

Hybrid rice development in Indonesia: constraints and opportunities

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Abstract. This paper reviews the constraints and opportunities of hybrid rice development in Indonesia. Indonesia has released more than a hundred hybrid rice varieties; Indonesian Center for Rice Research (ICRR) developed 21 varieties. Extensive trials were conducted on the various aspects of seed production by government sectors and private companies. Significant progress has been made in hybrid rice seed production, with seed yield increasing from 1 t/ha to 3 t/ha. Various problems should be considered to develop a good seed production system. The constraints are the low outcrossing rate, shortage of suitable land, high cost and labor, lack of trained personnel, climatic fluctuations in rainfall and temperature, and limited hybrid rice seed grower. Private sectors investment in hybrid rice has been increased. Positive support from government and private companies will boost hybrid rice's adoption rapidly. Collaboration of hybrid rice dissemination across institutions was a meaningful way to encourage hybrid rice adoption. Optimizing seed production technologies could significantly increase the present level of hybrid seed yield. The opportunities are an increase of rice demand, various materials genetic, distribution of rice ecosystem, and public-private sector partnership that developed on hybrid seed production to accelerate the adoption of hybrid rice. It supports not only the research and development but also the dissemination and adoption.

1 Introduction

As a staple food, rice plays an essential role in providing food security in Indonesia. Indonesia is one of the world's largest rice consumers. The national census in 2020 showed that the Indonesian population was 270.20 million, increasing significantly from 237.64 million to the earlier census in 2010. It means that rice production is required to increase every year to ensure food security for Indonesian consumption.

In 2020, the Indonesian Statistics Agency [1] recorded that the area harvested at 10,79 million ha, with total production reported at 55.16 million tons. The average yield for all Indonesian rice recorded at 5.2 ton/ha. Rice consumption in Indonesia has 114,4 kg/capita/year, and this consumption is still high compared to other Asian countries that consume approximately 65-70 kg/capita/year. The government increases rice production

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through several strategies, including extensification and optimization of food cropland, intensifying the use of input production technologies, and finding new high rice yield varieties.

Hybrid rice crossed from two different plants with different traits. Due to their heterosis effects, the hybrid rice varieties could increase yield by 15-20 percent over inbred varieties [2]. Various yield trials show that hybrid rice in Indonesia has a 15-25% higher grain yield advantage than the currently popular inbred superior rice varieties, such as Ciherang, Mekongga, IR64 and others [3,4]. This paper reviews the constraints and opportunities of hybrid rice research and development in Indonesia. It highlights how to progress the development of hybrid rice in Indonesia from 1983 until now, and breeding strategies to face global agriculture challenges and the performance of released hybrid rice varieties in the farmer field.

2 Hybrid rice performance

The research of hybrid rice in Indonesia began in 1983. Little was achieved in the early stages, but hybrid rice research intensified through some collaboration between IAARD with IRRI, FAO, private companies, and others through promising hybrid combination, new CMS, maintainer, and restorer lines. Since 2002, ICRR hybrid rice research progressed through the International Rice Research Institute (IRRI). As a result, two hybrid rice combinations Maro (IR58025A/IR53942) and Rokan (IR58025A/BR827-35) released as the first generation of hybrid rice varieties in Indonesia [5].

Indonesia has released more than a hundred hybrid rice varieties since its founding in 1983 with superiority at grain yield, resistance to major pest and disease, and good grain quality. Among those, twenty-one released by IAARD and thirteen of them possessing resistance to brown planthopper and bacterial leaf blight (Table 1). Over the past decade, governments and private companies have conducted extensive trials on all aspects of seed production. Progress has made in hybrid rice seed production, with seed yield increasing from 0.95 to 3.9 t/ha.

Table 1. Some hybrid rice varieties released during the period of 2010 – 2019.

Hybrid Variety	Year of release	Average yield (t/ha)	Resistant to:			
			Brown planthopper	Bacterial leaf blight	Tungro	Blas
Maro	2002	6.24	-	-	-	-
Rokan	2002	6.44	-	-	-	-
Hipa 3	2004	8.5	+	+	+	-
Hipa 4	2004	8.01	+	+	+	-
Hipa 5 Ceva	2007	8.4	+	-	+	-
Hipa 6 Jete	2007	7.36	-	-	-	-
Hipa 7	2009	7.6	-	-	+	-
Hipa 8	2009	7.5	-	+	-	-
Hipa 9	2009	8.1	-	+	-	-
Hipa 10	2010	8.1	-	+	-	-
Hipa 11	2010	8.4	-	+	-	-
Hipa 12 SBU	2011	7.7	+	+	-	-
Hipa 13	2011	7.7	-	+	-	-
Hipa 14 SBU	2011	8.4	+	+	-	-
Hipa Jatim 1	2011	8.2	-	-	-	-
Hipa Jatim 2	2011	9.3	-	+	-	-
Hipa Jatim 3	2011	8.5	-	-	-	-
Hipa 18	2013	7.8	+	+	-	-
Hipa 19	2013	7.8	+	-	-	+
Hipa 20	2019	9.54	+	+	-	+
Hipa 21	2019	8.99	+	+	-	+

Source: ICRR [6].

The performance of hybrid rice varieties in the farmer field is unstable. The results of the demonstration plots indicated that the hybrids could not always express their superior yield over the best-inbred check variety. The yield average of inbred was 7 t/ha, while hybrid rice yield was range from 7 to 9 t/ha (Fig 1). Therefore, farmers should plant hybrid rice varieties in suitable locations.

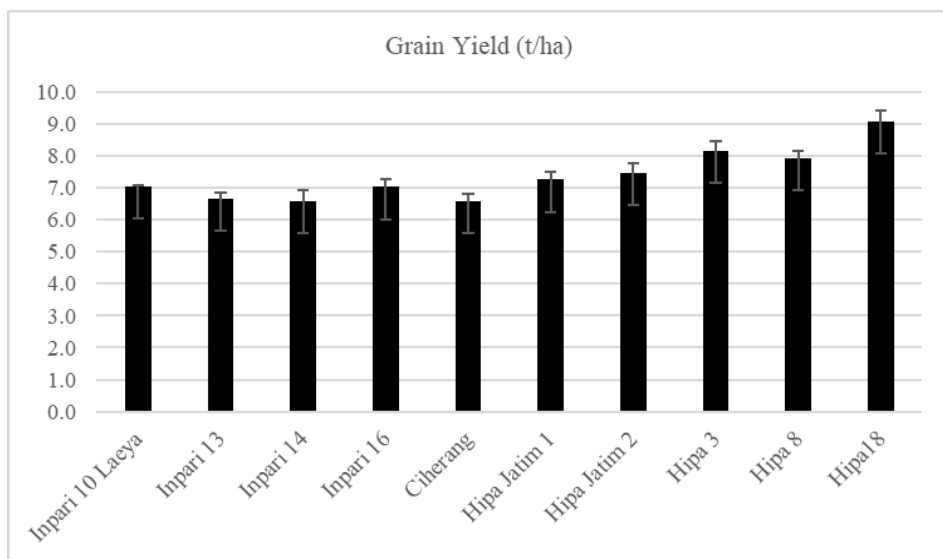


Fig. 1. Grain yield of inbred and hybrid rice varieties, Kepanjen, Malang, East Java, CS I 2014.

3 Constrains development of hybrid rice

3.1 Breeding

The Indica hybrid rice generally yields about 20% or higher than inbreed varieties. There is a deep genetic relationship. Currently used rice varieties have limited heterosis and linked to plateaus of indica hybrid rice production yields [7]. The inter-subspecies hybrids resulted from a higher level of heterosis and the exploitation of different species, encouraging increasing rice yield significantly [8]. However, the main problem of utilizing the heterosis between other subspecies is sterility. The wide compatibility varieties (WCVs) potential for hybrid rice breeding programs to solve hybrid sterility in indica/japonica hybrids [9]. The limited germplasm for inter-subspecies breeding is one barrier. The low heterosis in the Indica hybrids causes an inadequate or inconsistent yield advantage that discouraged the adoption.

Most of the male sterility cytoplasmic lines used in hybrid rice development in Indonesia have the same cytoplasmic source, namely "wild abortion" (WA). Therefore, this narrow genetic diversity of CMS sources leads to genetic homogeneity, a limited degree of heterosis, and vulnerability to hybrid pests. Other cytoplasm like Kalinga and Gambiaca have identified as the alternative male parent in the ICRR breeding program. Meanwhile, the restorer lines specific for Kalinga and Gambiaca-type need developing to produce a higher yield of hybrids [10]. In some cases, hybrids are required in local conditions such as grain quality and resistance to certain diseases and pests or lack some desirable traits. In addition, the breeding program hybrid rice must be synchronized to local environments and Indonesian preference.

3.2 Seed production

The average of hybrid rice seed yields is 1 – 2 ton/ha. The low yield caused by several things, i.e. the low outcrossing rate of sterile male lines, the complexity of management seed production, inadequacy of expert personnel for hybrid seed production, low purity and quality of parental seeds. In addition, the low yield makes the cost of seed production to be high. Research of hybrid rice seed production has conducted [11, 12] but still developing to solve the above problems.

Further, climatic fluctuations, i.e. rainfall, temperature, or light intensity, could harm the outcrossing rate. As a result, seed yield may be reduced or even completely fail. The quality of hybrid seeds described by genetic purity and germination ability has been one of the problems. Some private company have collaborated with contract farmers for hybrid rice seed production. Commonly, they inferiority at postharvest facilities, i.e., seed dryers and storage.

Suitable land and labour are other constraints in hybrid rice seed production. A private company must collaborate with the farmer's group caused has limited access to the large scale of land at locations suitable. Also, hybrid seed production is labour intensive from sowing until the processing requires more labours than inbred. The lack of rural labour limited the scale of hybrid seed production. All these constraints caused in a deficient supply of hybrid seeds and high seed cost, causing the low adoption of the hybrid rice technology.

3.3 Social and economics

The hybrid rice technology requires strong investments in development and commercialization. Every planting season, farmers have to purchase the seeds at a higher price than inbred seed. It prevents poor farmers from planting hybrid rice. Especially when rice prices are low and stagnant, input prices tend to rise. Due to low-profit margins, farmers cannot accept hybrid rice [13]. Also, caused by the generally poor quality of grains, the market price of hybrids is lower than that of inbreds, further reducing the benefits of hybrids. When rice production is much higher in high-yield areas, farmers tend to choose high-quality from popular inbred rice [14].

3.4 Environment

Seed hybrid rice production in a tropical area has hampered many problems, i.e. fluctuating temperature and rainfall, pests and diseases, predominantly brown planthopper, bacterial leaf blight, and blast.

4 Opportunities hybrid rice technology

4.1 Increase of rice demand

Rice consumption in Indonesia is calculated by multiplying the annual per capita rice consumption by the population. Indonesia has the highest per capita rice consumption (140 kg of rice per person per year). Indonesia has a high population growth rate. It is a great opportunity to develop hybrid rice technology and support rice productivity improvement.

4.2 Material genetics of parental lines

Breeding for Indica-restorer lines and Indica-CMS lines in ICRR has resulted in some parental lines and hybrid combinations. Indonesia has many javanica germplasm that potential to converted into restorer and cytoplasmic male sterility lines. Development parental lines with different CMS source to be the opportunity to achieve a higher heterosis level. [15,16] was developed new cytoplasmic male sterile lines with three diverse cytoplasm background, i.e. Kalinga, Gambiaca and Wild Abortive. Advances in molecular biology, genomics, and biotechnology hopefully give significantly improved hybrid rice breeding conventional breeding.

4.3 Distribution of rice ecosystem

Rice produced with both the lower and upper limits of the climate variable: average temperature (17–33 °C), annual rainfall (100–5100 mm), and solar radiation (25–95% of potential). Indonesia has four rice ecosystems; irrigated rice is the primary production system, covering more than 58,70% of the total rice area, 5.3% is upland, 27.2% rainfed lowland, and 8.8% swampy area (Fig. 2). In general, rice yield is optimized in irrigated area and low in rainfed lowland and swampy ecosystems. Furthermore, the primary breeding target hybrid rice is planting in an irrigated ecosystem. But based on a demonstration farm in other ecosystems, some hybrid rice varieties having high yield, especially in rainfed lowland [5].

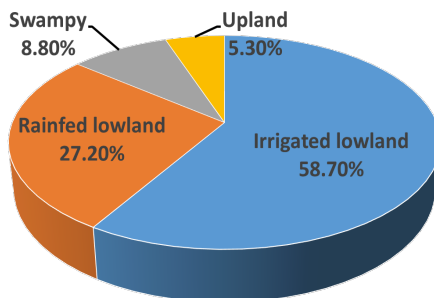


Fig. 2. Distribution of rice ecosystem in Indonesia.

4.4 Public Private Partnership (PPP)

Nowadays, private sector investment in hybrid rice research and development has increased. The governments and public institutions have launched various partnerships with the private sector for developed hybrid technology, i.e. demonstration farm, seeds subsidy, intensive dissemination, etc. As a result, many new hybrid rice hybrids have been developed and commercialized by private companies. Some of the hybrid varieties released by ICRR have licenced to some companies for commercialization. There have also been positive institutional changes to increase the efficiency of public sector management and attract more investment in the private sector. In addition, the advent of strong PPPs has provided the prospect of expanding the scale of hybrid rice adoption [17].

5 Lesson learn

The ICRR experience in hybrid rice technology for more than 40 years will provide lesson learn to develop and improve hybrid rice programs in the future. Global climate change has boosted the pest and diseases outbreak during the last several years, improving the hybrid rice with resistance to pain and diseases. Arable land reduction due to purpose sifting in Indonesia reached 110.000 Ha per year, Therefore developing new hybrid rice with high yield potential with good rice quality will be necessary. The potency of hybrid rice seed production is still low (1.0 – 1.5 t/ha). It causes the price of hybrid rice seed to be very high. The simplicity of seed production of new hybrid rice combination was essential. Elaboration of hybrid rice dissemination across institution identified as a vital way to encourage the adoption. The government's support and commitment was the main factor in the success of its hybrid rice program [18].

Progress has made in hybrid rice seed production, with seed yield increasing up to 3 t/ha. Optimizing seed production technologies could significantly increase the present level of hybrid seed yield. Therefore, the development of hybrid rice seed production is needed to increase hybrid seed yield. Furthermore, the improvement of purity and quality hybrid seed is significant through seed certification and quality control [19]. Public-private sector partnership developed on hybrid seed production to accelerate the adoption of hybrid rice technology, and some companies initiated to produce seed of public hybrids. It supports not only the research and development but also the dissemination and adoption of hybrid rice technology. Support of smallholder farmers for hybrid rice adoption. National coordination mechanisms and international cooperation on hybrid rice development. [20]

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