Case Study 2: Male Sterility for Hybrid Seed Production: Lessons from the Seed Production Technology for Africa (SPTA) Project

Component: Breeding, variety release, and maintenance

Subtitle: Male sterility for hybrid seed production: Experiences from the CIMMYT Seed Production Technology for Africa (SPTA) project

Executive Summary:
Male sterility has always been an attractive technology to reduce the cost of hybrid maize production by saving on the high cost of detasselling female parents. Available male sterility technologies have had shortcomings in various aspects. The SPTA project utilizes a dominant non-pollen-producing maize gene, Ms44, to create female parent plants that are unable to produce pollen, and which do not need to be detasseled during the hybrid seed production process. Unlike detasselling, with the Ms44 SPT system, the full seed yield potential of the production female line or single cross can be realized. The MS44 system, however, utilizes a transgenic fertility restorer (maintainer) line. SPT is being used in the USA and is under testing in Kenya and South Africa. The technology can revolutionize hybrid maize production in many maize-producing countries in Africa if access to the traits and their use can be negotiated with Corteva and CIMMYT.

Context:
The International Maize and wheat Improvement Center (CIMMYT) is assisting the Kenya Agricultural and Livestock Research Organization (KALRO and Agricultural Research Council of South Africa (ARC) to access the technology from Corteva to develop, test, deploy and use in seed companies an advanced seed production system in Africa for the benefit of smallholder farmers. The unique seed production technology developed by Corteva Agriscience seeks to transform the seed production process in sub-Saharan Africa.

This technology utilizes a dominant non-pollen-producing maize gene to create female plants that are unable to produce pollen.

SPTA is a Bill & Melinda Gates Foundation (BMGF) funded humanitarian project to improve maize hybrid purity and productivity in Africa. Seed Production Technology for Africa (SPTA) – CIMMYT

Challenges and Objectives:
Smallholders in sub-Saharan Africa regularly use outdated maize hybrids and open-pollinated varieties that limit yield potential. Studies show that only 57% of sub-Saharan Africa's maize growing area is planted with recently purchased seeds. This is despite the availability of improved maize hybrids developed to help farmers deal with biotic (pests and diseases) and abiotic (drought) stresses. These improved varieties often do not reach smallholders because of inadequate seed systems and marketing opportunities. The SPTA project was launched to improve access for smallholders to high-quality seeds of modern maize varieties.

Male sterility is defined as an absence or non-function of pollen grain in plants or the incapability of plants to produce or release functional pollen grains. The use of male sterility in hybrid seed production has great importance as it eliminates the process of mechanical emasculation.

Male sterility has been studied and used in maize hybrids seed production with varying experiences. Male-sterile plants are those that fail to produce functional pollen grains. Male sterility is of five (5) types:

1) Genetic or genic male sterility (GMS),
2) Cytoplasmic male sterility (CMS),
3) Cytoplasmic genetic male sterility,
4) Chemical-induced male sterility and
5) Transgenic male sterility.

In maize, male sterility can result from either nuclear or mitochondrial gene mutation. The former is referred to as genetic or genic male sterility (GMS) and the latter as cytoplasmic male sterility (CMS). CMS is caused by mitochondrial genes together with nuclear genes and has been used in commercial hybrid maize production, but this method can suffer from poor genetic diversity, potentially increased disease susceptibility, and unreliable restoration of CMS lines (Williams, 1995).

The SPTA project targets small and medium seed production companies in Africa to strengthen their capacity to produce high-quality hybrid maize more efficiently and at a reduced cost. SPTA efforts will contribute to a more vibrant private seed sector by providing higher quality hybrid seed using a technology that fits well within existing production systems of small and medium enterprise seed companies.

SPTA technology addresses the challenges of high hybrid maize seed production costs, low grain yield from male fertile females, and overcoming bottlenecks of the use of traditional male sterility in hybrid seed production.

The Objectives of the project are:

- Improve the grain yield potential of stress-tolerant maize hybrids in low fertility environments.
- Develop a new hybrid production platform capable of producing sufficient early generation seed to support the production of high-quality certified seed each year.
- Reduce the production costs of seed companies in the sub-Saharan region.

The primary benefits to seed companies serving African maize smallholders include:

- SPTA technology will prevent female self-fertilization at each production stage step to improve hybrid genetic purity.
- It will reduce the need to detassel plants, cut down seed production costs, and improve female seed yield (Fox et al., 2017).

The SPTA technology fits well in the three-way hybrid production system used by most small and medium size seed companies in sub-Saharan Africa.

1. Improves seed yield of inbred and single-cross female parents.
2. No seed yield reduction was associated with leaf losses during de-tasseling.

3. Improves seed yield of inbred and single-cross female parents since 1) NPP plant does not invest in pollen production, and 2) No yield reduction associated with leaf losses during de-tasseling.
4. Stimulate the maize hybrid seed industry in Africa- The core facility to produce non-pollen producing (NPP) female inbred lines will be based in South Africa and in the long term, seed companies across Africa would have access to SPT-derived seed.

Interventions:
Seed production actors in Africa prevent self-fertilization by manual detasseling, a time-sensitive process that involves removing the pollen-producing tassels from the seed-bearing maize plants in the hybrid seed production fields. Detasseling is a labor-intensive and time-consuming process that, if not done well, can lead to self-pollination resulting in contamination of the hybrid product and reducing the final yield potential of commercial certified seed.

The SPTA project utilizes a dominant non-pollen-producing maize gene, Ms44, to create female parent plants that are unable to produce pollen, and which do not need to be detasseled during the hybrid seed production process. The process makes cross-pollination between the female and male parents more reliable, enabling the efficient and cost-effective delivery of high-purity hybrid seed.

With the Ms44 SPT system, the inbred line used as a seed parent to create a single cross female seed also does not produce pollen and does not need to be detasseled during the production of basic seed. Finally, since the process of manual detasseling often removes one or more leaves in addition to the tassel, up to 10% of female seed yield potential may be lost. With the Ms44 SPT system, the full seed yield potential of the production female line or single cross can be realized.

Ms44 is a Single base pair change (mutation) that creates non-pollen-producing (NPP) plants (Albertsen and Trimnell, 1992). It is Stable (works across genetic backgrounds and environments) and a Dominant gene (Ms44). Homozygous recessive lines (ms44/ms44) are pollen-producing (PP) but not good maintainers of NPP lines- 1:1 for PP and NPP and are not usable in seed production. To make Ms44 (NPP lines) usable for seed production, a transgenic maintainer was developed. MS44 is a maize gene, and hence not GM technology, only the maintainer line is transgenic.

A unique feature of the SPTA process is the utilization of an Inbred Maintainer line (IMT) which contains a transgenic construct that has been designed not to transmit through the pollen. This specially designed construct, along with specialized state-of-the-art seed sorting technology, produces non-transgenic, homozygous Inbred Non-Pollen producing seed (INP). This means the transgene is not present in the pre-basic or basic seed grown by partnering seed companies nor in the certified hybrid seed planted by farmers.

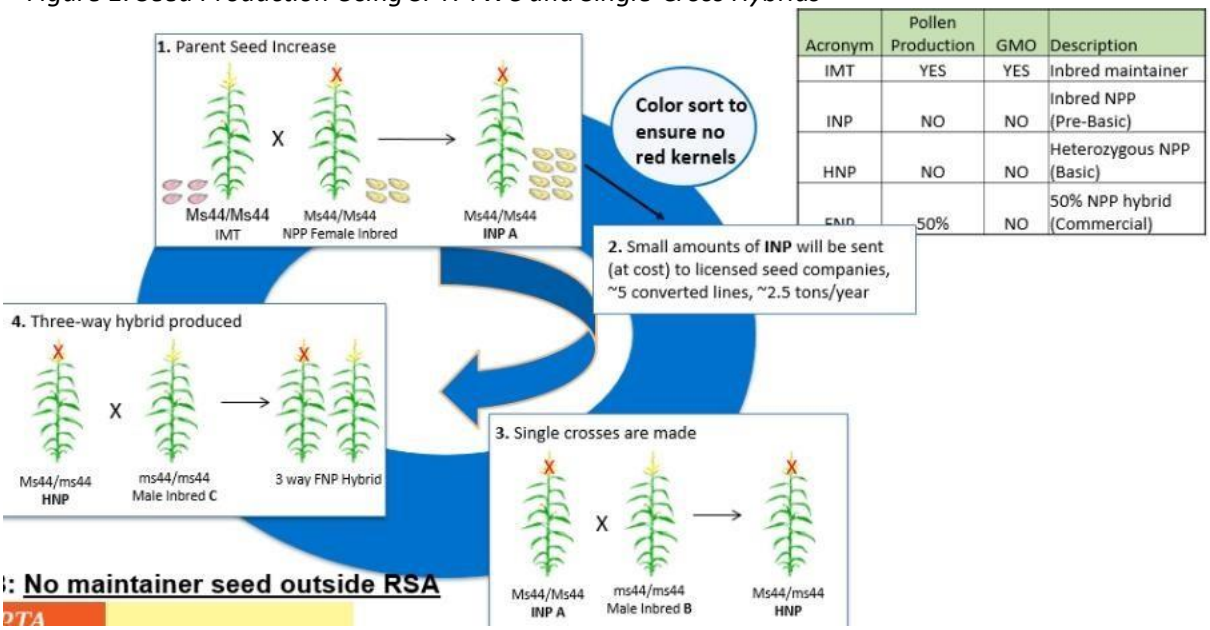
SPTA-produced Ms44 hybrids grown by farmers will have an equal number of pollen-producing and non-pollen-producing plants. These hybrids are referred to as Fifty percent non-Pollen producing (FNP). Since the pollen-producing plants provide more than adequate pollen for the entire maize field, the non-pollen-producing plants can utilize energy more efficiently, which would otherwise be used for pollen production, to support greater grain production.

Results:
For inbred line Conversions: CIMMYT commonly used elite lines entered the Ms44 conversion pipeline at Corteva and converted with Ms44 allele and maintainer construct.

An application dossier for deregulation of the maintainer in RSA is being developed. The maintainer was deregulated within the USA in 2021. The commercialization strategy for SPTA technology is under preparation.

Supporting Visuals and Quote:

Figure 1: Seed Production Using SPT: TWC and Single-Cross Hybrids



Acronym	Pollen Production	GMO	Description
IMT	YES	YES	Inbred maintainer
INP	NO	NO	Inbred NPP (Pre-Basic)
HNP	NO	NO	Heterozygous NPP (Basic)
FNP	50%	NO	50% NPP hybrid (Commercial)

Supporting Visuals or Quotes:

> *Use of the SPTA process ensures that the seed parent of the hybrid will not produce pollen, thereby eliminating the need for detasseling. This means seed producers can ensure higher integrity of hybrid seed while reducing costs and increasing seed yield - Mike Olsen – CIMMYT*

Future Plans: For SPTA technology to benefit seed systems in Africa, it needs to be rolled out to more countries outside Kenya and South Africa. Collaboration with partners such as Corteva and CGIAR maize breeding programs for access to MS44 to introgress current and future maize germplasm in African countries that are willing to adopt SPTA, could be useful.

On their part, African Countries need to align their biosafety policies to enable them to either access and use the transgenic maintainer line or be in a position to access EGS from South Africa and any other countries where the maintainer will be used. The process of availing and use of MS44 will require extensive communication and capacity building by Corteva and CGIAR with CESSA facilitation.

Call to Action (CTA)/Key takeaways:

- CESSA should sensitize national breeding programs and seed companies on SPTA science and benefits.
- CESSA should explore scaling up SPTA beyond Kenya and South Africa and negotiate access to the technology by other major maize breeding and seed production public and private sector institutions.

References

Albertsen, M.C. and Trimnell, M. (1992) Linkage between Ms44 and C2. Maize Genet. Coop. Newsletter. 66, 49.

CIMMYT. Seed Production Technology for Africa (SPTA) Project. Improving productivity through high-quality hybrid maize seed. 2020. Project Brief. CIMMYT.

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Fox T, DeBruin J, Haug Collet K, Trimnell M, Clapp J, Leonard A, Li B, Scolaro E, Collinson S, Glassman K, Miller M, Schussler J, Dolan D, Liu L, Gho C, Albertsen M, Loussaert D, Shen B. A single point mutation in Ms44 results in dominant male sterility and improves nitrogen use efficiency in maize. Plant Biotechnology J. 2017 Aug;15(8):942-952. DOI: 10.1111/pbi.12689. Epub 2017 Feb 7. PMID: 28055137; PMCID: PMC5506649.

Web resources:

Seed Production Technology for Africa (SPTA) CIMMYT: https://www.cimmyt.org/projects/seed-production-technology-for-africa-spta/

My Agriculture Information Bank: Male Sterility (https://agriinfo.in/male-sterility-1752/).

Male Sterility, types and utilization in hybrid seed production (ICAR-Central Agroforestry Research Institute) https://www.researchgate.net/publication/338187483_Male_Sterility_types_and_utilization_in_hybrid_seed_production