



Hybrid Rice Breeding: Principles, Methods and Future Prospects

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Abstract

Hybrid rice revolutionizes farming by harnessing hybrid vigor for 15-30% higher yields, pioneered by Yuan Longping to feed billions on shrinking lands. The biological basis of dominance and overdominance improving tillers and roots and tolerance to stress has been demystified as well as the breeding concepts of three-line CMS and two-line systems and the future of climate-adaptive, nutrient-enriched (Zn/Fe-packed) hybrids. It creates sustainable ways to feed the world of 10 billion through public-private cooperation and education of farmers.

Key Word: Hybrid rice, Vigor, Dominance, Sustainable

Introduction

Rice is not merely a crop, but the staple food of almost 3.5 billion individuals on earth. In the Asia with plates of steaming rice, to platters of staple food in Africa, rice is the food in the bowl every day of the world. And this is the issue that faces agriculture: arable land is decreasing, water resources are strained and populations are not declining. The ability to generate food on a smaller piece of land is now one of the biggest challenges of our generation. The silence of the hybrid rice became a silent saviour of the situation in this high stake game. It is through the exploitation of the natural energy of the so-called hybrid vigour that scientists were able to come up with varieties of rice that can produce much more grain than the old inbred varieties.

The genius is the man behind this innovation, who is the affectionately referred to as the father of hybrid rice, called Yuan Longping. His visionary research in the 1970s demonstrated that rice which had been viewed as incapable of being hybridized in an effective manner was capable of being genetically fused to reveal immense potential in yield.

What is Hybrid Rice?

Hybrid rice is produced by intermingling two genetically different parent lines and captures the benefits of heterosis or hybrid vigour, such as taller plants, deeper roots and more grains per stalk and in most cases, the hybrids have a

higher yield of 15-30% higher than the conventional varieties.

History and Evolution of Hybrid Rice

In China, as early as the 1960s-70s, hybrid rice was developed by Yuan Longping who identified cytoplasmic male sterility (CMS) in wild rice, which resulted in the first commercial three-line hybrid in 1973 that increased yields and prevented famine.

The public adoption of hybrids started in India in the 1990s, with projects such as the Indian Council of Agricultural Research and by 2020s, 5-10% of the rice area was covered such as Arize, followed by other countries, such as Vietnam and Bangladesh, to ensure food security.

Biological Basis of the Hybrid Vigor

When crossing two looks-all-right rice plants, what makes little plant grow faster, have one big root in the world and give 20 per cent more grain? This is known as Heterosis (or hybrid vigour). The following are the two theories

1. Dominance Hypothesis

Each rice plant has in its possession a hand of genes. They are bad genes, a few of them are recessive genes which may give rise to roots a little bit weaker, leaves a little smaller. These bad genes are normally matched in a purebred line bringing their weaknesses to the fore.

2. Overdominance Hypothesis

Theory implies that being mixed is always superior to being a pure being. In some genes, to have two versions (heterozygosity) is a biological synergy that is more effective than having two identical versions.

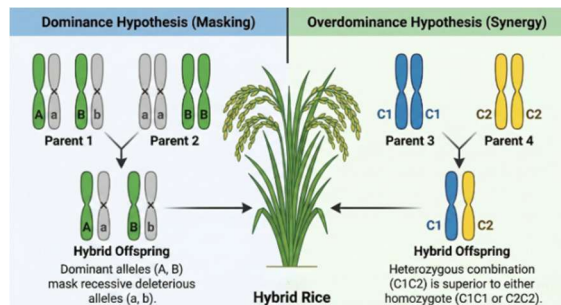


Fig.1. Hypothesis behind the Hybrid Rice

Visibly superpower: Characteristics Enhanced by Heterosis.

Once these genetic mechanisms fall into place, a rice plant receives a quantifiable boost:

- **Yield:** The headline feature. Hybrids just squeeze a greater amount of grain per hectare.
- **Tillering:** Hybrids have more productive tillers (the ones that carry grain) than the traditional ones.
- **Root System:** Hybrids have stronger and deeper roots at an earlier stage and this enables them to be better at scavenging nutrients.
- **Stress Tolerance:** They have very strong metabolism which serves as a buffer that helps to make them tougher towards drought or salty soil.

Principles of Making Hybrid Rice Breeding

It is not merely a science, but a great match-making at stake to come up with a successful hybrid. The breeders are searching a certain genetic desirable character that will make super variety.

Parental Line Selection: The basic rule of hybrid breeding is the genetic diversity. Crossing two similar parents genetically and not get a lot of hybrid vigour. The greater the heterogeneity of the parents, the greater the vigour of the hybrid offspring is bound to be.

Two Breeding Systems

1. **Three-Line System (CMS System)**-The classical & widely used method

The Three Key Lines

- **A Line (CMS Line)**
Male sterile, produces hybrid seed.
Eg: IR58025A

- **B Line (Maintainer Line)**
Male fertile, maintains A line.
Eg: IR58025B
- **R Line (Restorer Line)**
Restores fertility in hybrid.
Eg: IR40750R

2. Two-Line System

The new-generation, flexible approach

➤ Uses environment-sensitive male sterility:

- **TGMS** – Sterile at high temperature, fertile at low temperature.
- **PGMS** – Sterile under long day length, fertile under short days.

Why it's gaining attention

- No maintainer (B) line needed
- More parental choices
- Faster hybrid development
- Higher yield potential

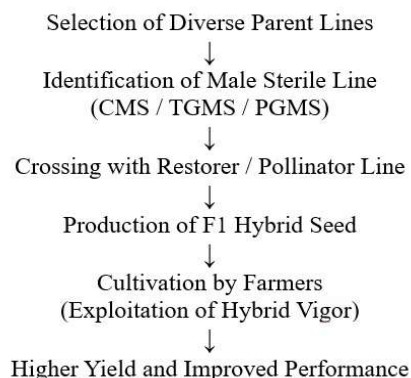


Fig. 2. Production of hybrid rice breeding system

Future Prospects of Hybrid Rice and Beyond

The hybrid rice of tomorrow is not only about combating famine but malnutrition and climate change.

- **Climate warriors:** Since the weather has become unpredictable, breeders are producing the hybrids known as Survivor. Flood tolerant varieties (Samba Masuri Sub1, CR Dhan 811, CR Dhan 804) can withstand a two week stay in water.
- **Medicine in a bowl:** Hidden hunger is a worldwide crisis. New hybrids are being produced not only to starch, but also to necessary minerals. With this as a way of fighting stunting and anaemia among children, with such a natural process of enriching a grain, one can use a simple daily meal as a means of combating these conditions.
- **Hybrid seeds are costly to manufacture:** Cheaper seeds for all. As a solution,

researchers are pursuing the so-called Apomixis, a method that will allow hybrids to reproduce themselves with seeds.

- **Sustainable Farming:** The modern hybrids are intended to be "smart eaters." They generate larger quantities of grain with 2030 percent less fertilizer and water.

Conclusion

Extension programs and demos are always important to raise awareness of farmers, enabling farmers to embrace hybrids without fear, by demonstrating real field yield increase

and control strategies to meet regional conditions. The collaboration between the public and the private will help in speeding up the process where the public research on resilient germplasm is combined with the scale of the private seed firms, which in the case of India has led to collective achievements in expanding the use of hybrids in the country. Hybrid rice is one of the pillars of the future rice farming, which integrates both genetics and sustainability to guarantee the plentiful and healthy harvests against climate and population pressures to make rice bowls remain full of corn.