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Review

Meeting demands for increased cereal production in China

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ABSTRACT

Meeting demands for increased cereal production in China is a great challenge and this paper provides updated information on cereal production and the potential adaptation of cropping systems to climate change, as well as on progress in improving yield potential and developing molecular markers and GM cereals in China. Maize production and soybean imports are increasing significantly to meet the strong demand for feed by a rapidly growing livestock industry. Extension of the rice and maize growing seasons in northeastern China and improvement of the cropping system through delayed wheat planting have contributed to improving cereal productivity despite changing climatic conditions. Significant improvements in yield potential of rice, maize, and wheat have been achieved. Comparative genomics has been successfully used to develop and validate functional markers for processing quality traits in wheat, and also for developing new varieties. Although transgenic *Bt* rice and maize, and maize expressing phytase have been developed, their commercialization has not been officially permitted. International collaboration has contributed significantly to cereal production by providing germplasm and improved crop management practices. Full integration of applied molecular technologies into conventional breeding programs and promotion of lower-input technologies, will play a key role in increasing and sustaining future cereal production.

1. Introduction

Over the past six years, food prices have been more volatile than over several previous decades. Feeding the world through increased cereal production should be listed as a global priority, although food safety and health issues, particularly in developed countries, are also important (Economist.com/special reports, 2011). Based on a 2012 FAO projection, the global population will increase from 6.58 billion to 9.36 billion from 2005/07 to 2050, and during this period world cereal production is projected to grow at 0.9% annually (i.e., from 2.068 billion tonnes to 3.009 billion tonnes). The significant increase in population, a slight increase in consumption per capita, a significant increase in consumption of livestock products, and the use of cereals for biofuel will be the main drivers of change (Alexandratos and Bruinsma, 2012). This means that average global cereal yields must increase from 3.32 t/ha in 2005/07 to 4.30 t/ha in 2050, of which wheat yields are projected to rise from 2.8 t/ha to 3.8 t/ha, rice from 4.1 t/ha to 5.3 t/ha, and coarse grains, mainly maize, from 4.7 t/ha to 6.1 t/ha. Achieving such increases in production will be very challenging due to limited land and water resources, soil degradation, salinization of irrigated areas, climatic vulnerability, competition from cash crops, urbanization and other land uses. Ray et al. (2012) reported that across 24–39% of the maize, rice, and wheat growing areas, yields have either not improved or declined, indicating the huge challenge of satisfying the increasing global demand for agricultural products. Meeting this demand will therefore require new investment in less favorable regions as well as strategies aimed at increasing yields in favorable environments. China and India, as the two largest developing economies, will play key roles in meeting the demands for cereal production globally. In this paper we will focus only on cereal production in China. Some of the challenges and opportunities facing India and some comparisons between India and China can be found in Lumpkin (2013).

China has always had food security as a national priority, since it has to feed 20% (currently 1.3 billion) of the global population with

Abbreviation: GM, Genetically modified; GWAS, Genome wide association study; QTL, Quantitative trait locus; SNP, Single nucleotide polymorphism; SSR, Simple sequence repeats.

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Fig. 1. The People's Republic of China, adapted from He and Bonjean (2010).

about 5% of the planet's water resources and 7% of the arable land (Zhang, 2011). The total arable land is about 120 million ha, or less than 0.1 ha per person which is far below the world average. China's water resources are unevenly distributed in location and seasonal availability, and the total water resources per capita are about one-quarter of the world average. However, China's progress in cereal production has been internationally recognized since the establishment of the People's Republic of China in 1949. Total "grain" production, including cereals, soybean, potato and sweet potato (based on conversion factors used in China, 5 kg of potato and sweet potato are equivalent to 1 kg of cereal grain), was a little over 100 million tonnes in 1949 and reached 500 million tonnes in 1998, while per capita grain production increased from about 200 kg to about 400 kg in the early 1990s. This was accompanied by a 2.5-fold increase in population and a 4.5-fold increase in grain production (Zhang, 2011), largely achieved by technological changes such as adoption of improved varieties (including hybrid maize and hybrid rice), improved cropping systems, and much greater use of irrigation, fertilizers and pesticides. Increased grain production was also the result of policy changes, particularly after China adopted its open policy in 1978, which gave farmers more individual options and responsibility.

China's demand for cereal consumption will increase significantly in the future. Although there are no projected figures for each cereal for 2030–2050, Zhou et al. (2012) reported recent trends in China's food consumption and made projections of production and trade of major cereals and crops in China to 2020. Assuming that grain production per capita will increase from the current 400 kg–470 kg in 2033 (Wang et al., 2010), grain production will need to increase by at least 35% over the next 20 years (Zhang, 2011). This is based on population projections to 2030 and significant increases in demand for livestock and fruits and vegetable products, and also on the rapid pace of urbanization. China's population is projected to reach a peak of around 1.45 billion in 2030. Based on a 2009 report from the Chinese Academy of Science (Anonymous, 2009), the average per capita consumption of vegetables and sugar will increase by 50% from 2004 to 2050, during which the average annual per capita consumption of poultry meat, milk and dairy products, and aquatic products will increase from 41 kg to 84 kg, 15–16 kg to 100 kg, and 15–16 kg to 48 kg, respectively. The proportion of cereals used for human consumption will decrease from 49% in 2010 to 43% in 2020, but that of cereals used for animal feed will increase from 36% to 41% during the same period (Wang, M.H., unpublished data). Meeting the demands for cereals will be a great challenge since it must be achieved with less land, labor and inputs, and with less impact on the environment. When Lester Brown asked "Who Will Feed China" in 1995 (Brown, 1995), the whole world was listening and China was shocked. China's food security could be even more challenging if climate change brings unpredictable droughts and rainfall patterns and increased occurrence of biotic stresses. However, it must be pointed out that much more effort is needed for a reasonable projection on Chinese cereal production and demands since there is a significant imbalance between current trends and the project demands.

The previous target for food self-sufficiency was around 95%, but this could decrease to 90% in the near future. In 2012, around 11% of total agricultural products consumed in China were imported, and it is likely that China will need to import more in the future. China's food security has also become an international issue since increased imports of cereals by China, even if only a small percentage of the Chinese domestic market, could significantly