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BRIEF BACKGROUND

Heterosis (also called *hybrid vigor*) is the phenomenon in which F1 hybrids derived from diverse parents show superiority over their parents. Hybrid varieties with heterosis are popular in many crops, including vegetables. Hybrid rice varieties also have remarkable strengths such as high grain yield compared to inbred rice cultivars.

However, the production cost of F1 hybrid seeds in rice is much higher compared to other crops because of the unfavourable rice flower structures for outcrossing. Hence, in spite of the advantages of hybrid rice varieties, hybrid cultivars seeds are more expensive compared to the seeds of inbred varieties. Enhancement of outcrossing rates is a major challenge to provide superior F1 hybrid variety seeds to rice farmers with relatively lower cost and price.

It would be beneficial to develop rice female parental lines with improved outcrossing rates, useful for increasing hybrid seed production. However, domesticated rice is a self-pollinating (inbreeding) crop, with very low rates of outcrossing. The low rate of outcrossing causes poor hybrid seed production (seed set

of ~20%), resulting in high costs for hybrid rice seeds. One of the major reasons for the low outcrossing rate in rice is the morphological weakness of stigma (head of the pistil). To produce hybrid F1 seeds, eventually the stigma of the female parents should capture pollen grains from the male donor plants for fertilization, but the stigma of cultivated rice is short and stays inside the hull during pollination, limiting pollen access.

IRRI previously reported on an ambitious research project aiming at developing rice female lines with a long-exserted stigma, a desirable phenotype for high outcrossing rate. A long-exserted stigma trait had been found from the wild relative of rice, *Oryza longistaminata*, which favours outcrossing in nature, unlike the self-pollinating cultivated rice species *O. sativa*. Recently, the genetic element controlling the long-exserted stigma phenotype from the *O. longistaminata* was successfully identified through genetic analysis, and was transferred to popular hybrid parental lines using marker-assisted selection.

In initial field trials, the new parental lines exhibiting a long-exserted stigma showed a significant high outcrossing rate. Fine mapping and gene validation experiments using transgenic approaches revealed that the single dominant gene on chromosome 8 originated from *O. longistaminata* is responsible for the long-exserted stigma phenotype.

This invention has the potential to improve the production of elite hybrid rice seeds that would be affordable for use by smallholder farmers. The invention would greatly facilitate the development of new rice female lines with long-exserted stigma.

NEED FOR FURTHER INVESTMENT

Further breeding and testing investments are needed. In particular:

- The HO trait needs to be introgressed in a number of elite female lines representing a wider range of genotypes from both two-line and three-line hybrid systems, to be used for the production of new hybrid rice varieties; and
- Hybrid seed production trials should be performed in a number of different agro climatic conditions and with a number of different genotypes, to produce robust data on the improved hybrid seed production caused by the HO trait.
- Horizontal transfer of the long-exserted stigma gene originated from *O. longistaminata* into other Gramineae crops such as wheat for testing functionality of the gene in Gramineae for use in hybrid seed production.

Several years will be necessary to produce the new female lines and generate the data from production trials. Additional financial resources and testing capacities are required which are beyond IRRI's capacity. For these reasons, IRRI seeks to attract partner organizations that can contribute financial and technical support for further development and utilization of the HO trait. The same partners, and others, will be asked to use the invention for scaling up, for the benefit of rice growers in developing countries.

This new PCT patent application allows IRRI to pursue its own research program on the “HO” trait and to grant access to this innovation on terms that will create incentives for additional research and development as well as investment by downstream partners.

IRRI's licensing strategies are designed to provide royalty-free licenses to NARES partners, and limited-exclusive or non-exclusive commercial licenses for private companies, with a commitment to impact assessment and impact acceleration. We ensure that our patent applications, and the patent claims, do not extend to farmers access and use of landraces per se. IRRI will continue to comply with all obligations of the SMTA including benefit sharing, where applicable.

In addition, as per IRRI's policy, royalties paid by future licensees to IRRI shall be shared with the benefit-sharing fund of the International Treaty for Plant Genetics for Food and Agriculture (see www.fao.org/3/a-i0510e.pdf), even when conditions for benefit sharing are not triggered.

As a non-profit international organization, IRRI promotes responsible technology transfer and intellectual property management in accordance with its Intellectual Property and Commercialization Policy (IP&C Policy)¹ and with the CGIAR Principles on the Management of Intellectual Assets (“IA Principles”)². This patent application conforms with the IA Principles concerning intellectual property applications, i.e., necessary for the further improvement of the innovation or to enhance the scale or scope of impact on target beneficiaries, in furtherance of the CGIAR Vision.

CURRENT STATUS

In 2023, IRRI advanced this patent application for this invention from “PCT” (Patent Cooperation Treaty) application to National Phase Application in USA, Europe, Philippines and India. This patent application, and the PCT patent claims, do not restrict access to the original material that was the source of the HO trait. Materials used to develop the HO trait came from in-trust germplasm of the multilateral system (MLS).

This patent application, part of a HO patent family first applied in 2016, is expected to create incentives for seed companies and other organizations to partner with IRRI and invest 1) in additional and expanded research and development of the HO trait, as well as 2) to produce and introduce HO hybrids at production scale. Through these partnerships, the research and development of the HO trait will be accelerated, and the eventual commercialization of less expensive hybrids will allow farmers to benefit from affordable hybrid seeds.

IRRI intends to provide non-exclusive, royalty-free licenses to NARES partners for research, breeding, and non-commercial dissemination. For private sector partners, IRRI plans to provide non-exclusive research, breeding, and commercial licenses, with a commitment to impact assessment and impact acceleration. IRRI licensees will be bound to comply with all obligations of the SMTA. As part of the future commercial licenses, IRRI will require private licensees to make a contribution to the Benefit Sharing Fund of the Treaty, even when the obligation to contribute to benefit-sharing is not triggered automatically as per the SMTA terms and conditions.



In addition, and as per IRRI's policy, royalties paid by future licensees to IRRI shall be shared by IRRI on a voluntary basis, with the benefit-sharing fund of the [International Treaty for Plant Genetics for Food and Agriculture \(ITPGRFA\)](#).

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