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Crop improvement for enhanced grain quality and utilization

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Abstract

Cereal grain based foods are very diverse, ethnically determined, and influenced by concentration and composition of grain constituents. It is now well recognized that grains based food products in addition to meeting the calorific requirements should also be enriched in grain constituents that prevent diseases and promote human health and well being. In the 1st ICC India Grains Conference session 'Crop improvement for enhanced grain quality and utilization' presentations addressed both the traditional and current global and India specific cereal grain quality objectives and strategies to meet the challenges of dynamic grain quality requirements.

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Introduction

Cereal crops such as wheat, maize, rice, barley, sorghum and millets are staple food crops which contribute more than fifty percent of calories in the human diet. Cereal crops are grown over a diverse range of climatic and edaphic zones from the tropics to the edge of the Arctic Circle. Global cereal production has more than doubled during the last forty year period from 1961 to 2001, and modest gains in production have been achieved over the last few years (FAO Crop Prospects and Food Situation, No 3, October 2011). Cereal crops exhibit genetic diversity for grain characteristics including morphology, proximate composition, milling properties and end use quality Also, cereal grain based foods are diverse and ethnically determined which are influenced by grain constituents and climatic conditions. During the last decade it has also become evident that in addition to being an energy source, cereal grain constituents play an important role in the prevention of many diseases and promotion of overall human health. Recent advances in genomics technologies and functional studies have unraveled the genetic factors underlying several major and minor grain components which can be manipulated through biotechnological /technological approaches for human good. All presentations discussed several of the factors mentioned above.

Cereal grain quality improvement research in India

Dr S.K. Dutta (ICAR, India) presented recent strides made by researchers at the Indian Council of Agricultural Research (ICAR) in increasing yields of field crops in India, which saw cereal production exceeding 215 million tonnes in the year 2011. He also emphasized India's commitment to agriculture which is reflected in more than a billion US dollars being spent by ICAR. Various aspects of grain quality improvement in wheat, maize and small grain cereals were also presented. In maize special emphasis was placed on specialty corn products. However, he also outlined rice grain quality improvement, especially the development of golden rice in which he had been a major participant as a researcher.

Wheat

Professor Peter Shewry (Rothamsted Research, UK) discussed the relatively new aspects of wheat grain quality enhancement, consumption of whole grain products to reduce the risk of several medical conditions such as type 2 diabetes and/or cardiovascular diseases. His presentation summarized wheat grain constituents related research findings of the recently completed very successful European Union HEALTHGRAIN research project. Wheat dietary fibre components exhibit a significant range of natural diversity. Being heritable these traits are amenable to genetic improvement by classical breeding technologies. Targeting Induced Local Lesions IN Genomes (TILLING) was successfully used to increase wheat grain amylose concentrations by combining starch synthase 2 alleles in wheat. Cereal grains with increased dietary fibre and/or resistant starch result in increased intestinal viscosity and glycaemic index, which can reduce the incidence of cardiovascular disease and/ or type 2 diabetes.

Dr S.P. Singh (National Agri-food Biotechnology Institute, Mohali, India) using synchrotron radiation showed differential spatial iron accumulation in *Triticum aestivum* and *Aegilops kotschyi* grains. In high iron accumulating genotypes, high iron concentrations were detected in vascular tissues as compared to low iron genotypes where aleurone cells had more iron concentration.

Wheat kernel hardness is an important trait that affects milling properties and grain end use. Two puroindoline genes (PINA and PINB) located on chromosome 5D when expressed result to soft texture. A new Pina-D1 allele Pinaa-D1t was reported potentially an additional factor influencing wheat kernel hardness (Dr. M. Bhave, Swinburne University of Technology, Melbourne, Australia). The PIN based peptides are also known to have anti-microbial properties.

Chapatti bread is the most common form of wheat grain consumption in India. Dr. G. Sreeramulu (Unilever R&D, Bangalore, India) compared flour from several wheat varieties to identify the biochemical basis for chapatti pliability. Results suggest that high molecular weight glutenin subunit 1B20 and starch granules composition with higher proportion of 'A' type granules play an important role for Chapatti softness. These results can be used to develop elite wheat varieties by breeding varieties with 1B20 glutenin subunit, with drought and disease resistance for better chapatti quality characteristics.

Rice

Rice is consumed by three billion people worldwide. Dr D.S. Brar (International Rice Research Institute, IRRI, Philippines) emphatically highlighted that rice quality preferences are regionally and ethnically determined which explains why improvement of grain quality varies with the region. However, current objectives include biofortification of rice to increase pro-vitamin A, high iron and zinc concentrations in polished rice. Screen house and confined field trials have confirmed that Pro-vitamin A-enriched golden rice perform similar to some elite rice varieties currently in use. Molecular marker assisted breeding is also being used to enrich polished rice with iron and zinc. The long-term objective is to pyramid vitamin and mineral enrichment in a single genotype. Rice with increased amylose concentration to improve resistant starch concentration is also an important target to reduce the type 2 diabetes epidemic around the world.

Dr Sarla Neelamraju (Directorate of Rice Research, Hyderabad, India) also presented genomics strategies to increase iron and zinc concentration in rice. Natural variation for iron and zinc concentration was shown to be present in deep water rice genotypes. Genetic mapping studies identified chromosomes 2, 3, 8 and 12 to be associated with rice and zinc concentrations. Several simple sequence repeat (SSR) markers associated with zinc and iron concentrations have been identified and are being used in marker assisted selection to develop bio-fortified rice germplasm.

Millets

Pearl Millet [*Pennisetum glaucum* (L.) R. Br.] is a warm season cereal inherently rich in mineral nutrients and widely cultivated in some of the harshest climates in Asia and Africa. Dr K.N. Rai (ICRISAT, India) showed that to screen a large number of genotypes for iron and zinc, X-ray fluorescence (XRF) is a more effective and rapid method than inductively coupled plasma spectrometer (ICPMS). A wide range (80–100 ppm for Fe and 30–76 ppm for Zn) was observed in germplasm collections. Genetic studies revealed that these two micronutrients are under additive genetic control. Thus, to produce hybrids both parents should have high micronutrient concentrations. Results showed that increased micronutrients did not affect plant performance or grain yield.

Maize

Maize (*Zea mays* L.) is a very versatile cereal crops which is adapted to diverse agro-climatic zones. Dr Sain Dass (Indian Maize Development Association, New Delhi, India) in the Ensuring Grain Food Quality and Safety session pointed out that maize contributes nearly 9% to the Indian food basket and is a substantial contributor to Indian agricultural GDP and generating 600 million person days in farm employment. Hybrid technology has made significant grain yield improvements. Specialty corn varieties developed in India have created niche markets with added value to the producers. Dr D.P. Chaudhary (Directorate of Maize Research, ICAR, New Delhi, India) described the genetic variability of carbohydrates in Indian maize germplasm. Wide variation in amylose and amylopectin concentration can be utilized for food, feed and industrial applications.

Transgenic technology for grain quality enhancement

Transgenic technology is one of the fastest growing crop improvement strategies in the world. Globally in 2011, GM crops were grown on 160 million hectares, up 12 million hectares from 2010. Dr K.K. Sharma (ICRISAT, Hyderabad, India) described GM technology and its role in overcoming challenges in crop productivity and human health issues. ICRISAT researchers have engineered beta carotene biosynthetic pathway in groundnut (peanut, *Arachis hypogeal* L.) and pigeon pea [*Cajanus cajan* (L.) Millsp] to achieve several-fold increases in beta carotene concentrations. Iron and zinc enhancements have also been achieved in ground nut. However, challenges still remain in the active adoption of GM technologies. Dr Sharma suggested a co-operative approach by leading agricultural research, nutrition and health organizations to encourage the adoption of GM technologies both by public and governmental regulatory agencies.

In conclusion, the session provided an overview of achievements in cereal grain quality enhancement with special focus on research being carried out in India. However, the challenges both in grain quality enhancement and technologies are very similar in India and around the world. Therefore a concerted collaboative effort is needed to meet the needs of the global population by increasing crop productivity, engineering grain quality and commensurate grain technology to meet the specific needs of consumers for cereal based food products.