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International Maize and Wheat Improvement Center
Centro Internacional de Mejoramiento de Maíz y Trigo

TRANSGENIC MAIZE IN MEXICO: FACTS AND FUTURE RESEARCH NEEDS

8 May 2002

El Batan, Texcoco, Mexico—In recent weeks and months, debate over the possible arrival of transgenes in Mexican landraces has received extensive media attention.

As an international research institution based in Mexico (the center of origin of maize), charged with conducting socially and environmentally responsible research on maize, CIMMYT is making every effort to put forward a science-based, factual response to the transgene controversy. Our focus is on understanding the implications of the possible presence of transgenes in Mexican landraces for: (1) the conservation of maize genetic resources; (2) genetic diversity; (3) people and their communities; and (4) the environment.

In some instances this response has been misrepresented. Among the assertions raised in the media are reports that our maize gene bank (part of the Wellhausen-Anderson Plant Genetic Resources Center) contains Mexican landraces carrying transgenes. CIMMYT has also been subjected to accusations of remaining silent and inactive on the broader transgene-landrace issue. Neither of these assertions are based on fact and both are untrue.

We believe that it is essential to rely on facts and fundamental concepts, and to identify gaps in our current knowledge, in order to set the discussion on a constructive course. Accordingly, we are responding to some of the questions that have arisen in the wake of reports over the possible presence of transgenes in Mexican landraces.

What Is Happening in CIMMYT's Maize Gene Bank?

There is no evidence, to date, that any of the Mexican landrace accessions in the Wellhausen-Anderson Genetic Resources Center (CIMMYT's gene bank) are carrying the most common promoter associated with transgenic plants (cauliflower mosaic virus 35S or CaMV 35S).

CIMMYT has screened more than 150 Mexican landraces (100 designated gene bank accessions and 52 Oaxacan landraces collected for gene flow research and other purposes) and has failed to find the presence of CaMV 35S. The most recent results were published on 3 May 2002 (see CIMMYT website). Screening is continuing on landrace accessions collected after 1996 (the date that commercial transgenic maize was released in the United States) as time and resources allow. In addition, no new maize materials will be added to the "in trust" collection without first being tested for the presence of transgenic material, as part of the overall characterization of the sample. CIMMYT, to the extent possible, will provide only pre-1996 accessions to our partners, unless the accessions have been screened for the general presence of transgenes (e.g., CaMV 35S) or unless the recipient guarantees that such screening will be done.

A critical aspect of maintaining gene bank materials is periodic regeneration and increasing of the seed stocks of each accession. At CIMMYT, these activities are undertaken with controlled hand-pollination expressly to maintain the genetic structure of the original seed accessions. To further ensure that all extraneous pollen is kept out, additional buffer zones will be used for the regeneration blocks. To ensure the integrity of regenerated seeds once they are in the gene bank, CIMMYT follows strict identification procedures. The seed samples must conform to so-called "passport data" on seed type and color. They are held under secure conditions and managed through unique computerized identifiers. Requests for seeds are processed according to the seed passport information.

The Questions: Back to Basics

If transgenes are present in Mexican landraces, what would be the effects in farmers' fields, on genetic diversity, and on the wild relatives of maize? Answers to these important questions meld a range of factors, including population genetics, farmer management practices, environmental selection pressures, and even regulatory considerations. CIMMYT has worked on farmer management and genetic diversity issues in Mexico through most of the 1990s and intends to play a role in helping to answer such questions. Before delineating the work CIMMYT believes necessary to determine the impact of transgenes introgressing into Mexican maize, it is necessary to review some of the key points underlying the issue.

Maize landraces: Static entities or a dynamic flow?

A widely held misconception about maize landraces is that what we find in remote areas of Mexico today is essentially the same as the maize found in the same location 100 years ago. It's not. Maize is an open-pollinating species, so individual maize plants readily exchange genes with other maize plants growing nearby, a characteristic recognized long ago by local farmers as a means to adapt varieties to their own preferences and ecology. Today's farmers in Oaxaca, Mexico, for example, readily notice when their maize has been inbred over too many generations and lost vigor. Some will say the maize "gets tired" (se cansa) and will seek out other maize varieties to mix with it. In short, diversity in farmers' fields is not a static condition, but rather a dynamic process maintained by an influx of new genes, together with farmer selection. Likewise, landraces themselves are not static but are constantly evolving, while maintaining the traits desired by the farmers.

Do single-gene traits displace genetic diversity?

What happens when a characteristic controlled by a single gene, such as transgenic, Bt-based insect resistance or herbicide resistance, is introduced into the genetic background of an established variety? Current knowledge and theory in maize genetics suggests that there should be little impact on genetic diversity. Most genes in maize are independent, meaning that they will diffuse independently through a maize population rather than remain linked to other genes in that population. For instance, if a modern yellow-grain variety (such as those imported from the United States) carrying a transgene, such as Bt, is planted in a field with a traditional white-grain landrace, after a few generations, there would be plants with yellow grain and the transgene, with white grain and the transgene, with yellow grain and no transgene, and with white grain and no transgene. So, although the gene has introgressed into a field, diversity has not decreased—in fact, one could argue the opposite is true. Overall genetic diversity has increased. Whether this increased diversity is desirable is a different issue (see below).

What happens in farmers' fields?

But what actually happens in the real maize fields of Oaxaca and other Mexican states? It is critical to remember that maize varieties grown by farmers, including smallholders, are subject to both environmental selection and human management practices, which greatly influence whether a gene (and trait) is lost or fixed and at what frequency it occurs.

Tracking the effects of environmental selection is relatively straightforward compared to assessing the impact of farmer management practices. If the transgene confers a trait that works against the survival of the plant, plants carrying that gene will be eliminated from the gene pool through natural selection. If there is no environmental selection pressure acting on the gene (for example, if no stem borers, which are the target of the Bt biopesticide, are present to act on maize carrying the Bt gene), population genetics models indicate that the gene will be fixed at the frequency at which it was introduced, or it will be lost over time. Finally, if the gene confers a selective advantage, it will increase and spread through the population. Again, since the transgenic maize varieties now being commercially grown use single-gene traits, in none of these cases should overall genetic diversity be decreased. There are implications, however, for the rate of diffusion (or conversely, containment) of transgenes.

Perhaps the most influential and least understood influence on genetic diversity and the "maintenance" of landraces is farmer management practices, particularly the practices farmers use to choose seed for planting the following year. This fosters gene flow. It is very likely that the ancestors of today's Oaxacan farmers used similar practices to develop maize from a weedy grass to the relatively robust grain that is sown now. One can hypothesize that if small-scale Mexican farmers had access to transgenic varieties, and if farmers perceived these varieties as valuable, they would probably foster their diffusion into their local maize populations. Clearly this is a complex process that merits much research, since there are many unknowns, particularly when it comes to the impact on farmers' livelihoods and even the evolution of their farm management practices.

Finally, there is the question of potential impacts on the wild relatives of maize: *Tripsacum* and teosinte. It is very difficult to produce maize x *Tripsacum* hybrids, although CIMMYT has produced some using sophisticated laboratory techniques. The only known naturally occurring maize x *Tripsacum* hybrid is "Guatemala grass," a vigorous but sterile forage that can be propagated only vegetatively.

Mexican annual teosintes are the closest relatives of maize. It has been observed that maize genes can flow easily into teosinte, but the long history of maize and teosinte sharing the same fields in Mesoamerica has not produced a "swamping" of the teosinte by maize, suggesting that some genetic mechanisms may be at work to maintain the genetic integrity of teosinte (see below).

Given the difficulty of creating maize x *Tripsacum* hybrids, it seems extremely unlikely that transgenes would introgress into the *Tripsacum* genus. Introgression into teosinte would be much more likely, and the same principles related to natural and farmer selection cited earlier should apply. In short, one would not expect to see a negative impact on diversity per se, but only limited research has been conducted to date on this aspect of gene flow.

Where To From Here?

This brief look at some of the underlying issues related to transgenes and Mexican landraces has focused mostly on potential impacts on genetic diversity. The observations are drawn from basic models and will need to be validated through targeted experiments. Clearly potential impacts of an introgression of a transgene would extend also to the environment, farmers' welfare, marketplace concerns such as consumer acceptance, intellectual property considerations, and the regulatory sphere. These issues should be taken up in appropriate fora.

Given CIMMYT's mandate and the need to resolve some of the issues in the current controversy, we believe it would be particularly useful to pursue the scientific inquiries and activities described below:

Further research on farmer management practices

Incomplete knowledge of smallholder farmer management and seed selection practices poses a major constraint to determining what factors influence the diffusion of genes (including transgenes) into maize landraces and what the potential impacts might be. There is an urgent need to address this gap in our understanding with further research. Other key related questions should also be addressed: How may this process of diffusion affect the livelihoods of small-scale maize farmers? Can this process and its impacts be managed? And if so, how?

Establishment of a landrace database

There is an urgent need for a centralized database on the maize landraces of Mexico and the rest of the world. This database should contain information on the landraces' agronomic and quality traits, and when feasible, genetic information. Aside from serving as a "baseline" for diversity and being useful in breeding programs, this database would have other practical applications. In the dispute on patenting high oil-content maize, for example, no data were readily available to show that Mexican landraces with high oil content were being cultivated prior to the patent applications. If we do not have access to this kind of information, it can reduce the value of biodiversity.

Research on the reversibility, containment, and remediation of genes that have introgressed into maize landraces

Looking to the future, with the advent of new crops and crop products—transgenic or otherwise—if genes that should not be openly and freely distributed make their way into the environment, it may be necessary to have options in hand for either controlling their diffusion or reversing it. This task should be manageable at the gene bank level, but considerably more challenging at the field level if there were a massive introduction of an undesirable gene or set of genes (e.g., industrial product traits that may affect the food uses of maize). Should such a scenario become reality, it would be critical to have much more information on the factors affecting gene flow in maize and how they might be harnessed to reverse, contain, or help ameliorate the impact of the diffusion of a deleterious or unwanted gene. Research in this area should be given high priority.

Research on the long-term interaction between teosinte and modern maize varieties, including transgenic varieties

While "snapshots" of the maize / teosinte interaction have been looked at in the limited number of studies on this area, there is a lack of knowledge about what happens over the long-term interaction. More in-depth studies are needed to better ascertain what, if any, impacts modern varieties and farmer management practices are having on the genetic diversity of this wild relative of maize.

In conclusion, it is CIMMYT's view that one of the positive aspects of the recent debates is the renewed interest and support for research on gene flow, both within species (e.g., maize landraces) and between species (e.g., maize and its wild relative teosinte). Evidence of this resurgence is the recent scientific methods workshop held at Ohio State University, "Ecological and Agronomic Consequences of Gene Flow from Transgenic Crops to Wild Relatives" (www.biosci.ohio-state.edu/~lspencer/gene_flow.htm), sponsored by the Biotechnology Risk Assessment Research Grants Program, US Department of Agriculture (www.reeusda.gov/crgam/biotechrisk/biotech.htm). We applaud such efforts and stand ready to work with others on the critical research needed to bring science-based answers to the complex issues surrounding the maintenance of genetic diversity in the center of origin of maize.