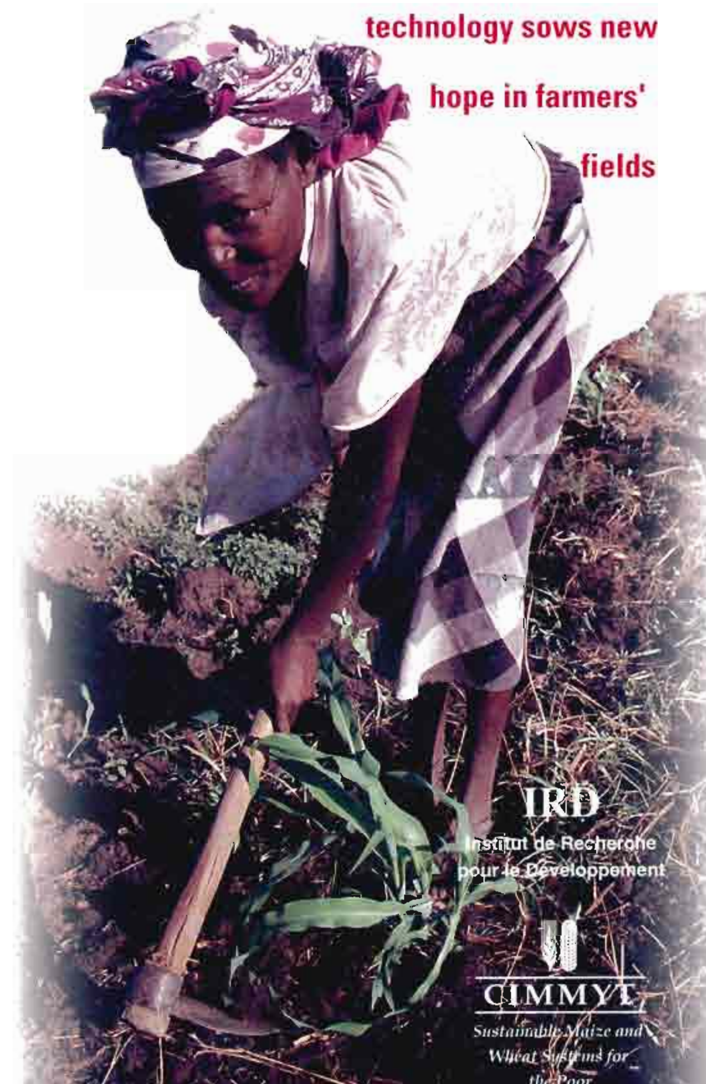
IRD CIMMYT
The Apomixis Project

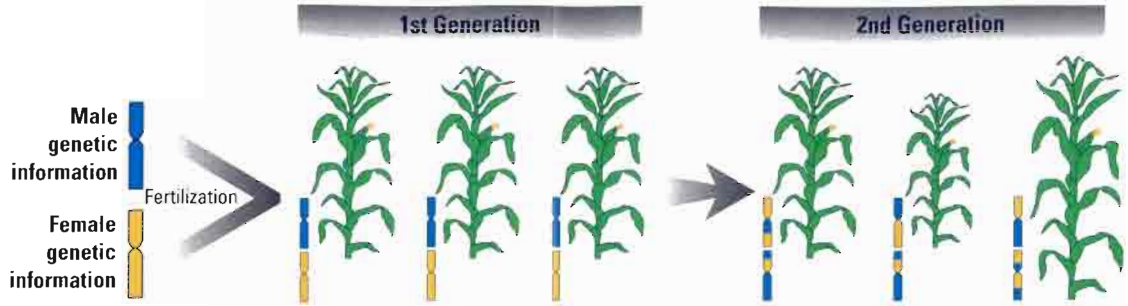
A revolution in seed technology sows new hope in farmers' fields



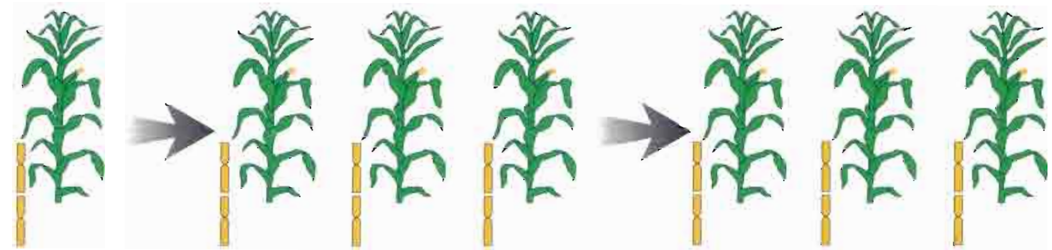
IRD
Institut de Recherche pour le Développement

CIMMYT
Sustainable Maize and Wheat Systems for the Poor

Poor and subsistence farmers, lacking hybrid and improved maize varieties, struggle daily to eke out an existence from low yielding plants that offer little resistance to destructive insects and diseases. In many of the world's poorest nations, less than 10% of the maize land is planted to hybrids, in large part because farmers cannot either obtain or afford seed on an annual basis. In response, CIMMYT and IRD have mounted a concerted effort to understand and transfer apomictic traits to maize—an advance that could forever change the development and use of improved varieties in some of the world's neediest regions.



Sexual Reproduction: Hybrid maize that has been produced through sexual reproduction displays identical genetic makeup. The depiction of the second generation represents the use of seed recycled from hybrids, a common practice in many developing countries, and its varied results.



Apomictic Reproduction: Hybrid maize that has been produced apomictically (asexually) would also display identical genetic makeup in the first generation but *retain* its genetic composition and characteristics through the second generation and beyond.

What is Apomixis?

Apomixis—asexual reproduction through seeds—results in plants that are exact clones of the mother plant. This trait occurs naturally and has been identified in more than 400 species of plants, including citrus and wild relatives of maize, wheat, and pearl millet.

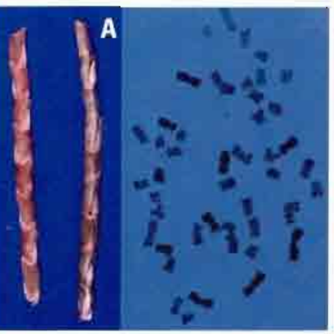
Maize reproduces sexually. Each "parent" contributes half the requisite number of chromosomes (10+10=20), with a new combination of chromosomes and traits resulting from each cycle of fertilization. In hybrids, plants are manually fertilized with select pollen to produce the desired progeny. This control, however, is lost in the second generation in farmers' fields, and with it, many of the beneficial hybrid traits.

Tripsacum, a wild relative of maize, reproduces through apomixis. Its total complement of chromosomes is transferred from mother plant to progeny, making each offspring a clone of its ancestor. This direct transfer of chromosomes and traits can be maintained indefinitely.

Project Goals and Activities

The IRD-CIMMYT Apomixis Project was launched in 1989 with the goal of transferring the naturally occurring, untapped trait of apomixis to maize, an achievement that could dramatically and directly improve farmer productivity in the developing world.

Building on decades of IRD (formerly ORSTOM) apomixis research, project scientists are working to create apomictic maize. A hybrid between maize and its wild relative *Tripsacum* is being backcrossed in pursuit of a true apomictic maize variety. To date, more than 250,000 plants have been screened over 10 cycles. This long-term strategy has provided very encouraging results. It will yield a final product that should be unconstrained by intellectual property rights, thereby guaranteeing its free access to developing world clients.



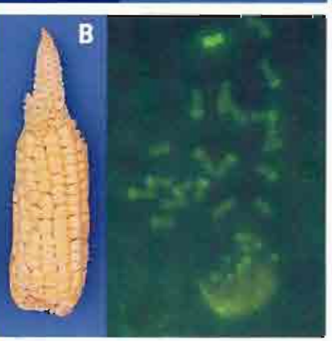
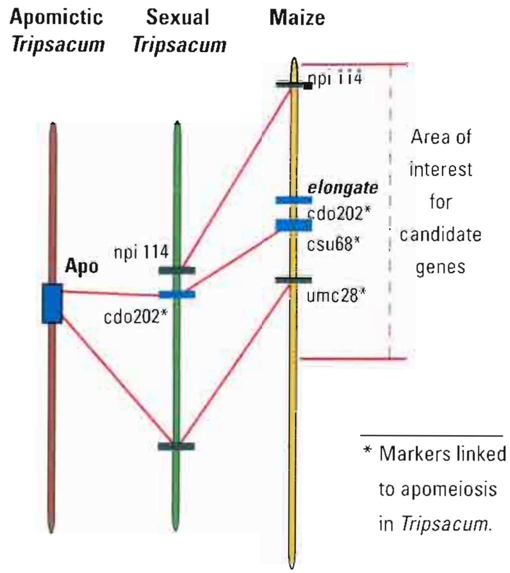


Figure A shows a maize-*Tripsacum* F_1 hybrid produced early in the project and its genetic makeup. The 36 light blue chromosomes are from Tripsacum; the 10 dark blue chromosomes are from maize.

Figure B shows a more recent maize-*Tripsacum* hybrid (BC5) resulting from extensive backcrossing and screening. The single bright yellow chromosome is from *Tripsacum* and the 20 faint yellow chromosomes are from maize.



The candidate gene approach. Mapping shows that maize and *Tripsacum* exhibit a common genetic constitution. We are looking for gene(s) in maize that would be located in the same segment of the genome as apomixis is in *Tripsacum* (as revealed by molecular markers) and that express modifications in the mode of reproduction similar to that observed in apomicts. *Elongate* is the first identified candidate.

A second strategy, added in 1993, is based on identifying and isolating the apomixis genes in *Tripsacum* and transferring them directly to maize. This complex approach relies heavily on biotechnology and requires extensive genetic mapping, the isolation of "candidate genes" from maize and their counterparts from *Tripsacum*, and the successful splicing of the genes into maize. If successful, this effort may yield results more quickly than the backcrossing approach, with technological implications extending far past maize.

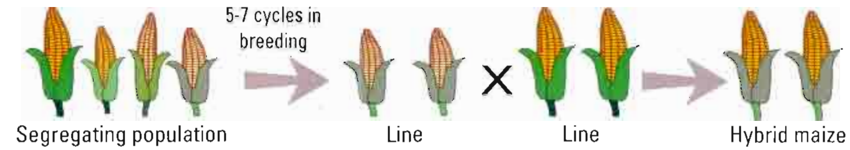
A Word About Diversity

A valid concern raised about the clone-like nature of apomixis is its possible effect on genetic diversity. Diversity in the agricultural systems of industrialized countries is already fairly restricted. By contrast, in the world's developing regions, landraces, wild relatives, and farmers' cultivars may be found in close proximity. This project's focus has been on "facultative" apomixis, in which sexual reproduction occurs in approximately 3% of a population, thus allowing gene flow and diversity to continue. In *Tripsacum*, for example, more than 1,500 genotypes have been identified, clearly indicating that apomixis does not preclude diversity (the wide diversity between two *Tripsacum* genotypes is demonstrated in the photo below). Nevertheless, as with any new technology, CIMMYT and its partners will exhaustively test and later assess the potential impact of apomictic maize prior to its release.

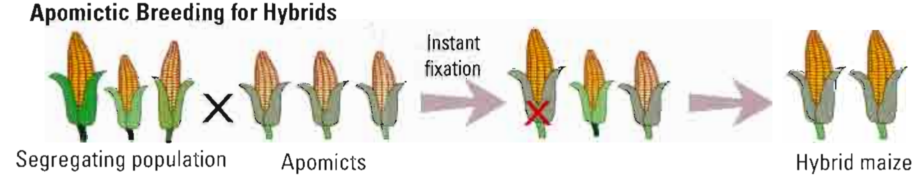
Benefits of Apomixis Technology

Breeders will be able to greatly reduce the time and expense required to produce new varieties. A single apomictic plant can instantly "fix" a desired genetic composition, in contrast to conventional breeding that requires thousands of plants, grown and selected over several years. *Niche breeding*, developing cultivars with useful traits tailored to limited agroecological areas, also becomes economically feasible with apomicitic maize.

Conventional Breeding for Hybrids



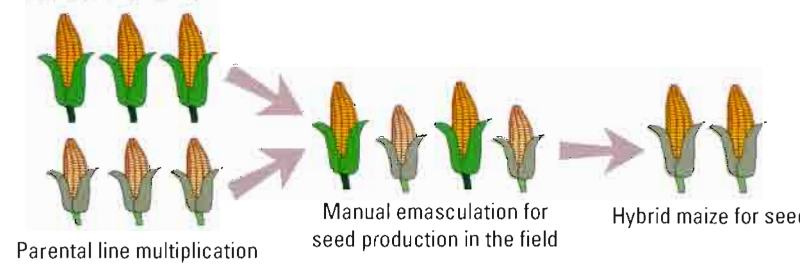
Apomictic Breeding for Hybrids



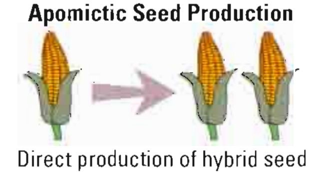
X = Breeder selection.

Seed producers will be able to produce hybrids at considerably lower cost and with less opportunity for error. Apomictic technology minimizes the labor-intensive procedures needed to produce hybrids because stringent control over pollination is no longer required. Lower production costs should translate directly to lower seed prices for farmers.

Conventional Seed Production

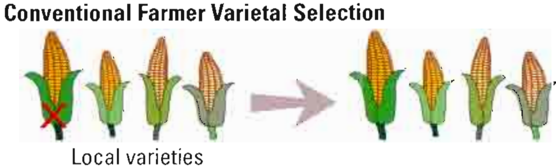


Apomictic Seed Production



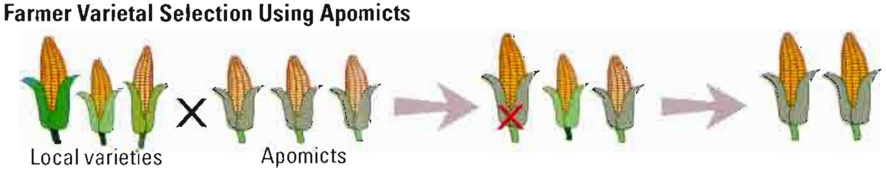
Farmers will benefit in numerous ways. Improved seed obtained from commercial or public sources can be recycled indefinitely, while maintaining critical yield-enhancing properties. Furthermore, farmers would retain the option of being their own breeders and seed producers. By crossing apomictic maize with selected varieties in their fields, farmers can "fix" the genetic make-up of a preferred variety, or even a plant, for many growing seasons to come.

Conventional Farmer Varietal Selection



Farmers' selections continue to segregate. Desired traits are not always retained.

Farmer Varietal Selection Using Apomicts



Crossing local varieties with apomicts allows farmers to "fix" desired traits in their maize.

X = Farmer selection for seed.

Major Accomplishments to Date

Discoveries

Although progress has occasionally been slower than hoped, researchers have made substantial headway in learning about the mechanisms responsible for apomixis. Project work revealed key structural differences between the ovaries of sexual and asexual plants that have led directly to the development of new screening tools. These, in turn, allow the identification of apomictic specimens with much greater certainty, using quicker testing procedures.

The path to apomixis

A large step forward was taken with the development of apomictic maize-like plants that carry a few chromosomes of *Tripsacum* added to the maize genome. Crossing and screening will continue with these apomictic plants until a true apomictic maize is produced. In addition, mobile DNA sequences known as transposons, which induce mutation when inserted into genes, have been introduced into apomictic materials. The aim is to identify and isolate the individual genes associated with apomictic control.

Candidate gene identified

Molecular genetics studies have led to the identification of a very promising "candidate" gene involved in the control of apomixis. This gene (called *elongate* in maize) is now being cloned and experiments will soon be underway to verify its function.

Acknowledgments

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