Bio-containment of transgenes by cytoplasmic male sterility and xenia in maize

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Coexistence in maize

No wild relatives in Europe

No volunteers

Cross-pollinator

Pollen mainly transported by wind

Transgenic pollen flow to neighboring non-GM fields

Approaches for transgenic pollen flow mitigation:

- *Isolation distances*
- *Pollen containment by male sterility*

Cytoplasmic male-sterile (CMS) maize

Cytoplasmic male sterility (CMS) occurs naturally in maize

Form of male sterility induced by the complementary action of nuclear and cytoplasmic genes

- ✓ ***CMS originated from mutations in the mtDNA***

  Failures in energetic pathways in the anther tapetum and/or microspores

  ➡ **No production of pollen or production of non-viable pollen**

- ✓ ***Maternally inherited trait widely used in breeding***
- ✓ ***Three types of CMS in maize***
- ✓ ***Nuclear restorer-of-fertility genes (rf genes)***

Cytoplasmic male-sterile (CMS) maize

Avoidance of the release of GM pollen ???

Fertile hybrid ***CMS hybrid***

"Growing a mixture of a ***transgenic cytoplasmic male-sterile maize hybrid*** *in combination with a lower proportion of a* ***non-transgenic fertile hybrid*** *as pollen donor."*

Cytoplasmic male-sterile (CMS) maize

Partial or full restoration of pollen fertility

Sterile *tassel*

No pollen

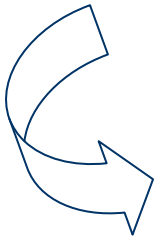
Fluctuating *tassel*

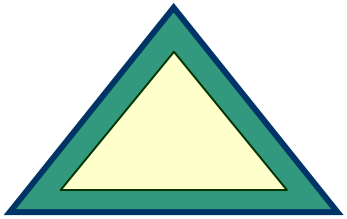
Viable pollen?

Fertile *tassel*

Viable pollen

Why?
How?
When?





Ring field trials 2005/2006

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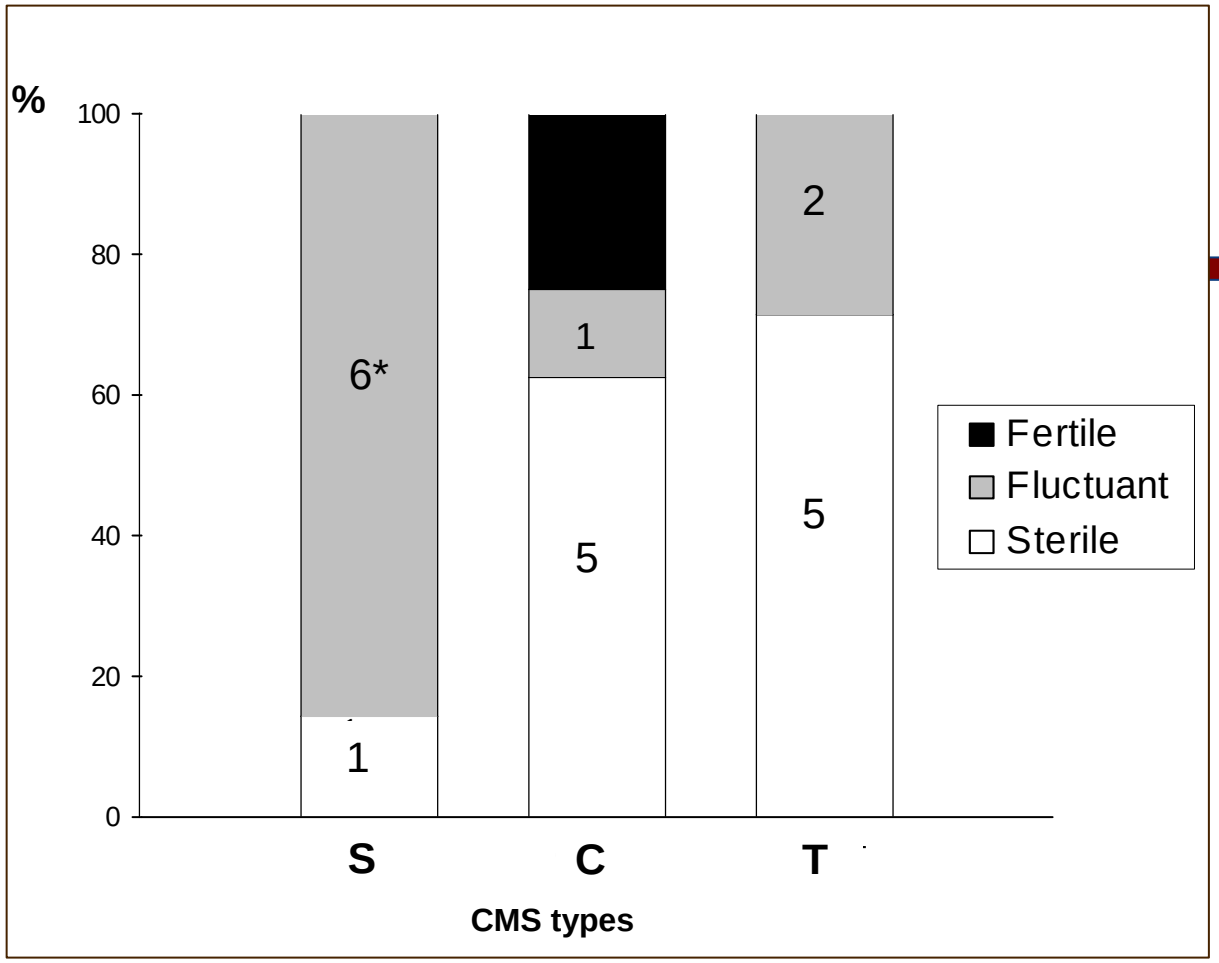
- → 3 genetic backgrounds: CMS-T, CMS-C and CMS-S
- → 22 modern hybrids from main European breeders
- → 18 environments: 1 environment = 1 location x 1 sowing date

Co-Extra
CO-EXISTENCE & TRACEABILITY

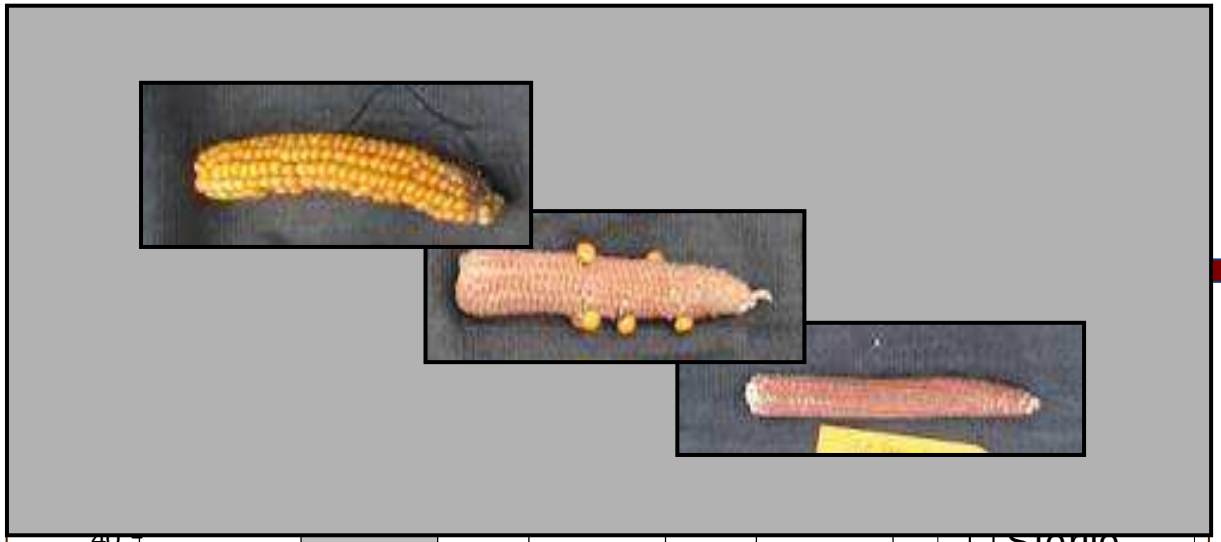
Stability of the CMS trait?

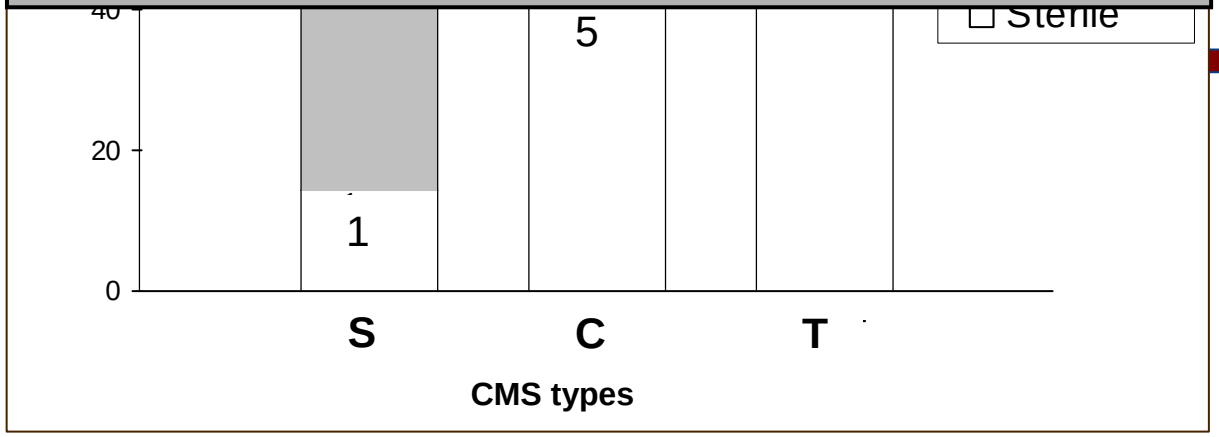


Restoration of fertility occurs in all S, C and T cytoplasms

*** Number of hybrids per class**

Stability of the CMS trait?



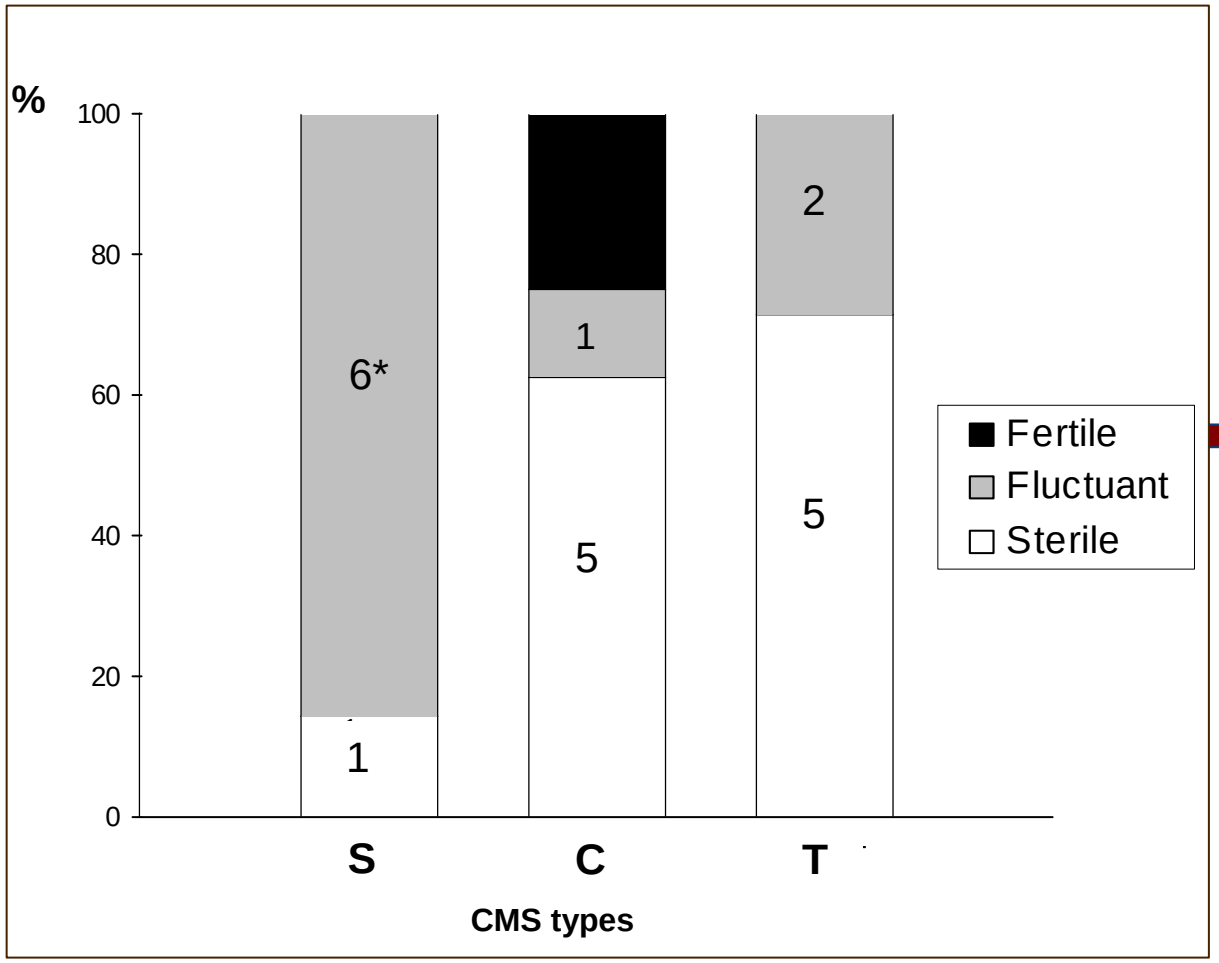


Restoration of fertility occurs in all S, C and T cytoplasms

Pollen produced By fluctuant plants Is often not fertile

*** Number of hybrids per class**

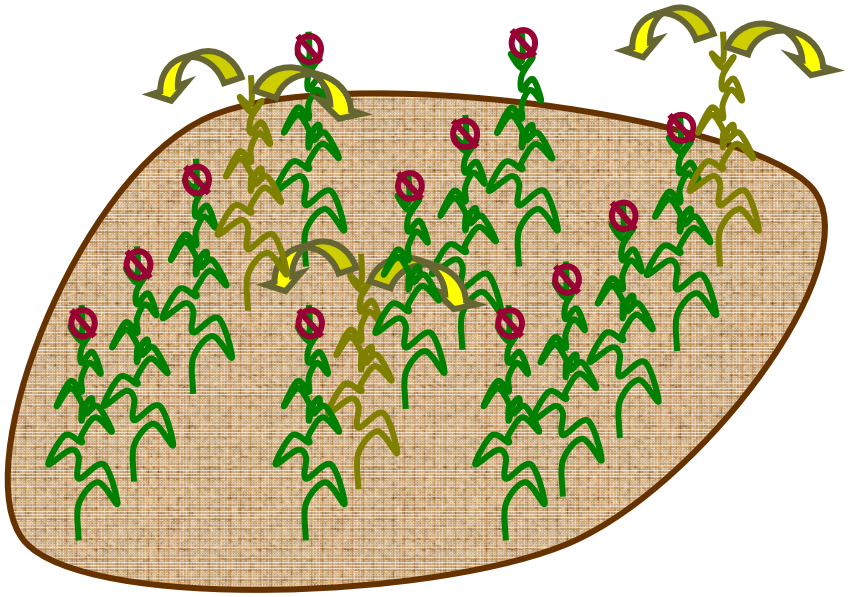
Stability of the CMS trait?



There are 100% stable hybrids of all CMS types

* Number of hybrids per class

Maize Plus-Hybrids



GM CMS maize hybrid *(80%)*

+

Unrelated conventional fertile hybrid *(20%)*

Advantages of the system

- Pollination ensured
- No or less release of GM pollen
  (interesting even for HT hybrids)

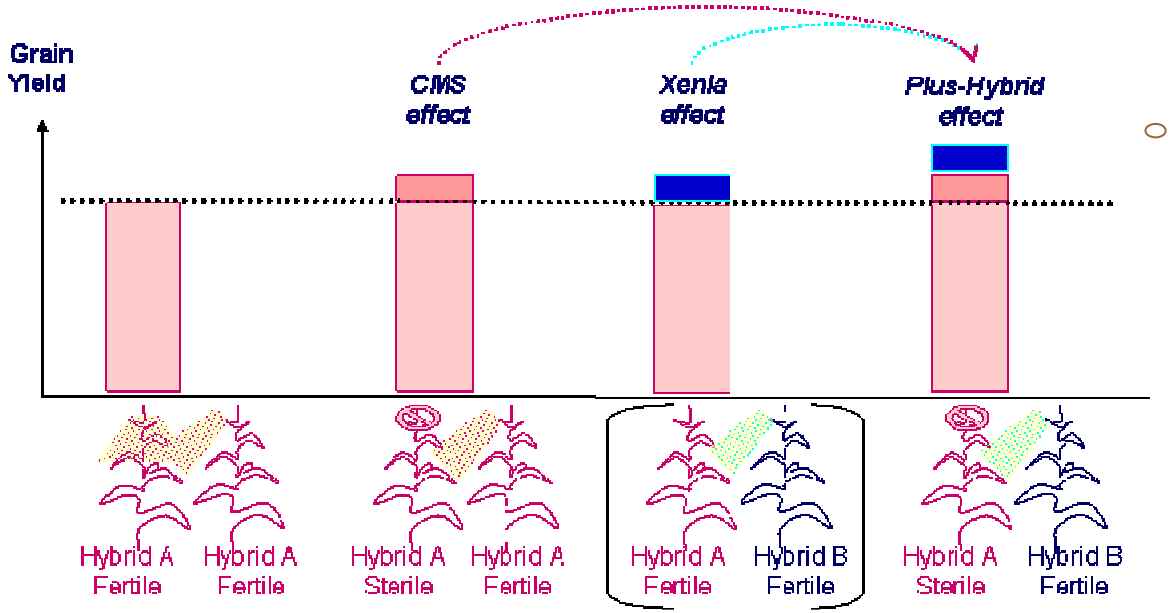
Bonus with this system

Plus-Hybrid effect combining both CMS and Xenia effect

Significant grain yield increase

Gain in yield with CMS and xenia

Plus-Hybrid effect on maize grain yield



CMS effect

No pollen production, more resources available during the ear and kernel development

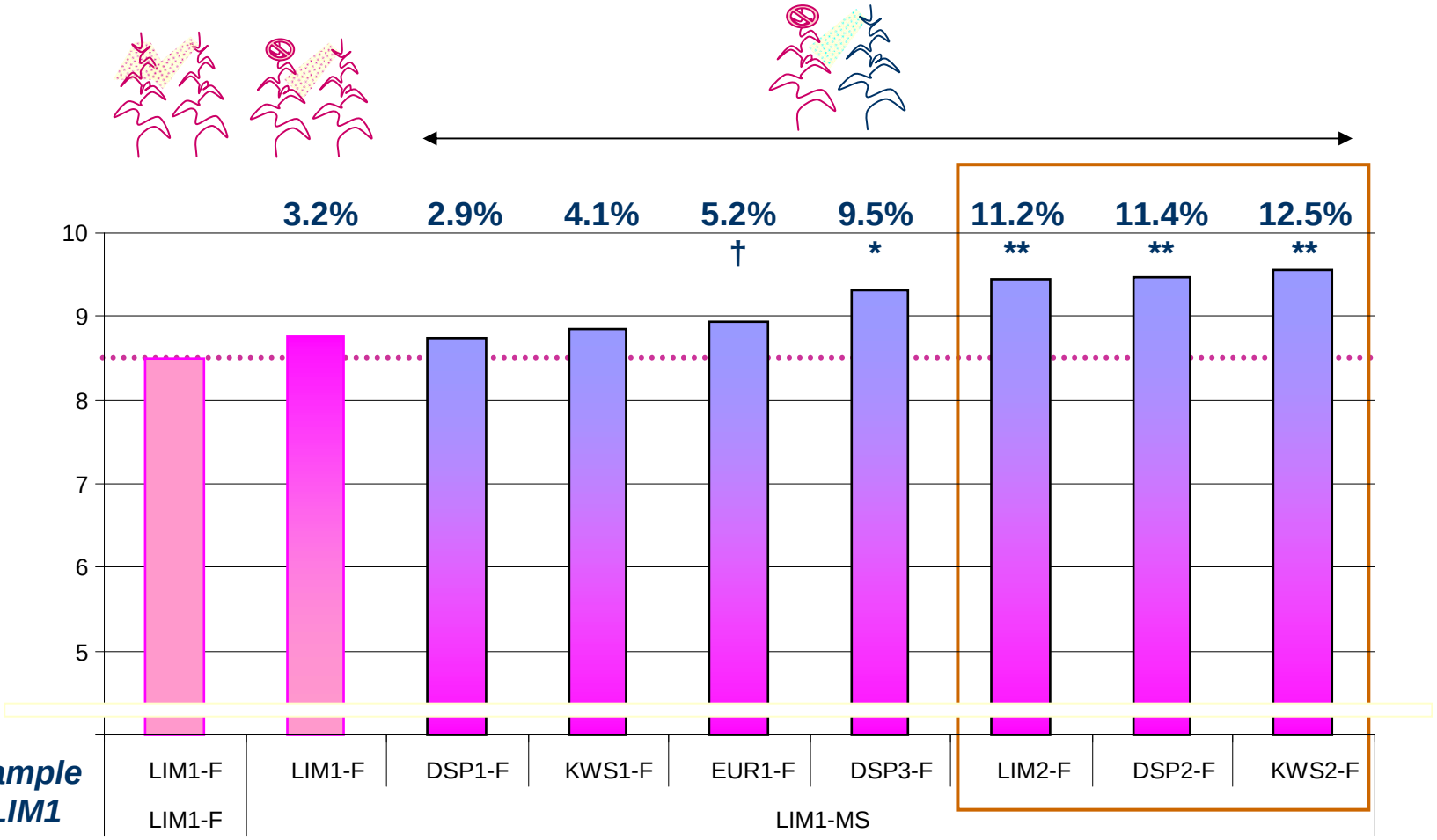
Xenia effect

Allo-pollen direct influence on colour, weight and composition of the maize kernel

= **Plus-Hybrid Effect**

Gain in yield with CMS and xenia

Plus-Hybrid effect on grain yield *(11 environments)*



ns, not significant ; †, *, **, significant at the probability level of 0.2, 0.05 and 0.01 respectively

CMS, a real potential biological mitigation technique !

Cytoplasm T → **e.g. Pharmaceuticals**

\+ Well-known restoration system

\+ **100% stable under a wide range of environments**

\- Sensitive to *Bipolaris maydis race T*

→ **Possibility for breeders to develop resistant backgrounds**

Cytoplasms C and S → **e.g. Bt, HT**

\+ Many male-sterile hybrids

→ Possibility for breeders to develop stable backgrounds

\- Undetermined *Rf* genes involved

Related Publications

Weider, C., P. Stamp, N. Christov, A. Husken, Foueillassar, K.-H. Camp, and M. Munsch.
Stability of cytoplasmic male sterility in maize under different environmental conditions. Crop Science 2009. 49:77-84.

Munsch, M., P. Stamp, N. Christov, A. Husken, Foueillassar, K.-H. Camp, and C. Weider.
Modern maize hybrids can improve grain yield as Plus-Hybrids by the combined effects of cytoplasmic male sterility and allo-pollination. Maydica 2009. *in press*

Munsch, M., P. Stamp, N. Christov, A. Husken, Foueillassar, K.-H. Camp, and C. Weider.
Grain yield increase and pollen containment by Plus-Hybrids could improve acceptance of transgenic maize. Crop Science. *Tent. accepted*


Stability of Cytoplasmic Male Sterility in Maize under Different Environmental Conditions


MODERN MAIZE HYBRIDS CAN IMPROVE GRAIN YIELD AS PLUS-HYBRIDS BY THE COMBINED EFFECTS OF CYTOPLASMIC MALE STERILITY AND ALLO-POLLINATION