Strategy Paper

Nineth TAAS Foundation Day Lecture

21st Century Challenges and Research Opportunities for Sustainable Maize and Wheat Production

by

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Progress Through Science

Trust for Advancement of Agricultural Sciences
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Progress Through Science

Trust for Advancement of Agricultural Sciences (TAAS)

GOAL

An accelerated movement for harnessing agricultural sciences for the welfare of people.

MISSION

To promote growth and advancement of agriculture through scientific interactions and partnerships.

OBJECTIVES

- To act as think tank on key policy issues relating to agricultural research for development (AR4D).
- Organizing seminars and special lectures on emerging issues and new developments in agriculture.
- To institute national awards for the outstanding contributions to Indian agriculture by the scientists of Indian and other origin abroad.
- Facilitating partnerships with non-resident agricultural scientists visiting India on short period.

21st Century Challenges and Research Opportunities for Sustainable Maize and Wheat Production

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Shaping maize and wheat for the future

Maize

Globally, maize is a staple food for 900 million people earning less than US$ 2 a day (maize CRP), and is consumed indirectly by even more in the form of dairy and animal products. The demand for maize is expected to double by 2050 as populations increase and people include higher amounts of animal products in their diets. This challenge will be further exacerbated as abiotic and biotic stresses resulting from climate change, urban sprawl, groundwater depletion and soil degradation result in increasing loss of yields. This scenario will reduce national and regional agricultural systems' ability to adapt and react. As maize consumption increases, production shortages and erratic yields will result in price fluctuations and increasing stress on impoverished farming communities that are dependent on maize for their livelihoods.

Maize is the third most important cereal crop in India after rice and wheat, accounting for ~9 per cent of total food grain production in the country. In the last 10 years, there has been a significant increase in both the production of maize, from 14 MnMT in 2004-05 to 23 MnMT in 2013-14 and the area, from 7.5 Mn hectare in 2004-05 to 9.4 Mn hectare in 2013-14 (KPMG India, 2014). Current yield levels across the majority of India are fairly low with less than 3 t/ha (indicated in red in figure 1), although there are a few high yielding locations achieving more than 5 t/ha (indicated in green). The increase in acreage is a result of profitability, varietal adaptability to diverse agro-climatic conditions, and the lowering of water tables in the rice belt of India. The increase in yield is attributed to the introduction of single cross hybrids and improved agronomy.

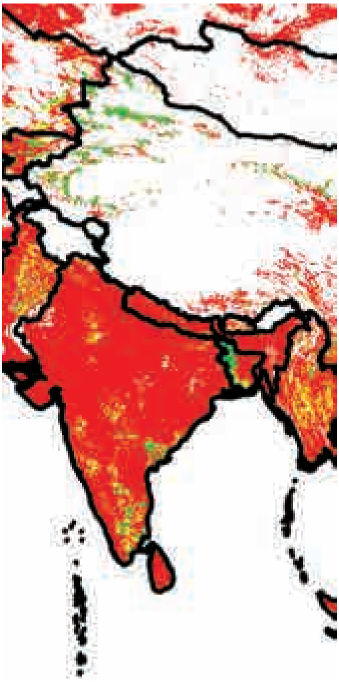

Figure 1: *2005 yield levels in India. Obtained from Kai Sonder at CIMMYT, 2015*

Wheat

The history of wheat dates to the beginning of agriculture and Middle Eastern civilization. Today wheat is grown on 215 million hectares (WHEAT CRP, 2014), making it the most widely grown staple food crop. More importantly for the poor, wheat is eaten where it is grown and provides 20-50 percent of daily calories and up to 20 percent of daily protein to 2.5 billion people (Reynolds *et al.*, 2012). From South Asia through to Central Asia across the Middle East and on to North Africa, wheat is a staple food. Demand for wheat is not isolated to these traditional wheat-eating regions. Today African countries spend about US$ 12 billion annually to import some 40 million tons of wheat. What was once considered a minor crop for consumers in Sub-Saharan Africa, wheat demand is growing faster than for any other commodity and is now considered a strategic crop for food security by African leaders (Negassa *et al.*, 2013). This has largely been driven by urbanization, globalization of diets, rising incomes and an increase of women in the workplace.

Perhaps what is most concerning are the predictions for the near future. Demand for wheat in the developing world is projected to increase 60 percent by 2050. India, the world's second largest wheat-consuming and producing country after China, has 17.5 percent of total world population and 20.6 percent of the world's poor. Wheat is predicted to be the staple crop most significantly affected by climate change (International Panel on Climate Change, 2014), because of its sensitivity to heat and the fact that it is grown all over the world. Current projections predict that with every degree Celsius increase in temperature, wheat yields in semi-tropical areas could drop by 10 percent. Increasing intensity and variability of weather events driven by climate change will lead to an increased threat to the South Asian agriculture as seen with the 2014-15 wheat crop which suffered a 5.5% yield loss compared to 2013-14 due to late season rain damage.

The future of both maize and wheat productivity will have a huge impact on future global food security because maize is the number one crop for total production and wheat is the number one crop for production area and because they are widely grown at a broad range of latitudes and temperatures, water regimes and nutritional levels. For food prices to remain constant, yield must increase 1.2-1.7 percent for maize and 1.1-1.7% for wheat annually (Reynolds *et al.*, 2012). The approach to increase yields at this pace must combine emerging environmental, socioeconomic and scientific research innovations (Cooper *et al.*, 2014).

Getting the most out of the crop

Advancing yield gains in wheat

Global wheat yields must increase at a rate of 1.7% per annum to keep up with the demands of 9 billion people by 2050 and must increase at an even more rapid pace in India . Current productivity is only increasing at a rate of 1.1% and even stagnating in some areas. This challenge requires boosting yield on the current or even reduced cultivated land area. At the fundamental level this will be achieved by improving wheat's ability to capture and process the sun's energy, through photosynthesis, and making sure that the captured carbon ends up in the wheat grain. For example, only about 1 percent of light energy hitting a wheat field ends up in the parts that are eaten, compared to maize's 3-4 percent potential efficiency and sugarcane's 8 percent or more efficiency. Even increasing wheat's photosynthetic efficiency from 1 percent to 1.5 percent would allow farmers to dramatically increase their yields on the same amount of land, using no more water, fertilizer or other inputs (IWYP, 2014).

A consortium of world scientists has speculated that the radiation use efficiency (RUE) of wheat, could be increased ˜50% through collection of strategies such as modifying the specificity, catalytic rate and regulation of

Rubisco and up-regulate Calvin cycle enzymes, and agronomic strategies including optimizing light interception and N distribution of canopies while minimizing photoinhibition (Reynolds *et al.*, 2012). Figure 2 below shows that yield potential is a function of the light intercepted (LI) times RUE times the partitioning of biomass to yield (HI) (Reynolds *et al.*, 2012, Reynolds, 2015).

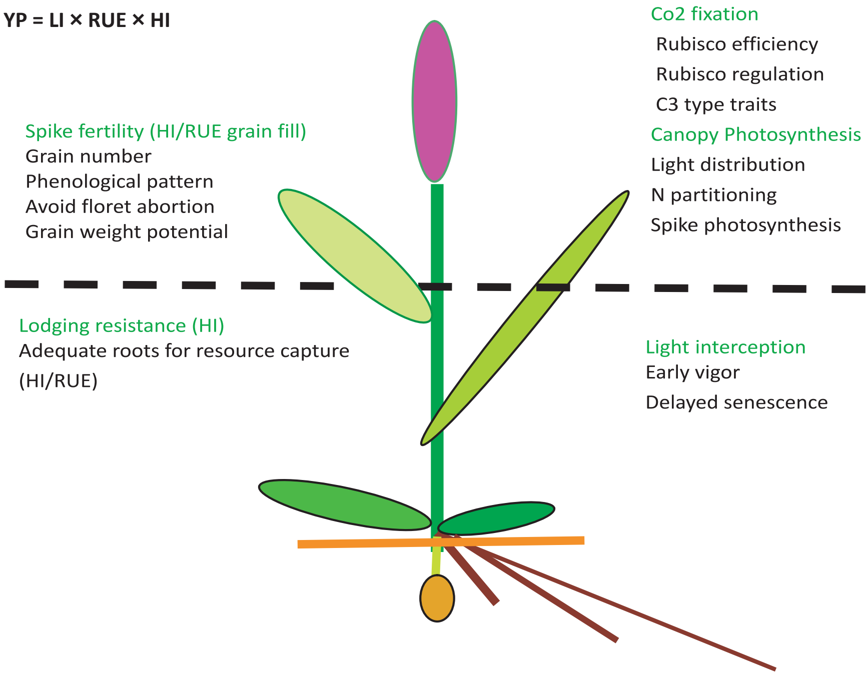

Figure 2 *Conceptual model of traits that contribute to yield potential (Reynolds et al., 2012)*

Taking advantage of Biological Nitrogen Fixation and Biological Nitrification Inhibition in maize and wheat

In the last 40 years the quantity of synthetic nitrogen fertilizer applied to crops has increased rapidly. Use of nitrogen fertilizer has resulted in significant yield increases but with considerable environmental impacts. Critics of the Green Revolution have raised valid concerns about the sustainability of imbalanced, intensive cultivation and its socioeconomic impacts. However, so far, no realistic alternative scenario has been proposed that would allow the world to meet the production demand posed by its expanding population, while lowering the environmental impact. What should be made clear to all is that the tremendous yield benefits of nitrogen fertilizer have not been widespread. Smallholder farmers in sub-Saharan Africa use a fraction of nitrogen fertilizer compared to those in the developed world, mostly due to cost and limited access to fertilizer. On average, only 9 kilograms of fertilizer per hectare of maize is applied by such farmers (CIMMYT, 2015).

If cereals could be transformed to host nitrogen fixing organisms, global agriculture would have less need for fossil fuels and would cause less pollution from runoff. However this transformation would require the transfer of the nitrogen-fixing ability of legumes into the monocot cereal crops (especially maize, rice and wheat). Re-engineering the biology of a cereal crops to include the nitrogen fixing symbiosis, is seen as a way to reduce dependence on nitrogen fertilizer including its financial and environmental costs (Beatty & Good, 2011). The aspiration to develop nitrogen-fixing crops is long-standing, but recent discoveries suggest that this dream may be within reach. Engineering this trait requires the interplay between comparative and quantitative phylogenetic approaches. Recent discoveries suggest that quantitative phylogenetics associated with comparative phylogenomics and phylogenetics would generate traits and genomic features associated with nitrogen-fixing symbioses (Delaux, Radhakrishnan, & Oldroyd, 2015). Transforming cereals to fix atmospheric nitrogen should go hand in hand with improvements in their photosynthetic efficiency in order to avoid a yield penalty from the energy demand of BNF.

Nitrification, a microbiological process that generates nitrate (NO_3) may enhance losses of nitrogen fertilizer. This is the only known biological process that generates nitrous oxide (N_20), a greenhouse gas contributing to climate change (Moreta *et al.*, 2014). Certain plants can suppress soil-nitrification by releasing inhibitors from roots, a phenomenon known as biological nitrification inhibition (BNI) (Subbarao *et al.*, 2007). There is no detectable BNI in root exudate of maize or wheat (Subbarao *et al.*, 2007), however some tropical grasses like *Brachiaria* spp., food crops like sorghum and wheat-wild relatives like *Leymus* spp. can suppress soil nitrification by releasing BNI compounds from roots, thereby reducing N_2O emissions (Moreta *et al.*, 2014). Reduced nitrification is essential to reduce N_2O emissions and to improve nitrogen use efficiency in agricultural systems. As part of a comprehensive approach incorporating genetic and agronomic management solutions, BNI-technology will reduce nitrogen losses, facilitate nitrogen retention and improve soil-health in next-generation climate-smart production systems.

To increase production and reduce pollution, alternative fertilization approaches that are both affordable and environmentally benign are necessary for the future of sustainable agriculture. Any increase in plant available nitrogen would have an important impact on the ability of smallholder farmers to increase productivity on their farms.

Novel strategies to develop better crops

There are a number of rapidly developing game-changing technologies that are poised to revolutionize basic research and plant breeding. Advances in genome editing tools are enabling crop researchers to precisely and easily manipulate a plant's DNA. The new and most powerful tool is known as CRISPR Cas9 (clustered regularly interspaced short palindromic repeats – associated protein 9). The simplest way to think of CRISPR is as a pair of molecular scissors that can be targeted to a specific genomic sequence using an easily engineered guide sequence, a short piece of RNA, that binds to its DNA target (Corbyn, 2015; Belhaj *et al.*, 2015). This technology holds promise for precision transformation with desirable traits, such as disease resistance or drought tolerance (Gill, 2015). Other genome editing tools have been around longer, though CRISPR-Cas9 may be easier and cheaper to use and have a lower rate of failure. The CRISPR-Cas9 system was originally a medical discovery but has successfully been applied in model plants, including maize, wheat, rice, tomato, and sorghum (Belhaj *et al.*, 2015) and promises to increase the efficiency of making genetic improvements (Gill, 2015). However one of the discoverers of this technology has recently proposed a suspension on its use until new safety concerns can be addressed (Wade, 2015). Also new legislation covering genome editing in light of the new CRISPR-Cas9 discoveries, especially within the European Union could potentially put restrictions on genome-editing technologies (Connor, 2014).

Managing future environments

Impending food production challenges will not be tackled by genetic gains alone. Global agriculture needs a strategy that will conserve and sustain natural resources such as land, water and biodiversity while significantly contributing to the rising demand for maize and wheat. This problem is further exacerbated by the inefficient use and mismanagement of production resources, especially water and fertilizer. Adaptation alone is not sufficient to sustainably overcome the challenges of climate change and variability. Business as usual production practices such as conventional tillage and farmers' nutrient and irrigation management systems will not reduce the above-mentioned challenges. However, new innovations are being developed to mitigate climate change challenges by adopting precision, agronomic and land management practices in cereal production systems (CIMMYT-CCAFS, 2014).

Conservation agriculture (CA) has the potential to improve crop productivity, enhance resource use efficiency, and ameliorate weather extremes. CA may provide both adaptation and mitigation benefits and sustain agricultural production under the inevitable effects of climate change and variability. CA has been promoted by CIMMYT in recent years to address the developing world's production challenges and includes practices such as nutrient management, minimal soil disturbance and permanent soil cover combined with crop rotation practices. The benefits of CA are increased crop growth and productivity (Jat *et al.*, 2014) especially under environmental stress, reduced production costs (Erenstein *et al.*, 2012) and enhanced resource-use efficiency (Kumar *et al.*, 2013).

Precision conservation agriculture and remote sensing technologies are other areas offering exciting potential. Agronomy driven by sensor technology can address these challenges by monitoring soil moisture, fertility, weather, crop growth and yield and thereby making better use of existing natural resources, improving nutrient and irrigation management and supporting genetic enhancement, and can provide farmers with a wealth of information to improve crop management practices.

With the rapid advancement and availability of technologies and data processing, sensor technology is increasingly becoming an important tool for the fine tuning of management practices. The quantity and quality of data is increasing, while prices are decreasing. In fact, in many instances data is freely available to the public (CIMMYT, 2014).

Water-wise technologies

Water is the most crucial input for agricultural production and expansion of the irrigated area has led to an impressive increase in crop production since the 1970s, but, its unrestrained use has resulted in depletion of surface and ground water resources and as a result serious water deficits are threatening agricultural sustainability. In India, during the period of 2008-2012, the total fresh water withdrawal was about 761 billion m^3 of which ~90% was associated with irrigation and livestock production (World Bank, 2013). In order to satisfy growing demand for food, India needs to produce 37% more rice and wheat by 2025 with nearly 10% less water (*Source*: HS Sidhu and ML Jat, BISA-CIMMYT, India).

Though there are a range of interventions available for improving water use efficiency in agriculture, their applications, accessibility, affordability and investment priorities are very situation-specific. However, precision irrigation management has demonstrated potential for saving water and improving water use efficiency. Recently, BISA-CIMMYT Ludhiana has initiated new research on precision-conservation agriculture in rice-wheat and maize-wheat systems. The initial results on layering sub-surface drip with conservation agriculture based rice-wheat and maize-wheat rotations have shown tremendous potential to dramatically cut irrigation water use while producing higher yield and doubled water use efficiency. As evident in table 1, by switching from conventional (CTTPR-CTW) to conservation agriculture (ZTDSR-ZTW), the rice-wheat (RW) system productivity was increased by 4% using ~15% less irrigation water. However, with layering sub-surface drip irrigation with CA, the productivity of the RW system increased by 8.6% with 50% less irrigation water use and 116% higher water productivity compared to the conventional farmer practice. In the maize-wheat system, the gains in productivity under CA+ sub-surface drip are larger than RW system. The biggest bottle neck in adoption of drip irrigation in cereal based systems is labor use in frequent shifting of drip lines for different operations and the life span of the tubing. Layering sub-surface drip in CA based systems is one of the best ways to resolve these problems and could facilitate faster adoption of drip irrigation system.

Table 1 Irrigation system, tillage and residue effects on rice* - wheat (RW) system yield, irrigation water use and water productivity in Western IGP (*Source*: HS Sidhu and ML Jat, BISA-CIMMYT, India)

Tillage, crop establishment	Irrigation system	RW system grain yield (t/ha)	RW system irrigation water use (cm)	RW system irrigation water productivity (kg/m^3)
CTTPR-CTW§	Flood	09.64a	143c	0.67a
ZTDSR-ZTW	Flood	10.03b (4.0)	122b (14.7)	0.82b (22.4)
ZTDSR-ZTW	Surface drip	10.20b (5.8)	71a (50.3)	1.44c (114.9)
ZTDSR-ZTW	Sub-surface drip	10.47c (8.6)	72a (49.7)	1.45c (116.4)

*Short duration basmati rice (Pusa basmati 1509)

§CTTPR-CTW-conventional till puddled transplanted rice & conventional till wheat, ZTDSR-ZTW: zero till direct seeded rice & zero till wheat

Figure in parenthesis are percent gains in yield and water productivity and saving in irrigation water over conventional farmers practice (CTTPR-CTW)

The impact of plant variety protection on germplasm exchange

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) is a legal tool to guide conservation of genetic resources and to ensure the fair and equitable sharing of the benefits arising out of their use (Food and Agriculture Organization of the United Nations (FAO), 2015). Under the treaty, all in trust CGIAR *ex situ* genebank collections were placed in the multilateral system, making them available on request for research, development and training. It is estimated that approximately 600 accessions are requested from CGIAR centers each day. To date, 132 countries have signed up to the treaty, to allow the open access flow of genetic resources.

In October 2014, the Nagoya Protocol (a supplementary agreement to the Convention on Biological Diversity) was brought into force to provide greater legal certainty over the benefits arising from the use of genetic resources (Convention on Biological Diversity, 2015). Signature countries are now establishing specific laws and regulations relating to it. The potential for the new Protocol to clash with the ITPGRFA is a cause for concern. Under the Treaty, all agreements are made on a multilateral basis, ensuring a global and coordinated approach. Food must flow across the borders and no single country should have the right to own genetic resources. This could change under the Nagoya Protocol, the introduction of bilateral agreements could lead to new and specific legislation in each country.

This could have a vast impact on CGIAR germplasm exchange. Unless the specific case and value of the germplasm held by CGIAR centers is considered in each country, the modifications in national legislation could inadvertently lead to greatly reduced exchange of CGIAR germplasm and hamper international cooperation built on the norms of public science (Jinnah & Jungcurt, 2009). Signatories to the protocol must use consistent language that recognizes the international nature of germplasm, especially collections held in trust by CGIAR centers. The bilateral nature of the Nagoya Protocol could also pose a risk that germplasm may be de-facto nationalized, preventing international organizations from exporting germplasm from countries that claim ownership and fail to provide consent.

Conclusion: Taking Borlaug's legacy forward

South Asia is home to 1.6 billion people and 40% of the world's poor and faces a range of multifaceted challenges including climate change, rapid population growth, persistent poverty, chronic malnutrition, and declining crop yields. By 2050, 25-30% of South Asia's wheat crop and 6-23% of the maize crop are likely to be lost due to higher temperatures (BISA, 2015). To address these challenges, CIMMYT and the Indian Council of Agricultural Research (ICAR) established the Borlaug Institute for South Asia (BISA) in 2011 to address food, nutrition, livelihood and environmental security in South Asia.

BISA is building on the Borlaug legacy by providing an international platform for agricultural research and development in South Asia. Key areas of research like those expressed in this paper have included genomic selection for heat stress tolerance in maize and wheat, conservation agriculture in wheat based cropping systems, water saving technologies, and the development of farm machinery. This has been achieved by offering an international platform for researchers to undertake cutting edge research to address 21st century challenges and research opportunities for sustainable maize and wheat production.

Bibliography

Beatty, P.H., & Good, A.G. (2011, July 22). Future prospects for cereals that fix nitrogren. Science Magazine, pp. 416-417.

Belhaj, K., Chaparro-Garcia, A., Kamoun, S., Patron, N. J., & Nekrasov, V. (2015). Editing plant genomes with CRISPR/Cas9. Current Opinion in Biotechnology, 76-84.

Borlaug Institute for South Asia. (2015). An International Agricultural Research Institute for Maize and Wheat Systems in South Asia. New Delhi: Venus Printers and Publishers.

Chen, K., & Gao, C. (2014). Targeted genome modification technologies and their applications in crop improvements. Plant Cell Rep, 575-583.

CIMMYT. (2014, May 29). CIMMYT, Oak Ridge Scientists Collaborate on Food Security Challenge. Retrieved from cimmyt.org: http://blog.cimmyt.org/cimmyt-oak-ridge-scientists-collaborate-on-food-security-challenges/

CIMMYT-CCAFS. (2014). Climate-Smart Villages in Haryana, India. CIMMYT-CCAFS.

Connor, S. (2014, July 21). Scientists renew calll for light-touch legislation on second-generation GM crops. Retrieved from The Independent: http://www.independent.co.uk/news/science/ scientists-renew-call-for-lighttouch-legislation-on-secondgeneration-gm-crops-9619769.html

Convention on Biological Diversity. (2015, June 9). About the Nagoya Protocal. Retrieved from Convention on Biological Diversity: https://www.cbd.int/abs/about/

Cooper, M., Messina, C.D., Podlich, D., Totir, R.L., Baumgarten, A., Hasumann, N.J., Graham, G. (2014). Predicting the future of plant breeding: complementing empirical evaluation with genetic prediction. Crop and Pasture Science, 311-336.

Corbyn, Z. (2015, May 10). Crispr: is it a good idea to 'upgrade' our DNA. Retrieved from The Guardian: http://www.theguardian.com/science/2015/may/10/crispr-genome-editing-dna-upgrade-technology-genetic-disease

Delaux, P.M., Radhakrishnan, G., & Oldroyd, G. (2015). Tracing the evolutionary path to nitrogen-fixing crops. Current Opinion in Plant Biology, 95-99.

Food and Agriculture Organization of the United Nations (FAO). (2015, June 9). The International Treaty on Plant Genetic Resources for Food and Agriculture Text. Retrieved from http://www.planttreaty.org/content/texts-treaty-official-versions

Gill, C. (2015, March 4). Researchers develop novel strategy to improve crops and treat diseases. Retrieved from www.phys.org: http://phys.org/print344675904.html

Intergovernmental Panel on Climate Change. (2014). Climate Change 2013. Cambridge: Cambridge University Press.

Jat, M.L., Bijay-Singh and Gerard, Bruno. 2014. Nutrient Management and Use Efficiency in Wheat Systems of South Asia. *Advances in Agronomy*, **125**: 171-259.

Jinnah, S., & Jungcurt, S. (2009). Could access requirements stifle your research? Science, 464-465.

KPMG India. (2014). India Maize Summit 2014. KPMG: KPMG India.

Moreta, D., Arongo, J., Sotelo, M., Vergara, D., Rincon, A., Ishitani, M., ... Rao, I. (2014). Biological nitrification inhibition (BNI) in Brachiaria pastures: A novel strategy to improve eco-efficiency of crop-livestock systems and to mitigate climate change. Tropical Grasslands, 88-91.

Negassa, A., Shiferaw, B., Koo, J., Sonder, K., Smale, M., Braun, H., ... Geleta, A.B. (2013). The Potential for Wheat Production in Africa: Analysis of Biophysical Suitability and Economic Profitablity. El Batan, Mexico: CIMMYT.

Powlson, D.S., Stirling, C.M., Jat, M.L., Gerard, B.G., Palm, C.A., Sanchez, P.A. and Cassman, K.G. 2014. Limited potential of no-till agriculture for climate change mitigation. *Nature Climate Change*, **4**: 678-683

Reynolds, M. (2015). Pre-Breeding for Yield Potential: Summary of International Data from 2nd. Wheat Yield Potential Workshop. Obregon, Mexico: CIMMYT.

Reynolds, M., & Borlaug, N. (2006). Impacts of breeding on international collaborative wheat improvement. Journal of Agricultural Sciences, 3-17.

Reynolds, M., Foulkes, J., Furbank, R., Griffiths, S., King, J., Murchie, E., ... Slafer, G. (2012). Achieving Yield Gains in Wheat. Plant, Cell and Environment.

Rosegrant, M.W., Koo, J., Cenacchi, N., Ringler, C., Robertson, R., Fisher, M., ... Sabbagh, P. (2014). Food Security in a World of Natural Resource Scarcity: The Role of Agricultural Technologies. Washington DC: International Food Policy Research Institute.

Sidhu, H.S. & Jat, M.L. (2015). Developing portfolios of precision water and nutrient management in conservation agriculture based rice-wheat rotation. BISA-CIMMYT-CCAFS.

Subbarao, G., Rondon, M., Ito, O., Ishikawa, T., Rao, I., Nakahara, K., ... Berry, W. (2007). Biological Nitrification Inhibition (BNI) - Is It a Widespread Phenomenon? Plant Soil.

Subbarao, G., Tomohiro, B., Masahiro, K., Osamu, I., Samejima, H., Wang, H., ... Berry, W. (2007). Can biological nitrification inhibition (BNI) genes from perennial *Leymus racemosus* (Triticeae) combat nitrification in wheat farming? Plant Soil, 55-64.

van Ittersum, M.K., Cassman, K.G., Grassini, P., Wolf, J., Tittonell, P., & Hochman, Z. (2013). Yield gap analysis with local to global relevance - A review. Field Crops Research, 4-17.

Wade, N. (2015, March 19). Scientists Seek Ban on Method of Editing the Human Genome. Retrieved from New York Times: http://www.nytimes.com/2015/03/20/science/biologists-call-for-halt-to-gene-editing-technique-in-humans.html?_r=0

WHEAT CRP. (2014). WHEAT CRP Annual Report. El Batan, Mexico: CIMMYT.

World Bank. (2013). Data. Retrieved August 15, 2013, from http://data.worldbank.org/indicator/ER.H2O.FWAG.ZS

Recent TAAS Publications

- Brainstorming Workshop on “Emerging Challenges before Indian Agriculture - The Way Forward”, March 6, 2009 - Proceedings & Recommendations.
- Brainstorming Workshop on 'Strategy for Conservation of Farm Animal Genetic Resources' 10th – 12th April, 2009 – Ranchi Declaration.
- Brainstorming Workshop on “Climate Change, Soil Quality and Food Security”, August 11, 2009 – Proceedings & Recommendations.
- Millions Fed: Proven Successes in Agricultural Development, January 19, 2010 (Translation in Hindi jointly published by IFPRI, APAARI and TAAS)
- National Seminar on “Quality Seed for Food Security through Public-Private Partnership”, April 13-14, 2010 – Proceedings & Recommendations
- TAAS Foundation Day Lecture on “Climate Change and Food Security: From Science to Sustainable Agriculture” by Dr. Mahendra M. Shah, May 7, 2010
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- Brainstorming Session on Prospects of Producing 100 million tons of Wheat by 2015 and presentation of Fifth Dr. M.S. Swaminathan Award for leadership in Agriculture - Proceeding & Highlights December 18, 2010
- National Dialogue on Building Leadership in Agricultural Research Management, Hyderabad, August 27 - 28, 2010 - Proceedings & Recommendations
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- TAAS Foundation Day Lecture on “Harnessing Knowledge for India's Agricultural Development” by Dr. Uma Lele, August 12, 2011
- Strategy Paper on "Implementing the International Treaty to Address

Current Concerns about Managing our Plant Genetic Resources" by Dr. R.S. Paroda. January 23, 2012

- The Sixth Dr. M.S. Swaminathan Award Lecture on "Challenges and Opportunities for Food Legume Research and Development" by Dr. M.C. Saxena, January 25, 2012
- Proceedings and Recommendations of Farmers' Led-Innovation. December 23-24, Hisar, Haryana, 2011
- Proceedings and Recommendations of Global Conference on Women in Agriculture. 13-15 March, 2012 New Delhi; India.
- The Seventh Foundation Day Lecture on "Ensuring Food and Nutrition Security in Asia: The Role of Agricultural Innovation" by Dr. Shenggen Fan, DG, IFPRI. January 11, 2013
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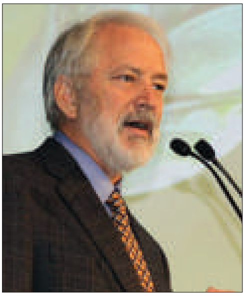
- Strategy Paper on "Managing Our Water Resource for Increased Efficiency" by Dr. R.S. Paroda. May 28, 2013
- A Brief Report on Seventh Dr. M.S. Swaminathan Award presented to Dr. William D. Dar, DG, ICRISAT, Hyderabad. June 24, 2013
- Proceedings and Recommendations of "Brainstorming on Achieving Inclusive Growth by linking Farmers to Markets", June 24, 2013
- Strategy Paper on "The Indian Oilseed Scenario: Challenges and Opportunities" by Dr. R.S. Paroda. August 24, 2013.
- Proceedings and Recommendations of "National Workshop on Outscaling Farm Innovation", September 3-5, 2013.
- Recommendations of Brainstorming Workshop on "Soybean for Household Food and Nutrition Security", March 21-22, 2014.
- Recommendations of Brainstorming Workshop on “Up-scaling Quality Protein Maize (QPM) for Nutrition Security”, May 20-21, 2015.



Thomas A. Lumpkin

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Dr. Thomas A. Lumpkin has made significant contributions in the field of agricultural research, education, development and administration, with particular focus on technology development, refinement and adoption of conservation agriculture in cereal and vegetable production systems of South Asia, ethno-botany and marketing systems.

He is at the forefront of guiding wheat and maize research for development (R4D) in the developing world, particularly in India and across South Asia. His passion is for improving the livelihoods of smallholders in developing countries through science-driven technologies, enabling them to produce more food while using fewer resources and in a sustainable way to ensure a new Green Revolution.

He has written numerous books and research articles on *Azolla*, azuki, edamame, wasabi, global horticulture and approaches to alleviate malnutrition and poverty in the developing world.

He is widely known among the CGIAR, international agricultural donor agencies and national agriculture systems in the developed and developing world for his leadership in agriculture, and for the reinvigoration of the International Maize and Wheat Improvement Center (CIMMYT) and the World Vegetable Center (AVRDC). As a leader in the oversight of the WHEAT and MAIZE CGIAR Research Programs (CRPs) since 2011 and 2012, respectively, Dr. Lumpkin has made intensive contributions in deploying improved wheat and maize varieties in India through innovative public-private partnerships.

He has made an impact in the region through his strong emphasis and focus on input-use efficiency, precision agriculture for smallholders, adaptation to the changing climates in South Asia through effective integration of climate-resilient varieties, resource-conserving technologies and institutional innovations for sustainable intensification of wheat- and maize-based systems. His vision for a new Green Revolution and research combined with an in-depth knowledge of constraints faced by the smallholder farmers of South Asia prompted him to launch the Borlaug Institute for South Asia (BISA) in India, in close partnership with the Indian Council of Agricultural Research (ICAR). He had also been the founder Director General of BISA, concurrent with his duties as Director General, CIMMYT.

Dr. Lumpkin has been associated with a number of well known professional bodies.

The Trust for Advancement of Agricultural Sciences (TAAS) has great pleasure in awarding Dr. Thomas Lumpkin the prestigious “Dr. M.S. Swaminathan Award for Leadership in Agriculture”.

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