as a feedstock. This increased demand and competition for maize has recently caused the Chinese government to put a halt to corn-based ethanol production in China[10].

In view of the increasing demand for maize, the Ministry of Agriculture in China has announced plans to expand national maize output to 150 million tons in 2010, up from 144 million tons in 2006[10] and 146 million tons in 2007 [11]. To achieve this goal of increased maize production on the land suitable for growing crops, the government is trying to mechanize farm operations and supply farmers with seeds from higher-yield varieties of maize[10]. I thought it would be interesting to investigate the potential impact of advanced seed technology on corn production in one of the major corn production centers in China, Hebei Province.

Geographic Summary of Hebei Province

Much of China's corn cultivation occurs in Northeast China and the North China Plain, including Hebei Province[13]. Hebei Province is bordered on the east by the Bohai Sea. It includes the capital city of China, Beijing, and Tianjin, a large port city. The Taihang Mountains rise in the western part of Hebei Province, and the Yan Mountains lie in northern Hebei. The Great Wall of China runs through northern Hebei from east to west.[14] At the end of 2005, the total population of Hebei province was calculated to be about 68.5 million[15].

The plains of Hebei Province are used for growing crops such as wheat, cotton, maize, tobacco, peanut, sesame, walnut, persimmon, and date. The main cereal crop is wheat.[16] Hebei Province experiences

periods of intense heat and frequent droughts as well as monsoons and floods. As noted below, there have been concerns raised recently about the water supply in Hebei Province.[17]

Demographic Summary of Hebei Province

About 45% of the working Chinese population is employed in agriculture.[20] This compares to about 14% of the working US population employed in farming and all related activities in 2002.[21] According to recent information from the USDA Economic Research Service, nearly all maize grown in Hebei is grown on small farms due to the fact that land is assigned to village families by the government based on the number of individuals in each family. A number of farmers do rent land from their neighbors but few statistics are available on this practice[22]. Data from 2006 regarding cotton farming indicate that most cotton farms are relatively small, 0.3-0.6 hectares (0.7-1.5 acres) in size, and are farmed by families.

Available information from the China 2000 Census reveals that the average family in Hebei Province consists of three to four residents The majority of households contain members of two generations[23],ranging from 15-64 years of age.[24] The amount of living space is usually 20-30 sq. meters (approximately 200-300 square feet) per person, less than half of that for the average American (approximately 721 square feet per person).[25] Annual income per household per the 2000 Census was 2000-3000 yuan[26] or about $250 to $375. Approximately 40% of per capita income is spent on food, which is four times the percent of disposable income spend on food in the United States[27]. The Hebei diet is largely wheat-based and includes steamed bread as well as potatoes, corn, and soybeans. Meats consumed include pork, beef, and mutton, poultry, and eggs.[18,28,29] Most vegetable, hog, and chicken farming is done on a small scale.[29] Although the rural population of China spent relatively little in absolute terms on food (approximately $107 annually per capita in 2003, compared with approximately $5,000 per capita in the US in 2002), the population is generally not malnourished, with a daily average intake of 2600 calories. Subsistence farming seems to be declining, as farmers grow more cash crops and livestock for sale, or migrate to the city to earn money which they send home to their families.[19] In terms of education, the illiteracy rate is quoted at five to ten percent in 2000 with improvement noted from the 1990 census.[29]

A number of factors may affect farm productivity and income in Hebei province. These include varying crop prices, the labor intensive nature of family farming, water-related issues including flooding and drought.[31,32] , and limited access to advanced seed technology.

The Current Status of Access to Advanced Technology Maize Seed in Hebei Province

To date, China has not allowed planting of genetically modified maize[22]. Reported maize yields for China in 2007 range from 5.4-5.5 metric tons/hectare (approximately 87 bushels/acre) , compared with yields of 9.3-9.5 metric tons/hectare (150 bushels/acre) in the United States[34]. Although seed technology may be one factor underlying this yield difference, there are many other factors which may influence yield (including soil quality, water, and pest issues as well as available fertilizer and mechanization resources), and it is difficult to attribute yield differences to available advanced seed technology alone.

There is some indirect evidence regarding adoption of new corn seed technology in China. Several major international biotechnology companies have increased their educational, research, and marketing efforts in China, forming joint ventures with Chinese companies to develop and market new seed varieties. Monsanto funded the establishment in 2001 of the Peking University-Yale Joint Center for Plant Molecular Genetics and Agrobiotechnology, and continues to support this center[36]. In 2007, Syngenta formed a five-year partnership with the Institute of Genetics and Developmental Biology of the Chinese Academy of Sciences, directed towards developing new traits for multiple crops for commercialization in China and beyond[37]. DuPont-Pioneer formed a joint venture named Pioneer Shandong Denghai Pioneer Seeds Company in 2003[38], and in 2006 became a participant in a joint venture named Dunhuang Seed

Pioneer Hi-Bred Company, with the goal of developing and distributing high-yield spring corn hybrids for sale beginning in 2008[39].

A genetically modified maize strain containing phytase, an enzyme which improves feed maize utilization and decreases phosphorus excretion by animals, has recently been developed by a Chinese agri-technology company, Origin Agritech Limited, and is scheduled to be released in 2009[33]. This company was founded in Beijing in 1997 with the mission to develop and commercialize new varieties of crop seed through a network of over 3,000 distributors throughout China and Southeast Asia. As of June 2008, Origin Agritech's portfolio included 58 corn seed and 15 cotton seed varieties. Several hybrid corn seed varieties were developed specifically for planting in Hebei Province[40]. In addition, most provinces, including Hebei Province, have local seed companies involved in corn seed development and/or distribution[22].The potential interest among small farmers in this technology is reflected in the story of a small farmer in Jilin Province (a major corn-producing region in Northeastern China) who decided to change to planting an oil-rich seed type on learning of the potential advantages of this variety[41].

Potential Advantages of Advanced Corn Seed Technology in China

Although more costly at present, there are a number of potential advantages to planting advanced corn seed varieties in China. The use of genetically modified varieties containing Bt may make maize resistant to insects such as corn borer, and thereby increase yield. Other modified varieties of maize might include 1) improved drought resistance or 2) higher-oil content.

Drought Resistant Maize

Maize is a relatively water-intensive crop[37]. Maize plants are most sensitive to water depletion during the period from the onset of tasseling to blister kernel development (40-80 days after plant emergence). This period of greatest water stress sensitivity generally corresponds in the Northern hemisphere to the warm months of July and August[42].

Water scarcity is a world-wide problem. UN-Water recently summarized issues associated with water scarcity, and noted that a major 2007 study showed that one third of the world's population may face water shortages due to either physical scarcity of water or economic barriers to obtaining water access. Problems associated with water scarcity include increasing water pollution, decreasing groundwater and river levels, and unequal allocation of water resources between competing water users.[43]

While China has approximately the same amount of total exploitable water resources as the United States (2,800 billion cubic meters per year), due to China's larger population the per capita water supply is only one-fourth that of the US. Also, water resources in China are unevenly distributed geographically, with 90% of the water in Northeast China and in parts of China south of the Yangtze River. The agricultural regions of the North China Plain have only one-tenth of world per-capita water levels.[44] The Chinese Ministry of Agriculture has classified 70% of farmland in China as dryland.[45] Although flooding is also a problem in China, economic losses from drought are greater, totaling approximately $35 billion per year in the 1990's compared with losses of $10 billion from flooding. The area affected by drought has increased steadily from the 1950's through the 1990's.[45]

Groundwater levels are dropping, and concerns have been raised regarding water pollution and water quality.[46-48] Severe dust storms originating in the deserts of Inner Mongolia and occurring approximately ten times yearly may affect the Northern plains, contributing to increasingly sandy soil which is not well suited for agriculture.[45,50] In early 2008, continuing drought conditions in Hebei Province resulted in drinking water shortages confronting 250,000 people[56].

There have been a number of academic and/or industrial research programs directed toward identifying drought-resistance traits and developing more drought-resistant corn varieties. As noted above, Syngenta has entered into a research agreement with the Institute of Genetics and Developmental Biology in

Beijing, with one of the major areas of interest being the identification and potential commercialization of drought-tolerance traits[37]. Pioneer[57] and Monsanto[58] are actively pursuing development of drought-tolerant corn seed with projected commercial release dates 5-7 years and 1-2 years in the future, respectively.

High-Oil Content Maize

The average maize kernel consists of about 70-75% starch, 8-10% protein, and 4-5% oil[59]. Usually, if the level of starch in the kernel is higher, the levels of protein and oil are lower. If the level of oil is higher, the level of protein will also usually be higher. Different levels of starch, protein, and oil in corn kernels reflect specific genetic characteristics known as quantitative traits[59].

High oil content may be a desirable characteristic of maize used for animal feed due to the higher energy density of this higher variety of maize. High oil levels including high levels of oleic acid, a monounsaturated fatty acid, may be associated with positive human health benefits compared to foods containing saturated fats or polyunsaturated fatty acids. Despite these potential advantages, however, high-oil containing maize has generally not been grown commercially due to lower yields associated with these varieties[60] .

Recently, agricultural scientists in China have developed a new strain of maize, Yunrui-21, which combines a high-oil content (6.06%) with a good yield (approximately 130 bushels/acre)[61]. In addition, several other strains of high-oil maize have undergone genetic analysis in attempt to isolate the genetic variation responsible for high-oil content. These include Illinois High-Oil (IHO) and Alexho Single-Kernel (ASK). In these varieties, a mutation was found involving an insertion of phenylalanine F469 in the acyl-CoA:diacylglycerol acyltransferase (DGAT1-2) gene[60]. This gene may be a promising target for future efforts to genetically modify maize for enhanced oil production.

Impact of Advanced Maize Seed Technology on Maize Cultivation in Hebei Province

There are several potential advantages which may be associated with the introduction of advanced maize seed varieties into Hebei Province. These include (1) reduced crop losses secondary to insect pests and (2) stable or increased yields in the setting of drought compared with the use of conventional seed varieties. In addition, the use of high-oil content corn might allow small scale farmers to receive higher prices per bushel for maize used as animal feedstock or processed for industrial applications such as corn oil production. Although there is currently a moratorium in China on the use of maize for ethanol production, depending on future market trends, cultivation of high-oil content maize might allow small scale farmers to diversify into production of biodiesel.

Recommendations Regarding Implementation of Advanced Maize Seed Technology in Hebei Province and the Roles of Corporations, Government, and Non-Governmental Organizations

In my opinion, the introduction of advanced maize seed technology in China should not occur in isolation, but should be combined with efforts to address other potential agricultural scientific and economic factors which may interfere with the successful implementation of these new technologies. These factors include:

- Availability of arable land, fertilizer and water supplies (including irrigation as required) and pest control measures
- Availability of sufficient acreage of arable land to individual farmers/families to enable economies of scale; availability of adequate skilled labor and mechanization

- Availability of seed varieties (either hybrid or genetically modified) adapted to local growing conditions; protection of related intellectual property

- Government policy facilitating the use of new seed varieties after appropriate testing (at present, the approval process for new maize seed introduction is among the most rigorous of all regulatory processes in China[31])

- Availability of cost-effective financing options to individual farmers/families; availability of transportation, storage, and processing infrastructure for harvested crops

Addressing these issues would most likely require cooperative efforts between local, provincial, and national governments, academia, domestic and international industry partners, and non-governmental organizations such as the World Bank.

Summary

China is the world's most populous nation and the second largest consumer and producer of maize. The Chinese economy has been growing at an extremely fast rate. With this rapid economic growth, there has been an increasing demand for and consumption of meat among the Chinese population. This increased demand for meat, as well as increasing requirements for maize for other agricultural and industrial purposes, will result in an overall increased demand for maize.

At present, maize production in China is barely able to keep up with current demand, much less anticipated future demand. Although data are limited, most maize cultivation in China appears to occur on a small-farm basis, and access to advanced maize seed technology including, in particular, genetically modified maize strains, has been limited. The introduction of advanced maize seed technology may improve yield by improving pest and drought resistance as well as by increasing oil content. Improved yield and the availability of maize with a higher oil content may improve both food availability as well as the availability of maize for industrial purposes including possible biodiesl production. Modifications such as these may ultimately lead to enhanced food and economic security for small-scale maize farmers in China.

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