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An Unexpected Method for Controlling Corn Pollen Dispersal

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Two reports[1,2] describe the characterization of experimental transgenic maize plants containing a wheat genomic DNA fragment encoding the Glu1-Dx5 gene. This gene encodes a high molecular weight glutenin, a storage protein that is a component of gluten, the complex polymer that gives wheat flour dough its elasticity. The motivation for transferring this gene to corn was to determine the feasibility of producing grain with altered flour properties that could allow development of improved or novel maize-based food products. In addition, production of individual wheat proteins in corn could be a valuable approach for studying gluten sensitivity because it allows proteins to be evaluated on an individual basis, something that is difficult to do with wheat-derived proteins.

In their initial evaluation of these plants, the authors unexpectedly determined that the wheat genomic fragment exhibited maternal inheritance in all four of the events that were characterized.[1] The second report[2] characterizes the mechanism that confers maternal inheritance to this transgene and demonstrates that this transgene can be used to prevent the transfer of another transgene (an herbicide resistance gene) to other plants through pollen. The ability to prevent the transfer of a transgene through pollen could have application in commercial production of transgenic crops.

In an effort to understand the biological mechanism conferring maternal inheritance to transgene loci containing the wheat genomic fragment, the authors examined the pollen of the transgenic plants. Because the transgene was inherited maternally, these plants were necessarily heterozygous at the transgene locus. Corn is a diploid species, but the pollen is haploid. In a transgenic corn plant that is heterozygous at a transgene locus, half the pollen would normally be expected to contain the transgene and the other half would not.

In the transgenic corn described in these studies, transgene DNA is present in the pollen, but the pollen exhibits reduced viability. In some cases, two classes of pollen were visually discernible, and one of these classes was not viable. The authors hypothesize that the pollen containing the transgene is among that which is non-viable. This leads to the hypothesis that pollen containing the transgene locus fails to develop normally and is non-viable, although it is still shed, while non-transgenic pollen from the same plant develops normally, is shed, and is viable. If this hypothesis is correct, the transgene locus functions as a pollen-specific gametocide, explaining its maternal inheritance.

It is not clear why this DNA fragment functions as a gametocide in corn. In wheat, the Glu1-Dx5 gene produces a storage protein that accumulates only in the endosperm of seeds. In the transgenic corn described in this study, the Glu1-Dx5 gene produces a protein of expected size in the endosperm, but also mediates the pollen-specific gametocide function that results in maternal inheritance of the transgene. The Glu1-Dx5 protein gene product is not detectable in the pollen of transgenic corn. It is possible that the gametocidic function is contained on the wheat genomic fragment but is not related to production of the Glu1-Dx5 transgene product. Intriguingly, when the Glu1-Dx5 gene is controlled by a maize endosperm-specific promoter, the transgene does not exhibit the gametocidic function, indicating that the Glu1-Dx5 coding sequence is not sufficient to cause the gametocidic function, and that the gametocidic activity is conferred by DNA present in the wheat genomic fragment but lacking in the construct containing the corn promoter, which includes several kilobases of DNA upstream of the Glu1-Dx5 translational start site, including the promoter of this gene.

Many important crop species, including maize, sunflower, and alfalfa, produce seeds mainly by cross pollination. With segregated grain markets, cross pollination can be a problem because it can occur between production fields of different types of grain. This can result in the inadvertent transfer of traits from one production field to another where these traits may not be desired.

Several methods have been proposed to control unwanted outcrossing, including use of mutants[3] or management strategies such as detasseling.[4] Maternally inherited transgenes are another solution to this problem of outcrossing and can be produced by chloroplast transformation.[5] Unfortunately, this technology is currently only available for a few species and has not been routinely successful in corn. A pollen-specific gametocide such as the one described[2] could be deployed so that it is genetically linked to a transgene of interest. In this system, pollen containing the transgene is not viable, and therefore cannot pass the transgene on to progeny. Non-transgenic pollen remains viable and is produced in quantities sufficient for fertilization of the crop. This approach could potentially be used to confer maternal inheritance to any transgene, regardless of the trait conferred by the transgene.

Several problems remain with this system as described. One problem is that because the transgene locus is maternally inherited, the transgene must be deployed as a heterozygote. Heterozygous plants would produce seed that segregate for the transgene locus, so only half of the seeds produced would be transgenic. There are several ways to overcome this deficiency. One approach would be to use a mechanism of selection for those plants containing the transgene, for example by incorporating a gene for herbicide resistance into the transgene locus. Another approach could involve incorporating a gene into the transgene locus that makes transgenic seeds distinguishable to mechanical sorters, for instance a seed color gene.

A problem with the use of Glu1-Dx5 as a transgenic pollen-specific gametocide is that it is not completely effective, so in some cases low levels of transgenic pollen are shed in some events. The Glu1-Dx5 transgene has been useful for demonstrating the feasibility of using a pollen-specific gametocide to control pollen dispersal, but it does not function well enough to be used commercially. Other transgenes that function as pollen-specific gametocides exist,[6] and may be better suited to this purpose.

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