Past and Future Innovations in Tropical Maize Improvement

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In the coming decades, maize will overtake rice and wheat as the most important cereal in the world. During 2005 the crop was planted on 147 million ha, having expanded by 38% over four decades. In Sub-Saharan Africa, the area sown to maize doubled during that period. Of the world total area, 98 million ha are gown in developing countries, and much of this is concentrated in places, such as sub-Saharan Africa and the Asian uplands, that are characterized by extreme poverty. The crop is thus especially relevant to hunger and poverty reduction.

Through the application of agricultural science, maize yields have increased by 120% worldwide and by 150% in developing countries. Nonetheless, yields remain low in the developing world, averaging only about 3.1 t/ha, even though the yield potential of maize is around 20 t/ha.

Globally, about 72% of maize production goes to animal feed, underpinning the well-known "livestock revolution" in developing countries. The crop is also used in a wide variety of products for niche markets, and new uses are expected to emerge during the coming decades (e.g., biofuel and bioplastics). Assessment of maize value chains will thus be particularly important.

This paper is organized around key areas in maize science innovation. Prominent among these is genetic improvement, or breeding, which is generally believed to have contributed ≥50% of maize yield gains in the USA during the past century. In tropical areas, improved cultivars, both hybrids and open-pollinated varieties (OPVs), also account for a major share of the yield increase. Bioinformatics will play an increasingly important role in exploiting genetic diversity for improved yield, grain quality and disease resistance. Research on the management of natural resources in maize systems will be important for sustaining gains in maize productivity. In globalized societies and economies, institutional partnerships will continue to be vital for sharing and developing improved germplasm and agronomic knowledge within and between the public and private sectors.

Genetic Improvement

Replacing maize landraces with suitable improved OPVs commonly doubles grain yields, and substituting hybrids for OPVs can further increase yields by 15-20%. In many tropical environments, adoption of hybrids alone has increased yields by more than 2 t/ha. Yet, for various reasons, only about 33% of the maize area in the tropics is planted to hybrids and an

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additional 15% to improved OPVs. Nonetheless, even these modest adoption rates have translated into tremendous production increases, and several tropical countries (e.g., India, South Africa and Vietnam) have become self-sufficient or net exporters of maize. It should be possible to achieve even greater production increases in the tropics by facilitating farmer adoption of improved OPVs or hybrids.

Average yields of the current mix of maize landraces and improved varieties grown in the tropics are commonly below 2 t/ha and exceed 3 t/ha in only a few countries. Thus, genetic improvement must continue to focus on traits that protect and stabilize yields, especially in risky environments characterized by high biotic, abiotic and other stresses. In southern Africa, for example, CIMMYT's maize breeding strategy is to select for grain yield and overall performance simultaneously under drought stress, low soil N stress, and favorable or optimal growing conditions. In dozens of trials, maize hybrids developed according to this strategy have shown a yield advantage of about 20%, relative to check hybrids from private companies, at low-yielding sites (<3 t/ha), declining to a statistically nonsignificant 3% at the highest yielding sites (>9 t/ha).

Agronomy Research

One major trend over the last 30 years in the modernization of maize production has been increased research on the sustainability of maize systems, with the aim of curbing environmental degradation. CIMMYT has been at the forefront of this work, working in partnership with numerous national organizations. As a result of these joint efforts, various technologies have been adopted to reduce soil erosion in maize systems, including the use of cover crops, minimum tillage and soil bed or ridging systems in Central America, Mexico and sub-Saharan Africa. Likewise, a wide range of interventions are available for improved management of soil fertility in Sub-Saharan Africa, such as the application of mineral fertilizers conditional on soil nutrient requirements, rainfall expectations and market economics; cattle manure management; legume rotations and intercrops; and agroforestry.

Increasingly, these components are being brought together through widespread promotion of the principles of conservation agriculture. This approach focuses on the maintenance or improvement of soil and crop systems through minimal soil disturbance, the use of crop residue mulches and crop rotation. In recent years many initiatives have promoted the use of these management techniques with strong farmer participation, and several of these are proving successful, with good rates of adoption.

Biometrics and Bio-informatics

Powerful methods and tools for statistical analysis are becoming widely available and are greatly enhancing experimental designs and research progress. Examples of tools that were previously considered "sophisticated" and are now "routine" inclclde: (1) spatial analysis methods, which permit greater precision in managed stress experiments through adjustment of treatment means, based on microenvironmental effects; (2) statistical analyses for understanding genotype x environment interactions; and (3) mixed linear models for QTL mapping, microarray and association mapping. In addition to ever-more-powerful statistical analysis tools, access to

databases that readily link and enable scientist to integrate new and old information from field trials, molecular analyses, conventional laboratory analyses, etc., will become routine.

Institutional Contributions

Both traditional and new partnerships have been central for enhancing the impact of modern maize technologies. The Southern Africa Drought and Low Soil Fertility (SADLF) Network and the Asian Maize Biotechnology Network (AMBIONET) are instructive and successful examples, which have contributed importantly to improving tropical maize production. Both have strengthened the capacity of partner institutions, while influencing others to increase funding for maize research and to adopt strategies and policies that enhance the impact of research on maize production and productivity.

Conclusion

Modern technologies have increased maize production over vast areas of the tropics. However, progress toward modern, or knowledge-intensive, agriculture has been uneven, and many tropical maize farmers have yet to benefit substantially. For some of them, diversification into higher value crops or nonagricultural livelihoods are attractive options. Yet, it will still be necessary and there will be ample opportunities for modern technologies to improve the maize production of many millions of farmers in the tropics.