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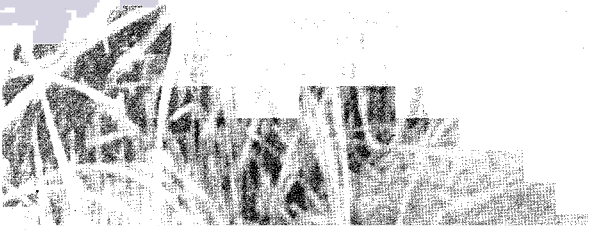


FOREWORD

In order to meet the future demands for rice in the Asia-Pacific region, it is necessary to enhance further the levels of productivity since more area is unlikely to be available for cereals. In this context, hybrid rice technology in China has made significant impact, registering a yield advantage of almost 2 t/ha over the conventional varieties. Hence, hybrid rice technology in China is already acclaimed as a "Success Story", which other nations in the region could emulate.

Asia Pacific Association of Agricultural Research Institutions (APAARI) has recently started a series, in which success stories based on realized gains through adoption of specific new technologies are being published for the benefit of others in the region. Earlier, two success stories have been published. These are:

1. Baby corn production in Thailand
2. Tilapia farming in the Philippines

In the present publication, details concerning development and adoption of hybrid rice technology in China have been presented with the hope that others concerned in the region would get sensitized and extend required support for the promotion of hybrid rice technology in their respective countries. I also congratulate both the authors Mr. Lou Xizhi and Dr. C.X. Mao for attempting this paper, which has subsequently been revised and edited in its present form by the APAARI Secretariat. I am sure the readers would find this publication both interesting as well as informative.

(R.S. Paroda)
Executive Secretary
APAARI

3 June, 1994

HYBRID RICE IN CHINA
- A Success Story

I. INTRODUCTION

Rice is a major staple food for the millions of people in the Asia-Pacific region. Almost 90% of the total rice is produced today in this region alone and a majority of the countries grows rice. Rice, therefore, is not only a staple food but also a way of life. It is a source of livelihood for millions of resource poor farmers. Future projections reveal that region may fall short of rice by almost 4 million tons by the turn of the century, unless increases are adapted to enhance further the production of rice at rates faster than before. Also more area under rice is unlikely. Hence, the only option left is to go for increased productivity.

Hybrid Rice in China

Spectacular gains in productivity have been achieved in China over the last two decades mainly through the adoption of hybrid rice technology. For example, from an area of 18 m.ha (54% of total rice area) under hybrid rice, China is producing about 118 m. tons of rice paddy, which is equivalent to what India produces from almost 42 m.ha. The successes with hybrid rice in China are so impressive that other nations in the region have started showing considerable interest in adopting this technology to also improve their rice production as well as productivity. This story focuses on the success of hybrid rice production in China, and the relevance of this technology for other rice growing developing countries in the region.

Impressive Panicles of Hybrid Rice

II. ROLE IN THE NATIONAL ECONOMY

In the 1970s, the Chinese government was searching for durable solutions to overcome the chronic problem of grain shortage that had resulted from increasing population and stagnant rice production. Hybrid rice was obviously selected as an alternative because of its high yielding ability and wide adaptability. Hybrid rice production technologies and the hybrid rice seed production systems were appropriately developed to meet the increasing demands of the farmers. The government initiated public awareness, extension and training programmes to facilitate acceptance of hybrid rice by the chinese people.

The steady improvement in the hybrid rice productivity has caught the attention of agriculturalists and development institutions around the world.

Today , China is the leading producer of hybrid rice in the world. Hybrid rice production has been of great benefit to the farmers and the nation, both in the context of food security and increased income.

Since 1976, the area under hybrid rice in China has increased steadily (Fig. 1). The hybrid rice area is now more than 50 percent of the total rice growing area of the country. Hybrid rice has brought great social and economic benefits to the chinese people, by increasing the total rice production by more than 270 million tons from 1976 to 1993 and also by decreasing the land under rice cultivation by almost 2 million hectares.

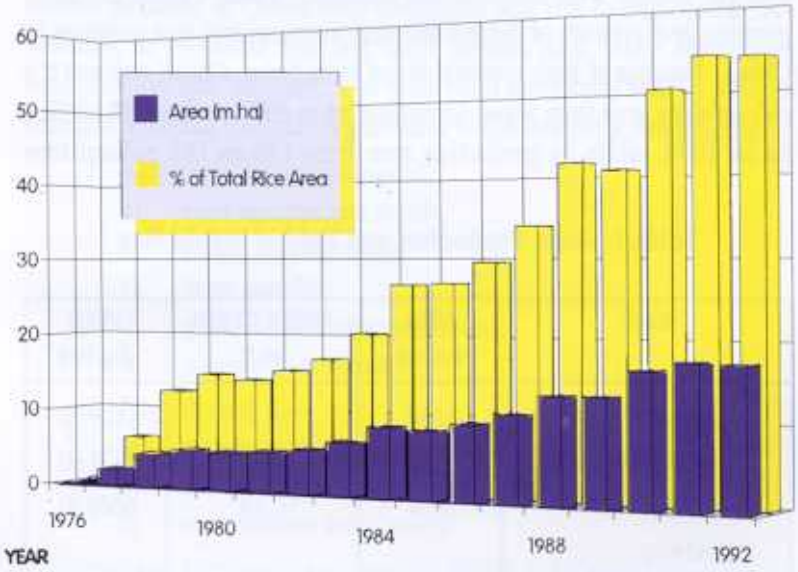


Fig. 1: Hybrid Rice Area in China

Source: Chinese Academy of Agricultural Sciences (CAAS), 1993

In the Asia-Pacific Region, the other rice producing countries could learn from the chinese experience and promote hybrid rice technology to improve their production as well as economy. It is with this objective, the details of hybrid rice technology in China are discussed here in brief.

III. HYBRID RICE PRODUCTION IN CHINA

In the 1970s, China became the first country to exploit hybrid rice commercially. Hybrid rice is now being produced throughout China in various eco-systems representing the tropical, sub-tropical and temperate conditions.

China is able to harvest an additional 40 to 50 million tons of rice paddy every year, mainly because of the average yield increase of 2 tons per hectare over conventional varieties. Table 1 gives the comparative performance of hybrid rice over conventional rice varieties in China. Because of high productivity of hybrid rice, China reduced it's rice growing area from about 35 million ha in 1979 to about 33 million ha in 1990, while its production rose from 140 to 188 million tons

Table 1: Area, Production and Yield of Hybrid Rice

KIND	AREA (m ha)	PRODUCTION (m t)	YIELD (kg/ha)
Total Rice	32.61	185.41	5685.70
Conventional Rice	14.97	67.93	4531.50
Hybrid Rice	17.64	117.48	6660.10
Hybrid Rice (As % of Total Rice)	54.10	63.36	117.10

Source: Chinese Academy of Agricultural Sciences (CAAS), 1991

during the same period (FAO, 1988; 1991). The other 2 million ha of land is now diverted for growing value addition crops by the farmers.

IV. DEVELOPMENT OF TECHNOLOGY

A. Advantages of Hybrid Rice

Rice is a self-pollinating crop. In other words, each plant pollinates and fertilizes itself, producing true to the type seeds of the same variety. The hybrid breeding technique involves two separate parental lines. When the resulting offspring has one or more traits that are superior to their parents, it is termed heterosis. Heterosis, therefore, results in superior performance. In the past, there were conflicting opinions among researchers as to whether heterosis existed in rice because it is self-pollinating. The commercial production and experimental evidence in China have confirmed that rice hybrids could successfully be produced and that these hybrids have many advantages over pure line rice varieties. The huge yield superiority held by hybrids over conventional varieties is attributed to the following characteristics:

1. Agronomic and morphological:
   a) more vigorous root system,
   b) greater tillering ability,
   c) larger panicles,
   d) greater number of spikelets, and
   e) superior grain weight.
2. Physiological:
   a) stronger root activity,
   b) more efficient nutrient transportation, and
   c) more efficient use of energy.

The data in Table 2 demonstrates that F_1 hybrids yield as much as 20% more than the conventional varieties. The heterosis has not only led to increased grain yield, but also enabled the hybrids to have wider

adaptability and better resistance to environmental stresses (drought, salinity, lodging, flooding and wind).

Table 2: Average Yield Comparison between Hybrid and Conventional Rice Varieties

YEAR	HYBRID RICE (kg./ha)	CONVENTIONAL RICE (kg./ha)	HYBRID YIELD INCREASE (%)
1976	4,200.0	3,469.5	21.1
1977	5,383.5	3,544.5	53.2
1978	5,353.5	3,780.0	41.6
1979	5,260.5	4,069.5	29.3
1980	5,296.5	2,940.5	34.4
1981	5,310.0	4,113.0	29.3
1982	5,865.0	4,447.5	31.9
1983	6,375.0	4,774.5	33.5
1984	6,405.0	4,992.0	28.8
1985	6,472.5	4,815.0	34.4
1986	6,600.0	4,857.0	35.9
1987	6,615.0	4,779.0	38.4
1988	6,600.0	4,539.0	45.4
1989	6,615.0	4,534.5	45.9
1990	6,675.0	4,642.5	43.8
1991	6,660.1	4,537.5	46.8

Source: Chinese Academy of Agricultural Sciences (CAAS), 1992

B. Development of Hybrid Rice

The Chinese government, realizing the potential of hybrid rice, established a research programme in 1964. Hybrid rice was first developed under the leadership of Prof. Longping Yuan at the Hybrid Rice

Research Center, Changsa, Hunan Province, China. The research was a cooperative effort between researchers from the Hunan Center, the Chinese Academy of Agricultural Sciences (CAAS) and various other institutions. Due to the painstaking nature of the hybrid research, the programme soon had a national scope. Eventually, the necessary technology was developed and the first set of hybrids were identified in 1974.

Early research results had indicated that self-pollinated rice can show heterosis when natural out-crossing occasionally occurred in the field. Applying methods for heterosis utilization developed for other crops such as pearl millet and sorghum, scientists decided to use male sterile and restorer lines for hybrid rice production based on identification of some naturally occurring male sterile plants in rice fields in 1964. Subsequently, Prof. Yuan and his research team tested more than 4000 crosses to obtain the maintainer lines, which would maintain the male sterility from generation to generation. Unfortunately, they did not succeed.

Later, wide hybridization between wild rice and rice cultivars was attempted. Theoretically, this would induce cytoplasmic male sterility and could be easily maintained. Due to the very late heading stage of wild rice and incompatibility between wild and cultivated rice, the research team failed again. Finally, a wild rice plant with aborted pollens (WA) was located in 1970 by Mr. Bihue Li and Mr. Keshau Feng in Nanhong Farm of Hainan Island. This discovery was the foundation for the successful three-line system (cytoplasmic male sterile, maintainer and restorer lines) rice hybrids. From 1971 to 1973, a number of cytoplasmic male sterile (CMS) lines, corresponding maintainer (B) lines, and fertility restoring (R) lines were successfully developed by different institutions in China. The first set of stable CMS lines included Erjiu Ai Ya, Erjiu Nan IA, V20A (most commonly

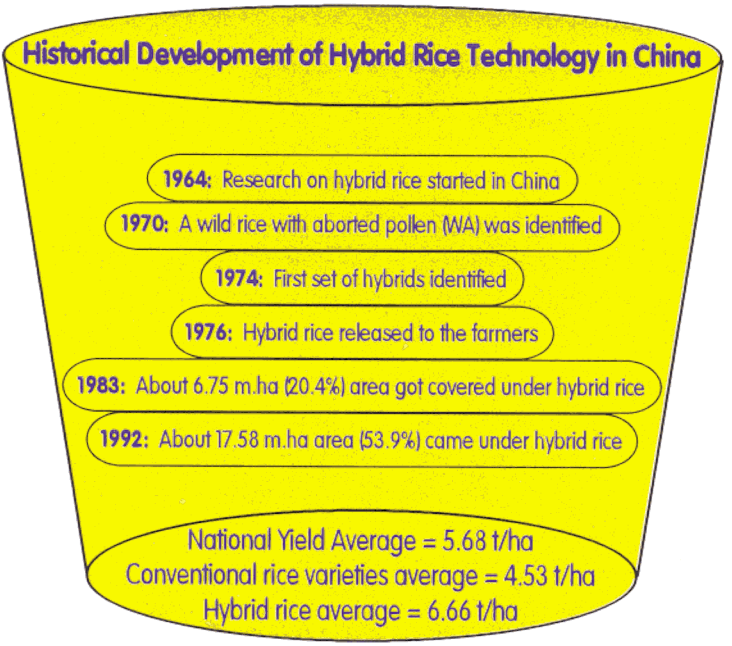
used later), Zheushan 97A and V41A. Similarly, the stronger restorer lines, such as IR24, IR661, IR26 and Thai Yin were identified through test-crossing.

By the end of 1974, the first group of heterotic rice hybrids with superior agronomic characteristics was developed by chinese breeders. While the first batch of heterotic rice hybrids were being demonstrated in the farmers fields, techniques for hybrid seed production were also developed. In 1975, hybrid rice was ready to be released for commercial production. Details of some of the popular rice hybrids released are given in Table 3. Interestingly, most of the IRRI rice varieties, having high yield potential, were found to be excellent restorers.

Table 3: Names of the Popular Rice Hybrids Released in China

Hybrid	Parentage
Wei-You 2	V20A x IR24
Wei-You 3	V20A x IR661
Wei-You 6	V20A x IR26
Shan-You 2	Zhenshan 97A x IR24
Shan-You 3	Zhenshan 97A x IR661
Shan-You 6	Zhenshan 97A x IR26
Nan-You 2	Erjiu Nan 1A x IR24
Nan-You 3	Erjiu Nan 1A x IR661
Nan-You 6	Erjiu Nan 1A x IR26
Si-You 2	VU1A x IR24
Si-You 3	VU1A x IR661
Si-You 6	VU1A x IR26

Source: Chinese Academy of Agricultural Sciences (CAAS), 1992



C. Commercial Production

Because agronomic management of hybrid rice differs considerably from that of conventional varieties, chinese researchers also developed production technologies to manipulate yield components such as plant population and canopy structure. Farmers were able to increase the production by taking the advantage of its responsiveness to fertilizers. Much of the increase in hybrid productivity came from the increased seedling vigour, vegetative growth and improved harvest index. The chinese scientists and the farmers found that the following practices were helpful in maximizing the yield:

a) raising strong tillered seedlings,

b) rationally close planting to establish a suitable plant population,

c) ''ideal'' application of fertilizer, both as basal and top dressing,

d) efficient water management, and

e) effective disease and pest control.

D. Seed Production

The development of an efficient seed production system was the key to the success of hybrid rice in China. In the early stages, the average yield for hybrid rice seed production was only 0.41 t/ha, which till 1981, still remained at 0.67 t/ha. Rice seed productivity improved immensely in the 1980s and 1990s. By 1991, the average yield of 2.25 tons per hectare (Table 4) could be obtained. In some areas, this has reached 4 to 5 tons per hectare. The great improvement in hybrid rice seed production was due to the development of efficient seed production methods, improved parental lines and the development of a good seed production system. The increase in seed yields obviously facilitated the faster spread of the technology by making more seed available at lower cost to the farmers.

Table 4: Hybrid Rice Seed Production in China

YEAR	SEED PRODUCTION AREA (th. ha)	YIELD (kg/ha)
1981	1,104	669.0
1982	1,546	909.0
1983	1,388	1,290.0
1984	1,047	1,414.5
1985	877	1,654.5
1986	1,005	1,995.0
1987	1,541	2,010.0
1988	1,358	1,626.8
1989	1,795	1,985.1
1990	1,974	2,247.5
1991	1,247	2,252.3

Source: Chinese Academy of Agricultural Sciences (CAAS), 1992

Hybrid rice seed production differs from that of the pure line varieties. It involves two steps: multiplication of CMS lines, and the production of F_1 hybrid seed. The existing hybrid rice seed production system was established and perfected in the 1980s. It includes three levels:

1. A seed company at the provincial level, responsible for purifying the parental lines and producing their foundation seed,
2. A regional (prefectual) seed company responsible for multiplying the seeds of CMS lines,
3. A local seed company at the county level responsible for producing the hybrid seed.

The farmers are organized in groups and contracted to produce the hybrid seed. The local seed company provides technicians to train and monitor the farmers.

Before commercial release, a newly developed hybrid must pass a multi-location and a regional yield trial for two seasons, and a production demonstration in the farmer's fields.

The key factors and approaches in obtaining a high yield of hybrid rice seed are:

1. ***Choice of field plot:*** The chosen fields for CMS line multiplication and the F_1 seed production must be properly isolated having adequate soil fertility and irrigation facilities, with no serious disease and insect problems.
2. ***Synchronization of heading and flowering:*** The prediction and adjustment of the flowering time of the two parents are crucial and must be timed well.
3. ***Appropriate field management:*** The proper row-ratio arrangement between male and female parental lines and application of gibberellin followed by supplementary pollination could help considerably in improving hybrid seed production.

The quality of hybrid seed would greatly depend on the genetic

purity of A (male sterile), B (maintainer) and R (restorer) lines. For this purpose, the Ministry of Agriculture established the minimum seed quality standards in 1985. These are given in Table 5. Also a procedure for purifying the parental lines to produce foundation seed is outlined in Fig. 2.

Table 5: Seed Quality Standards for Hybrid Rice in China

Line	Grade	Purity >%	Cleanliness >%	Germination >%	Moisture <%	Weed Seeds <(g/kg)
A line (CMS line)	Foundation seed	99.9	99.0	90.0	13.0	0
	1st class	99.5	99.0	90.0	13.0	0
	2nd class	99.0	97.0	85.0	13.0	5
B line (Maintainer)	Foundation seed	99.9	99.0	96.0	13.0	0
	1st class	99.5	99.0	96.0	13.0	0
	2nd class	99.0	97.0	93.0	13.0	5
R line (Restorer)	Foundation seed	99.8	99.0	96.0	13.0	0
	1st class	99.5	99.0	96.0	13.0	0
	2nd class	99.0	97.0	93.0	13.0	5
F_1 Hybrid	1st class	98.0	98.0	93.0	13.0	0
	2nd class	96.0	97.0	90.0	13.0	5

Source: Chinese Academy of Agricultural Sciences (CAAS), 1992

V. TRANSFER OF TECHNOLOGY

In the mid 1970s, the Chinese government commenced a campaign to get the information out about hybrid rice, and get the people (especially farmers) to accept and support it. From the central government all the way down to the local government, at least one high official had the responsibility for monitoring the progress of hybrid rice in China.

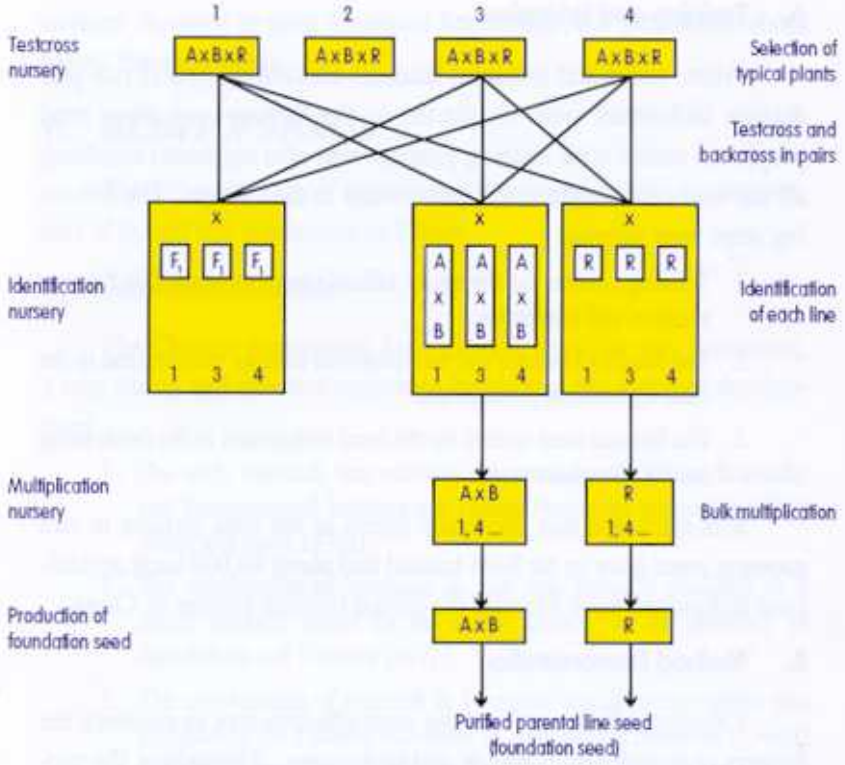


Fig. 2: The Procedure for Purifying Parental Lines

Source: Chinese Academy of Agricultural Sciences (CAAS), 1993

The propaganda system, including newspapers, radio and other kinds of mass media were mustered. They were quite successful in spreading the information about hybrid rice to nearly every family in the rural areas in a very short time. Two basic techniques were used to transfer the technology: A) Training and extension methods were intended to introduce the advantages of hybrid rice, and B) Method demonstrations to sustain farmer's interest and teach them about hybrid rice production by the "hands-on" method.

A. Training and Extension

Films, slides and technical manuals concerning hybrid rice production techniques were distributed to the farmers and other rural people. A nation wide training program was also organized involving all the levels from agricultural universities to the villages. The following steps were adopted:

1. Training courses for the senior officials were conducted at the universities and academies,
2. The local technicians and well-educated farmers were trained in the rural agricultural stations, and
3. The farmers were trained by the local technicians in the fields using method demonstrations.

It is estimated that about one fourth of the total farmers in rice growing areas have so far been trained and about 40,000 local agricultural technicians have attended the formal training courses in China.

B. Method Demonstration

"Seeing is believing"- is the most effective way to convince the farmers to accept new concepts and techniques. Throughout the process of developing and extending hybrid rice production technology, scientists and the government officials had undertaken essential field experiments, large area demonstrations and also established a number of model plots for the farmers.

The most difficult time to extend hybrid rice to the farmers was in the mid 1970s. In order to introduce the concept of hybrid rice to traditional farmers, demonstration plots comparing hybrid rice with conventional rice varieties were set up in target areas. Experienced government agronomists and technicians monitored the demonstration plots. Farmers from the target areas were brought in for field visits. The farmers interacted with the government officials and the extension

workers in order to gain increased knowledge and experience about hybrid rice technology.

VI. SECRETS OF SUCCESS

The following factors appeared to have been crucial for the success of hybrid rice production in China:

A. Government Support

The Chinese government has provided, from the very beginning, a very strong and effective support to hybrid rice research and development.

1. The early research was actively supported by the China Scientific and Technological Institute and Hunan Provincial government (late 1960s and early 1970s).
2. The exploitation of heterosis in rice was formally declared as a major research thrust for the entire country by the Ministry of Agriculture and Forestry (1972).
3. The coordination of research in 14 major rice growing regions was assigned to the Chinese Academy of Agricultural Sciences (CAAS) and Hunan Provincial Academy of Agricultural Sciences (1972).
4. The development of rice breeding institutions was assigned to the National Hybrid Rice Breeding Cooperative (1983).
5. The coordination of the national hybrid rice breeding research, information, training and germplasm collection was assigned to the Hunan Hybrid Rice Research Center (1984).
6. The convening of nine regional (1972-1982) and six national (1976-1987) meetings to monitor and direct research was undertaken by the State Council, Department of Agriculture along with the local governments.

B. Coordination of Research

The Chinese government facilitated effectively the required coop-

eration between various research and extension institutions.

1. The rice research institutions were coordinated by panels of rice breeding experts:
   a. Basic and theoretical research was performed by the well equipped universities and institutions.
   b. Breeding and applied research was performed by the provincial Academies of Agricultural Sciences.
2. The National Hybrid Rice Research Cooperation Group (established in 1972 (by CAAS and Hunan Academy of Agricultural Sciences) to facilitate the development of regional hybrid rice research networks.
3. The CAAS convened annual meetings to direct the orientation of research, develop network plans, and to monitor network cooperation.

C. Government Subsidies

Subsidies provided by the Chinese government greatly facilitated the development of hybrid rice in China.

1. Commercial hybrid rice seed production in the early years was subsidized to ensure sufficient supply of cheap seed to the farmers.
2. Subsidies on fertilizers and pesticides ensured that inputs, crucial to hybrid rice production, were available to the farmers at affordable price.

D. International Cooperation

In the early 1970s, China established a relationship with the International Rice Research Institute (IRRI). In fact, the first group of commercially used restorer lines came from IRRI. Due to the success of the first commercial hybrids, China worked with IRRI in evaluating and releasing restorer lines. As a result, rice hybrids using IRRI restorer lines are grown on several million hectares presently.

The research capabilities of Chinese scientists, especially for basic and strategic research, thus got strengthened through required inter-

national cooperation and linkages.

VII. FUTURE CONCERNS AND STRATEGIES

Although hybrid rice research and development in China has made tremendous progress in the past 30 years, there are also some concerns for the future. The yield potential of the existing rice hybrids has reached a plateau (Fig. 3) and the total growing area under hybrid rice has reached almost an optimum level. Also concerns about quality of hybrid rice are becoming important in the recent past.

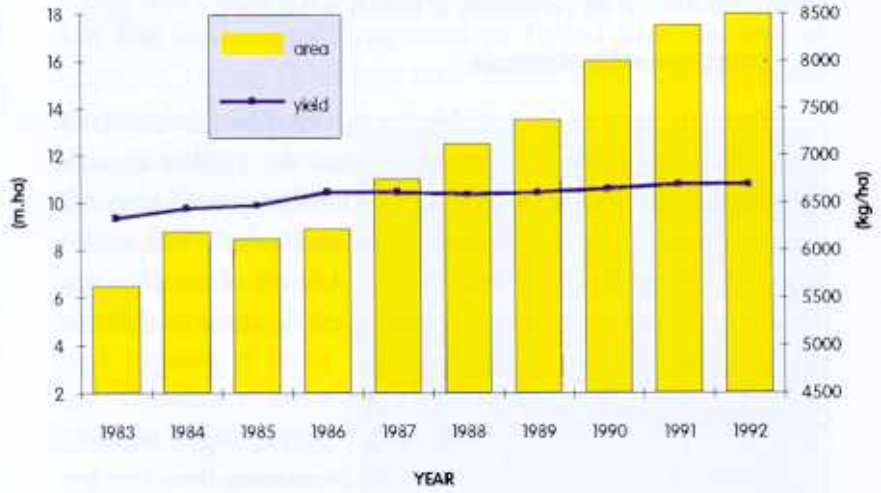


Fig. 3: Area and Yield of Hybrid Rice in China from 1983 to 1992

Source: Chinese Academy of Agricultural Sciences (CAAS), 1992

A. Improvement in Breeding Methodology

The challenge for China now is to ensure further area increase under hybrid rice production. Researchers plan to follow the following strategies in this regard:

The classical three-line system involving CMS, maintainer and restorer lines is expected to remain effective and useful for the future. However, as it is quite complicated, simpler systems, such as two line (using thermo-sensitive genic male sterile (TGMS) or photo-sensitive (PGMS) materials) or one line (using apomixis, which has ability to set seeds without fertilization) methods, once perfected, would be very productive. The use of simpler systems would provide quick development of new hybrids and allow use of less-skilled personnel. Also seed production costs would be reduced considerably. For quality improvement, research efforts are aimed presently to incorporate good quality germplasm lines in the production of both A and R lines.

B. Improvement in Heterosis

Presently, most of the available rice hybrids show the same level of heterosis. The researchers plan to alleviate this problem through inter-varietal rice hybrids by crossing *indica* with *japonica* (tropical) materials, using effectively the wide compatible genes. This should help in improving the productivity further. Also use of biotechnology offers considerable scope for transferring useful genes from different species or genus for future advancements.

C. Increasing Production

China is hoping to increase the area for existing three-line hybrids in a short period. The rice growing area in China is around 33 million hectares, of which 54% is presently under hybrid rice. The Chinese government plans to increase this area by another 10% by the year 2000. This is to be accomplished by:

1. Development of new hybrids for varying ecosystems where hybrid rice is not yet grown, especially the first season rice crop in south China where hybrid coverage is only 20% presently, and also the japonica type hybrids for the japonica rice areas in the north.

2. Increase the area of irrigation so that two crops of hybrid rice could be successfully grown in a year .
3. Increase the yield per unit area through appropriate agronomic management. China aims to increase productivity of rice to about 7.0-7.5 t/ha in hybrid rice area by the year 2000 through the use of improved hybrids and efficient crop management practices.

VIII. PROSPECTS IN THE REGION

The prospects are good for regional cooperation. China has already been quite active in sharing experience with hybrid rice technology and experience with regional and international institutions. The first International Symposium on Hybrid Rice was held at Changsha, Hunan, China from 6-10 October 1986. The symposium was attended by 16 countries, including 10 from the Asia-Pacific region (China, India, Indonesia, Japan, Malaysia, Philippines, Sri Lanka, Thailand, Republic of Korea and Vietnam). These countries began paying greater attention on hybrids into their national rice breeding programmes. Most of the countries are still in the early development stage. However, India and Vietnam seemed to be ready to launch commercial production of hybrid rice. FAO, UNDP and IRRI are providing active and strategic support to these two countries through active involvement and support from Chinese scientists.

Impressive Plant Type


Transplanting of Hybrid Rice

Transfer of Technology

Hybrid Seed Production

The private sector is also more actively involved now in hybrid rice R and D efforts. As a result, a number of multinational seed companies are actively involved presently to promote hybrid rice technology in the region.

In order to expedite regional development of hybrid rice, interested countries in the region, in cooperation with the International Rice Research Institute (IRRI) and FAO, should form a regional interest group for:

a) Exchange of information and germplasm,

b) Frequent joint visits and coordination meetings,

c) Collaborative research and development,

d) Cooperation among seed production organizations (private as well as public),

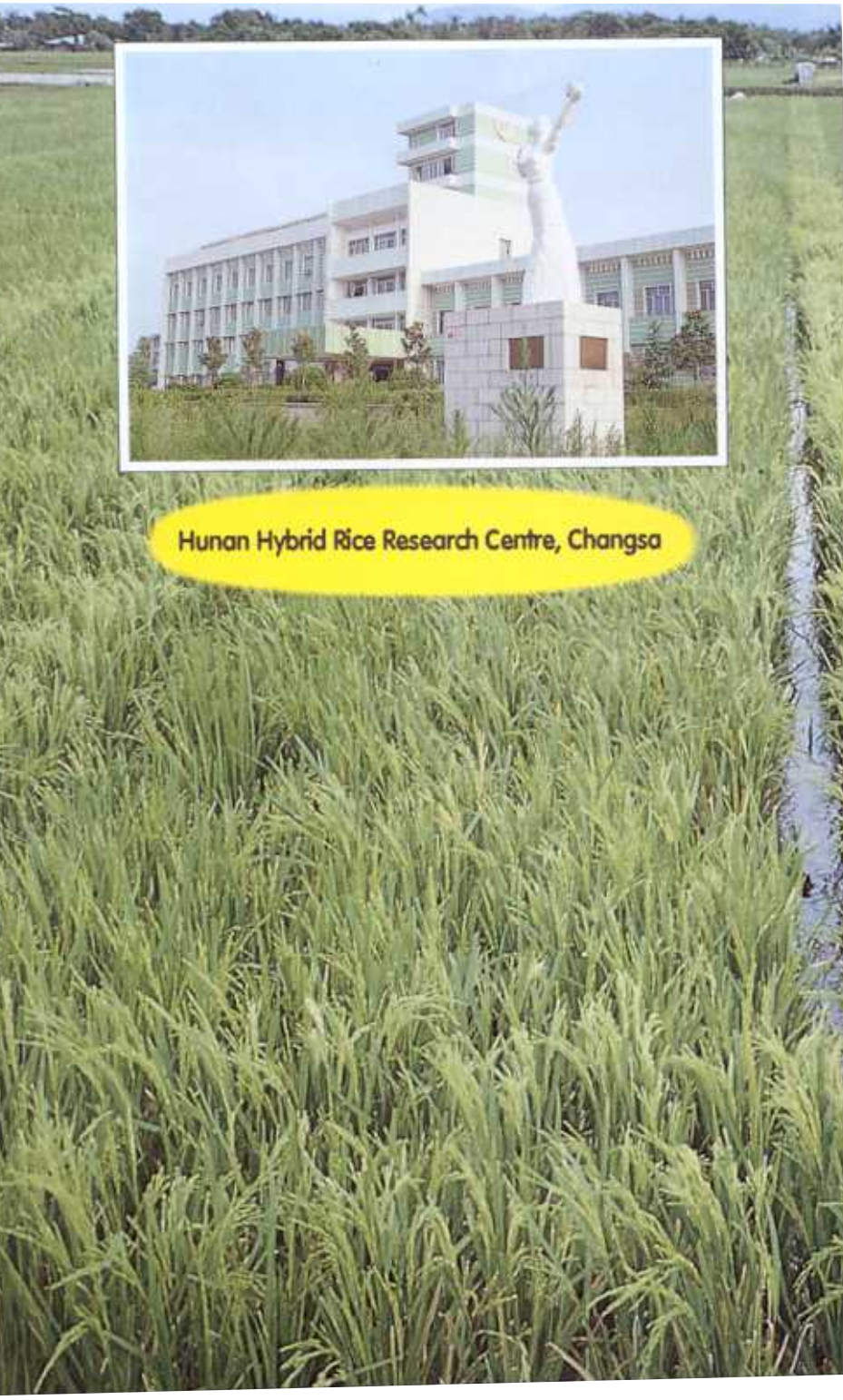
e) Human resource development (trainings, workshops, publications, study tours), and

f) Regional testing of hybrids for various eco-systems.

IX. EPILOGUE

Being a major staple food, rice has great significance in the Asia-Pacific region. In order to meet the increasing demand for rice, concerted efforts are needed to enhance further both the production and productivity in most of the countries growing rice. China has successfully demonstrated the specific advantage of growing hybrid rice, thereby increasing yield levels by an addition production of almost 2 t/ha over conventional varieties. Hybrid rice technology thus could help other countries in increasing their national average productivity provided research and development activities are effectively supported and implemented. Appropriate policy support in this regard would also be required. Therefore, by emulating the chinese experience of hybrid rice production, other nations in the Asia-Pacific region could also benefit significantly.

Prof. Longping Yuan (left), Father of Hybrid Rice



Hunan Hybrid Rice Research Centre, Changsa

Hybrid Rice in Upland

Hybrid Seed Production

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