Food and Agriculture Organization of the United Nations

Report on the

Regional Expert Consultation on Hybrid Rice Development in Asia under FAO-China South-South Cooperation: Constraints and Opportunities

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Changsha, China

FAO Regional Office for Asia and the Pacific
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Executive summary

1. INTRODUCTION

The Regional Expert Consultation on "Hybrid Rice Development in Asia: Constraints and Opportunities" was organized jointly by Food and Agriculture Organization of the United Nations (FAO) and CICOS of Ministry of Agriculture of PRC under FAO-China South-South Cooperation (SSC) framework on 1st -3rd November 2016 at Changsha, China to support the Regional Rice Initiative for improving rice production in the region. The goal of the Consultation was to review the constraints and opportunities for strengthening hybrid rice production in Asian countries. The main objective of the regional Expert Consultation was to bring countries in the region together to share experience, present the challenges they face and the possible solutions, and discuss programmes and activities aimed at promoting regional cooperation in future development of hybrid rice in the region.

The consultation was attended by 40 participants from 10 countries (Bangladesh, Cambodia, China, Indonesia, Lao PDR, Myanmar, Nepal, Philippines, Sri Lanka, and Thailand). A representative from International Rice Research Institute (IRRI) also attended.

The Regional Expert Consultation programme was structured in three technical sessions on specific themes, mainly, 1. Hybrid rice development in Asia (keynote speeches); 2. Sharing knowledge and experience; and 3. Towards a collaborative programme on hybrid rice. In addition, there were two panel discussions and group discussion. Professor Yuan Longping, Father of the Hybrid Rice gave a special lecture on "Progress in Breeding Super Rice Hybrid".

The inaugural session was chaired by Dr. Qi Shaowu, Director- General, Hunan Hybrid Rice Research Center (HHRRC), Changsha. In his opening remarks, Dr. Qi, welcomed the participants and informed that the event was organized jointly by FAO, MoA and HHRRC under south-south cooperation for further expansion of hybrid rice in other countries and attended by representatives from ten countries namely: Bangladesh, Cambodia, Indonesia, Lao PDR, Myanmar, Nepal, Philippines, Sri Lanka, Thailand and China. He stated that over the next three days participants will discuss all aspects of hybrid rice and also share our latest achievements in the development of hybrid rice technology in China. Dr. Qi expressed the readiness of HHRRC in assisting other countries by developing their capacity to adopt this technology in their countries. Spreading this technology beyond China in order to enhance global and national food security is one of our main objectives, he added.

Mrs. Lin Huifang, Deputy Director-General, CICOS, MoA in her speech expressed satisfaction at having the opportunity to attend this Regional Consultation. She thanked all participants for attending this forum and briefly reflected on China's role in inventing hybrid rice technology highlighting the support the MoA has been providing to concerned institutions in further research and extension in hybrid rice technology development. She pointed out that hybrid rice possesses advantage over inbred lines in terms of productivity and quality. The MoA seeks to transfer this technology to other countries in order to improve productivity and reduce poverty, she continued. This forum offers the scope to know more about what types of problems participating countries are facing in promoting this technology. With FAO, the MoA is working to develop this technology under south-south cooperation with the budget of USD 30 million and if other projects are considered, it will be USD 50 million. However, new problems mainly climate change and water scarcity are emerging very rapidly and these challenges need to be addressed jointly. She wished grand success of the consultation.

Mr. Vincent Martin, FAO Representative, China, in his opening remarks stated that 17 participants from 9 countries were attending the consultation. FAO has been assisting in implementation of USD 30

million programme funded by the Government of China under South-South Cooperation (SSC). This consultation was organized under this project. Mr. Martin thanked International Cooperation Services and HHRC for arranging this consultation. He disclosed that Chinese hybrids have potential to yield as high as 16 t/ha which attending countries should take note of as they proceed with adoption of this technology in their countries. With the initiation of SSC in 1996, China is providing assistance to scientists across the world in efforts to increase global rice output, he noted. Mr. Martin wished success of the consultation and urged FAO member countries to take advantage of this technology by forging cooperation with Hunan Hybrid Rice Research China (HHRRC).

In his introductory speech, Dr. Pham Van Du, Senior Agricultural Officer (Rice Expert), FAO Regional office for Asia and the Pacific welcomed all participants and expressed his thanks to HHRRC and IRRI to partner with FAO in organizing this event. Dr. Du informed that the main objective of the regional Expert Consultation is to bring countries in the region together to share experience, present the challenges they face and the possible solutions, and discuss programmes and activities aimed at promoting regional cooperation in future development of hybrid rice in the region. He expressed the hope that over the three days participants will engage in intensive deliberation and cross-fertilization of ideas that will help to come out with concrete and implementable recommendations. FAO will be happy to assist member countries in implementing these recommendations, if required.

2. KEY NOTES ON REGIONAL HYBRID RICE DEVELOPMENT

a. Hybrid Rice Research and Development across Asia

Professor Xie Fangming, Longping, High-Tech, China presented a paper entitled" Hybrid Rice Research and Development across Asia" in which he showed area under hybrid rice has been rising slowly and a declining trend in hybrid rice area is evident in China in recent years. He stated that hybrid varieties have low yield advantage (less than 1 tonne per hectare) over best inbred varieties and poor rate of heterosis (less than 15 percent) with unstable performance which act as major obstacles to its expansion. In addition, low yield of seed production (around 1-2 t/ha across Asia excluding China), high cost of hybrid seeds, poor grain quality of hybrid rice expressed in low milling and head rice yield, and high rate of chalkiness are other major constraints.

Prof. Xie opined that various diseases/insects in the tropics, lack of appropriate resistance screening and breeding and poor education of farmers for IPM are the major weaknesses in developing location-specific hybrid rice varieties in outside China. Added to these are poor seed quality, inconsistency in government policy (subsidy, seed production and extension) and insufficient knowledge among farmers and technical personnel. Increasing yields of hybrid, germplasm diversity and development of 2-line hybrids; increasing seed production with low costs; breeding for resistance to diseases and stresses; improving grain quality; decentralized research and development systems; and strong training and capacity development programmes are important in expanding this technology in Asia.

b. Hybrid rice: Meeting the Market Needs of Asia through a Revitalized Hybrid Rice Development Consortium (HRDC)

Dr. Jauhar Ali, Hybrid Rice Breeder, IRRI, presented a paper entitled "Hybrid Rice: Meeting the Market Needs of Asia through a Revitalized Hybrid Rice Development Consortium (HRDC)". Mr. Ali provided some statistics saying that hybrid rice areas in China covered 12.8 million hectare which is 41.4 percent of the country's total rice area. However, its coverage outside China in 2014 was 6.3 million hectares. It contributes extra production of 22.5 million tonnes of rice saving 6 million hectares of rice lands

globally. In order to justify the importance of hybrid rice, he mentioned that rice farming needs to be sustained in terms of yield and quality with ultimate goals of attaining food self-sufficiency and food security. He indicated that major constraints for slow growth in hybrid rice technologies in Asia are low rate of heterosis and low genetic pools; non-availability of better quality hybrids having more than 45 percent head rice recovery, less than 10 percent of chalkiness; and insects , pest and disease resistance (BLB, BL, ShB, BPH, SB). Lack of ideal parental lines with higher outcrossing rates, narrow flowering differences, lack of trained man power and fluctuation in climate changes keep seed production at low level. Poor dissemination to farmers with proper package of practices-poor seed quality, crop management (nursery-LCC-SSNM, IPM, harvest & marketing channels) also create obstacle to its expansion. According to him, hybrid rice yield advantage over 15 percent, quality seed production with more than 2.5 tonnes per hectare, incorporation of pest and disease resistance genes in targeted manner, grain quality matching consumer needs in target regions and having parental lines performing well under abiotic stress conditions like salinity, and drought can improve the situations in tropics. Describing hybrid rice programme of IRRI, he mentioned that IRRI has been focusing on development of parental lines for both 3-lines and 2-lines using genomic tools, higher outcrossing rates, higher combining ability and targeting market requirements. He informed that IRRI is moving towards 2-line by slowly phasing out 3-line system. Development of better grain quality parental lines (HRR >45%; Chalk <10%; Intermediate (18-24%)-India, Phil, Indonesia and high amylose (>24-28%)-Bangladesh is another thrust area of IRRI.

c. Sustainable Development of Hybrid Rice in Asia: Constraints and Opportunities

Dr. Pham Van Du presented a paper entitled" Sustainable Development of Hybrid rice in Asia: Constraints and Opportunities" where he highlighted the importance of hybrid rice for FAO member countries as a means to enhancing rice productivity in their countries and thus improving the status of food security. Continuing population growth, environmental degradation affecting rice eco-systems and adverse impacts of climate changes were identified as responsible for poverty and hunger in Asia which are more prominent among the rice farmers. He gave a brief account of the status of hybrid rice adoption in China and in other countries beyond China demonstrating the existing vast potential for increasing rice productivity subject to its successful adoption outside China.

Dr. Du identified the major constraints in adoption of hybrid rice. These are: (i) inconsistent yield of hybrid rice with low heterosis, poor grain quality; susceptibility to pest and diseases; narrow genetic base; poor yield in seed production and high cost of seed production. He also showed that lack of best management practices; yield gap between demonstration and farmers' plots and very high inputs costs are also major constraints to adoption of this technology by poor rice farmers. Lack of investment in hybrid rice, poor infrastructure, and lack of support services and long-term hybrid rice development plan are also obstacles to its development. He promoted HR based farming system, Save and Grow-Climate Smart Agriculture and curricula development through FFS which can encourage poor farmers to practice Hybrid rice cultivation. Another aspect for development of HR in countries needs to be considered is the improvement of HR value chain and market access. He concluded by saying increased trends in PPP, addressing IPR issues, promotion of biotechnology in breeding programmes, providing incentives to the growers, adopting value chain approaches, promotion of exchange of technology, germplasms and information, increasing public investment in R&D and infrastructure development and promotion of regional cooperation, networking and south-south cooperation can ensure rapid expansion of the technology.

d. Barriers in the Development of Hybrid Rice Technology in Asia

Mr. Subash Dasgupta, FAO Resource Person, presented a paper on "Barriers in the Development of Hybrid Rice Technology in Asia". Dr. Dasgupta mentioned that hybrid rice technology literally means bringing science onto farmers' fields. Hybrid rice technology significantly differs from open pollinated variety (OPV) in all perspectives – technical, social and economic. This technology invented in China rapidly spread in the country since the mid-1970s and now accounts for about 57 percent of the total rice cropped area. More than three decades later, hybrid rice technology is yet to find a significant niche in rice systems of major Asian rice growing countries outside China. Currently area planted to hybrid rice in these countries is, on average, well below 10 percent and vulnerable to high seasonal variability. Despite substantial efforts these countries invested beginning the late 1980s to mimic China's success with hybrid rice in their own countries with scientific collaboration with IRRI and FAO's technical assistance, hybrid rice still stands on the fringe of rice economies in these countries. It is, therefore, time we take a critical look at the factors which are persistently constraining large-scale adoption of hybrid rice technology in these countries. Revitalizing breeding systems, initiating location specific seed production and development of hybrid rice markets should be considered priority areas in advancing this technology.

3. SHARING KNOWLEDGE AND EXPERIENCES

a. Bangladesh

In Bangladesh, hybrid rice research and development programme got momentum through FAO- IRRI-ADB projects in 1998 and later a DFID financial support which was ended in June 2004. The experience is quite encouraging. During the past years, the emphasis on hybrid rice research at the Bangladesh Rice Research Institute (BRRI) has also been increased considerably with good progress. A total of 5 rice hybrids have been released in the name of BRRI hybrid Dhan 1 to 5 including 4 for Boro and one for Aman seasons of the country which are performing well. BRRI has also developed a CMS line adaptable to Bangladesh condition using Chinese CMS source. Three maintainer lines have been identified among indigenous elite lines which are being converted to CMS lines. Package of technology for seed production and cultivation of the released hybrid have been developed. Both public and private seed producing agencies are producing seeds of BRRI hybrid Dhan 2 and 3 @ 2-2.5t/ha seed yield following BRRI developed seed production technology. Research efforts are also being made to develop CMS lines and hybrids for Aus season. Despite these developments, the country's hybrid rice programme is still weak, relative to other countries, and would need to be strengthened through appropriate investments in manpower and other resources.

Till 2016 a total of 146 hybrid rice varieties have been approved by national seed board (NSB). Out of those varieties, only 11 from public institutes including 5 from BRRI, 5 from BADC, and 1 from university. Other hybrids were imported from China, India and Philippines where China was the biggest exporter (76.3 %). A significant increasing trend of hybrid rice acreage was observed in 2016 after a slight decline of hybrid rice acreage from 2011 to 2013. In 2014 and onward the area under hybrid rice cultivation increased from 0.659 mha to 0.82 mha in 2016. This expansion of hybrid rice accelerated mainly due to the inclusion of Aus season under hybrid cultivation. Total clean rice production from hybrid in the year 2010 was 3.01 million tonnes which constituted 8.97 percent of total rice production. It rose up to 3.61 million tonnes in 2014-15 contributing 10.39 percent of total clean rice production (34.71 million tonnes). Hybrid rice in food security can be successful only when the following two major

criteria will be fulfilled. Firstly, the yield advantage of a rice hybrid must be higher at a profitable level over any other conventional inbred variety, so that farmers could be encouraged to grow the variety. Secondly, grain quality must satisfy the consumer's preference. On the other hand, seed price should be within affordable range to the poor farmers. Sustainable research-extension linkage might be a prerequisite for a healthy technology transfer system to reach the end users. Marketing channel should be well-equipped with trained manpower and seed dealers. For sustainable rice production with minimum use of natural resources Boro cultivation area needs to be shift into Aus where hybrid rice adoption in the season got an opportunity for further expansion.

b. Cambodia

Hybrid rice is not used in Cambodia as an option to increasing rice production and productivity. However, a total of 408 hybrids from INGER have been tested during 1992-1995. All hybrids performed lower than IR66-a popular released varieties in both wet and dry seasons in Cambodia, in terms of yield. In 1998-2000, a private company working with Chinese hybrid companies failed to introduce hybrid rice to farmers. Among several reasons of failure, expensive hybrid rice seeds, poor soil fertility and uncontrolled water, farmers cannot afford high costs inputs and bold grain type and no market for hybrid rice are found to be major obstacles. Strengthening regional cooperation in research material exchange, knowledge sharing through training and visiting; creating funding opportunities for varietal development and extension project; and development of standard see production and processing delivery systems may help in introducing hybrid rice technology in Cambodia.

c. China

China is the originator of hybrid rice technology and is the first country in the world who commercialized hybrid rice production. It was planted in 17.6 million hectare of lands in 2013, constituting 54 percent of total rice area and contributing 57 percent country's rice production. Yield of hybrid rice was 7.5t/ha which was 20 percent higher than inbred varieties. By 2012, country has 520 seed enterprises which have the capacity to the hybrid rice breeding, seed production and marketing of hybrid rice production. Country produce 283 million kg/year hybrid rice seeds which created direct employment of 100 000 people/year and nearly 1 million people with indirect employment. Country released 5 883 rice varieties during 2008-2013 with yearly release of 400 varieties. Out of them hybrid rice varieties constituted 66.3-71.1 percent.

During 2005-2013, China released 73 "super rice" hybrids. Among them: 52 three-line hybrid rice varieties and 21 two-line hybrid rice varieties. In the block demonstration they gave 15t/ha yield. The seed production technology has been optimized in China. The highest seed yield obtained in 1995 (7.39 t/ha). The Chinese hybrid agronomists developed the systematic methods for high yielding field management: "3-ding"Cultivation Technology for Super Hybrid Rice; rice Precise and Quantitative Cultivation Technique for High Yield; the Improved System of Rice Intensification (MSRI); and nitrogen-efficiency and lodging resistance cultivation technique. Strong government leadership, high efficient organization, sufficient resource allocation, and technology generation and dissemination are main reasons for attaining success in hybrid rice technology in China. Among the various constraints facing Chinese hybrid rice technology- stagnation in area increase; lack of japonica hybrid with strong heterosis, big yield gap for super hybrid rice; lack of outstanding varieties although each year 400 hybrid varieties are released; and need of the breakthrough for the mechanized technology of hybrid rice seed production. Professor L.P. Yuan proposed a new idea of super rice variety who will provide 18t/ha yield. Works in this field are going on. Key scientific ideas of new strategies are morphological

improvement with utilization of the heterosis simultaneously; higher biomass by increasing plant height; further increase heterosis by exploitation of indica/japonica crossing; maintain high harvest index and enhancing the lodging resistant.

Professor L.P. Yuan gave a lecture on the "Development of Hybrid Rice for Food Security in the World". In background information Prof. L.P.Yuan told that rice feed more than half of the world population and it is expected that 60 percent more rice should be produced in 2030 than it was in 1995. He informed that currently 1 ha of rice production provides food for 27 people but by 2050, 1 ha will have to support 43 people. In this situation, hybrid rice can greatly increase rice production. Main issue in hybrid rice technology is that heterosis only exists in F1generation, so, it is needed to produce F1 hybrid seeds every year. On the other hand, by means of male sterile lines, large amount of F1 hybrid seed can be produced commercially. Prof. Yuan said that current total rice area in China is 29.5 million ha with average yield 6.4 t/ha. Hybrid rice covers 17 million ha which is 57 percent of total rice land with average yield of 7.5 t/ha. Hybrid has 20 percent yield advantage over inbred variety feeding 70 million more people annually. He also briefly stated evolution process of his super hybrid rice progamme and current status of it. In the phase one, he developed several super hybrid rice varieties by 2000. The average yield was around 8.3t/ha in large commercial production (over 1 million ha) in recent years. The goal of developing phase 11 super hybrid rice was achieved in 2004. The area under phase 11 super hybrids was nearly 1 million hectare in 2013 with average yield of 9.0 t/ha. The goal of phase 111 and phase 1V super hybrid rice was achieved in 2012 and 2014 respectively. Based on the previous progress, the phase V super hybrid rice breeding programme has been started. The yield target is 16 t/ha. Some promise combinations have been bred. Super 1000 yielded more than 15t/ha in 5 locations, and reached 16.2t/ha in Gejiu, Yunnan especially which hit the yield target of phase V.
He concluded his lecture by saying hybrid rice will play a key role in ensuring food security worldwide in 21st century and 50 percent of rice paddy cover by hybrid in the world, rice production can be increased by another 150 million tonnes which can feed 400-500 million more people. According to him, huge potential exists in Africa for the development of hybrid rice. In Africa, the total rice-growing area is 11 million ha with average yield of 2.5t/ha, the net import of milled rice is 9 million tonnes annually. If 50 percent of the paddy field is planted by hybrid rice with yield increase of 2t/ha, then there is no need to import rice grain anymore.

d. Indonesia

Research on hybrid rice started in 1983 and until 1990, there was no success due to difficulties in obtaining stable CMS lines with high outcrossing rates (≥ 25%), and adapted to Indonesian environment. Finally, in 2002, Indonesia released IR58025A/IR53942 and IR58025A/BR827-35 which showed consistently higher yield over inbred check. Since 2001, hybrid rice research has been intensified in collaboration between IAARD with IRRI, FAO, and others. As a result, ICRR had come out with several promising hybrid combinations and new CMS, maintainer, and restorer lines whcih resulted in developing quite good number of hybrid rice varieties. Major problems for hybrid rice expansion are low heterosis in the tropical hybrids cause a low or inconsistent yield advantage; the narrow genetic base of male sterile sources made the hybrids (90% CMS-wild abortive types); the hybrids lacked one or a few desirable traits i.e. grain quality, resistance to particular diseases or pests and finally deficient supply of hybrid seeds and high seed cost. Hybrid breeding approaches include development of breeding material including new developed parental lines & genetic source for

desirable characters from IRRI and others are still needed; broadening genetic diversity of male sterile sources and parents; exploitation of inter-subspecific hybrids; improvements in grain quality and high yield should become an important objective in hybrid rice development and breeding to develop hybrid rice resistant to BPH, BLB, and RTV.

Seed production and its costs remain a big problem in Indonesia as in other countries. To overcome the situation, works have been started on developing technology to increase hybrid seed yield; improvement in purity and quality hybrid seeds; strong seed certification and quality hybrid seed; fair national seed regulations or rules for the seed industry; and marketing and trade promotions for hybrid seeds with active involvement of private sectors. Government support require for the development of public-private sector partnership on hybrid seed production to accelerate the adoption of hybrid rice technology and some companies initiated to produce seed of public hybrids. Supports also necessary for the dissemination and adoption of hybrid rice technology. Support to small holder farmers and establishment of national coordination mechanisms and international cooperation are also essential for its promotion.

e. Lao PDR

The country is in the early stage of the evolutionary process of transforming agriculture from predominantly subsistence-oriented production especially in rice to more market-oriented production systems. Rice production of the country is still not stable varying from year to year and is often affected by natural calamity such as flood or drought which happens sometimes nationwide but frequently in some local areas of the country, and consequently leading to insufficient food consumption. In the plains, all cultivated land is devoted to lowland rice production in the wet season and for livestock grazing in the dry season. The upland and mountain farming systems are dominated by single wet season crop production and paddy is the most important crop mainly in shifting cultivation.

The government policy in the agricultural sector gives priority to increasing crop and livestock production in order to ensure food security, notably self-sufficiency in basic foodstuffs such as rice, and to ensure a more balanced diet by promoting the production and consumption of livestock products and other food items essential for the healthy nutrition of the population. Government programmes of support will focus on the introduction of technologies for intensive production of rice development of sustainable farming systems in upland areas. Although Lao PDR does not cultivate hybrid rice yet, but there is an ample scope to promote this technology in the country in order to rapidly increasing rice productivity in the country as rice productivity in the country is extremely low compared to other countries of the region. As private sector engagement in the development of agriculture is weak, government to government partnerships could play an important avenue to introduce this technology in Lao PDR.

f. Myanmar

Hybrid rice has been grown in Shan State, near border area of China, since 1995 - 96. Farmers from that area can purchase the F_1 seed from China directly and they also have market for selling their product. Market price of hybrid rice is lower than local inbred variety. Most Myanmar people like to consume the rice quality with intermediate amylase content. Only the people from hilly regions prefer more to eat sticky type of low amylase content. If there is stable market system with reasonable price, farmers from irrigated area will grow hybrids, as higher yield and short duration of rice hybrids. Hybrid rice cultivation is more favorable in summer growing season. Out of 7.2 million hectares of rice production areas, until 2014-2015, only 54 000 hectares are covered by hybrid rice constituting only

0.75 percent of total rice areas. Since 2003, growing hybrid rice had been encouraged by the government and seed production practices also had been done.

Nowadays, few private companies initiated to produce F_1 seed with the help of seed production experts from China. In this regards, staffs from Department of Agriculture had joined together with experts and they had learnt knowledge of seed production technology. Seed production in large scale has still some limitations for Public sector. The private companies of Great Wall Co. and New Ayer Co. are conducting seed production in both wet and dry season. Dry season is more suitable for the both seed production and cultivation of F_1 hybrids. Most of hybrid varieties are susceptible to major disease and pests especially in wet season due to favorable weather condition. Hybrid technology is an alternative way to increase rice production without area expansion with the present population and rice production. Some of existing inbred rice varieties are still higher yield potential of 6-7 tha^{-1} and higher market price. However, hybrids can be grown in summer season because most hybrids are higher yield with short growth duration. Most hybrids are susceptible to Bacterial leaf blight and leaf streak, which are more serious in wet season. Nowadays, some farmers from Delta area do have a practice of growing hybrids in summer. We can expect that with a significant increase in yield of hybrid over the best inbred by 20-30 percent or 9-10 tha^{-1}, could be successful in hybrid rice program in Myanmar.

g. Nepal

Most of the hybrid varieties of rice were introduced by private seed traders in the country. Mostly imported either from India or China. The process started since 2000. The official process of registration of imported hybrid rice seeds in Nepal started in 2010. The hybrid varieties: DY 18, DY 28 and DY 69 were registered for the first time in Nepal by National Seed Board (NSB). As of 2015, a total of 33 hybrid varieties were registered by National Seed Board (NSB). It has been reported that the share of area with hybrid rice varieties was 7.4 percent in 2015. In totality, hybrid rice coverage in Nepal is reported for Terai 83.00 % followed by hills 16.79% and mountains 0.22% of the total hybrid rice area in the country. Adoption of hybrid rice is important in order to increasing rice productivity in the country and thus food security and rice self-sufficiency status. Increase productivity and high income will lead to increase on-farm incomes and ensure supply of rice that reduce or stabilize prices for both urban and rural food-insecure households. Rice production in efficient ways will lead to increase trade competitiveness and promotion exports and import substitutions. Then government has taken policy decision to develop 13 hybrid varieties (8 from government sector and 5 from private sector) during 2013-2025. Lack of technical and infrastructural development, poor purchasing power of farmers to buy costly hybrid seeds, non-availability appropriate production technology for both seeds and paddy and poor capacity to develop F1 seeds are the major constraints to push forward this technology in Nepal. Develop infrastructure for hybrid research and seed production both in public and private sector, facilitate farmer's community seed producer groups or companies for hybrid seed production, ffurther collaboration for: Capacity building, Trainings/scholarships, Strengthen lab facilities and Other infrastructures and finally implementation of National Seed vision (2013-2025) could bring a breakthrough in this field.

h. The Philippines

Although the Philippines has a long history of promotion of hybrid rice technology, progress in terms of its area coverage is still very low and recent trends show that it has been declining. The Philippine Rice Research Institute has been working both on three-line and two-line systems for the development of high yielding hybrid rice varieties adapted to local conditions. Hybrid Rice breeding in PhilRice covers the development of parent lines and F1 hybrids, breeding methodology and seed production research, and screening and testing of hybrids in various target environments. As of 2015, five new hybrid varieties approved by National Seed Industry Council (NSIC) was added for commercial cultivation. Due to the success in the early stages of adopting the hybrid rice technology, the production of commercial hybrid rice was included as the key component in several government programmes that aim to increase rice production which will aid the country in becoming self-sufficient in rice. The programme helped in the increase of area where rice was harvested from 5,000 to 369,000 ha (2001-2015). However, due to lack of interest in commercial hybrid production by the next administration, the private sectors took over the production and marketing of hybrid seeds. However, with an average seed yield of 1.2 to 1.9 t ha^{-1}, it would be hardly possible to expand the hybrid rice areas in the Philippines in future. Hybrids occupied only 369 000 ha of lands out of 4 660 000 ha of rice harvested lands in 2015. Major hybrid growing areas are Luzon, Visayas and Mindanao islands covering 308 254 ha of lands. Out of total paddy production 18 149 501 tonnes, 2 075 473 tonnes came from hybrids. Low level of seed production rate and non-availability of suitable locally developed germplasms and non-access to exotic germplasms are considered major problems for the promotion of this technology. Well-rounded policies; research collaboration with international agencies; germplasms exchanges for diversity of national gene pools, high out -crossing rates, grain quality, and resistance to biotic and abiotic stresses of hybrids; and seed production with low costs could bring changes in the development of hybrid rice in the Philippines.

i. Sri Lanka

Hybrid rice development programmes in Sri Lanka started in 1980 with materials from IRRI and China but due to poor adaptability none of the tested materials could be used as hybrid variety. First hybrid was released in the country in 2005 and since then lot of success in terms of parental materials and hybrid rice variety development were achieved. However, their adoption rate is extremely poor and some agro-ecological zones hybrid could not out yield inbred varieties. Poor involvement of private sector; poor awareness and motivation among farmers and concerned officials; lack of suitable germplasm, technology and human resources; and lack of applying new technologies in Sri Lanka are identified as major constraints in hybrid rice development. Enhancement of the germplasm by exchanging materials from other countries and organizations; development of the international collaboration to get new technology from outside; capacity development of concerned stakeholders; development of short duration hybrids with high yielding management practices; identification of suitable places for seed production; more collaboration between breeders and agronomists for hybrid seed production; and improvement of hybrids for droughts and salinity may open-up new opportunities for hybrid rice development in Sri Lanka. Farmers are less interested in adopting hybrid rice technology as they cannot save the seeds for next year, high price of hybrid seeds, high fertilizers requirement, however, low yield of hybrid rice in complex environmental conditions are also major constraints.

j. Thailand

Hybrid rice research in Thailand started in 1979 and hybrid rice development programme through project initiated in 1980. In 2001, CP started hybrid research by introducing 8 hybrid varieties from China. In 2010, CP released CP 304, a high yield hybrid rice of 7.5 tons/ha. In 2011, Rice Department released its first hybrid rice variety, (RDH1) and inn 2013 RDH3 hybrid rice variety giving yield of 8.84 tonnes per hectare. However, technological constraints; social and economic constraints; capability constricts and policy constraints still remain major obstacle to promote this technology. Large diversity of rice germplasm; scope of effective cooperation between good partners (inside and outside country) to share resources and knowledge; availability of genomics and marker-assisted selection; and potentially clear policy of the government on hybrid rice could help in pushing this technology further. Key strategies and policy options to promote hybrid rice development in Thailand are increased capability of hybrid rice production by enhancing research and extension systems; strong programme of technology transfer and pub-private partnerships.

4. TOWARDS A COLLABORATIVE PROGRAMME ON HYBRID RICE IN COUNTRIES/REGION

a. Group discussion 1: Hybrid rice research

- Participants emphasized on the need to enhance heterosis by 30 percent and pest and diseases free parental materials.
- At least each country should have 5 breeders who will work only on the breeding of hybrid rice. It is necessary to create facilities to adopt modern tools and techniques of biotechnology in the breeding programmes.
- Capacity development of the concerned officers and technicians should receive top most priority to bring success in the breeding programmes.
- Site specific breeding programme may bring more benefit than central breeding systems.
- Decentralization of hybrid breeding programme is very important. Incentive to the breeders may accelerate the process of hybrid rice development.
- Government policy and adequate public funds are required to bring success in this field.

b. Group discussion 2: Hybrid rice seed production and extension services

- Hybrid rice seed production is a major obstacle for the expansion of the technology.
- Seed production productivity outside China is very poor ranging between 0.5 t/ha and 2.0 t/ha making the cost of production very high and small holder farmers are reluctant to buy seeds with such a high price.
- Major reasons of low productivity is non-availability of Chinese parental materials outside China. IRRI materials are less productive than China. Location specific seed production is still a big problem because of no technical how and resources.
- Public extension should give more attention to the demonstration of hybrid rice and arrange field days regularly.
- Public and private sectors should work together to bring this knowledge intensive technology to the farmers' fields.

c. Group discussion 3: Access and exchange of germplasms

- Access and exchange of germplasms may be ensured through Hybrid Rice Development Consortium (HRDC) of IRRI.
- To get access of exotic germplasms country capability in terms of rules and regulations of handling exotic materials and IPR should be followed strictly. Exotic germplasms should be used only for breeding purposes. Transfer of seeds from one country to other should be easier.
- It is also essential to have germplasms with traits like BLB, BPH, blast, Brown spots, Tungro, drought, salinity, and sub1 donors.
- Government policy direction should be in favour of germplasm exchange from one country to other country. It can also be done under the scope of the International Treaty of Plant Genetic Resources for Food and Agriculture (ITPGRFA) mechanisms.

Group discussion 4: Hybrid rice development across Asia: limitations and potentials

- Poor germplasm, high incidences of pest and diseases, inadequate trained manpower,
- Lack of clear government policy supports on hybrid rice, inadequate use of fertilizers, few varieties resilient to climate change (mainly high temperature), few educated farmers for hybrid rice technology, inadequate government cooperation, less infrastructure facilities, no quality control of seeds, low yield in all countries and lack of high quality varieties were found as major limiting factors to adoption of hybrid rice in countries other than China.
- Non-existence of public-private partnership towards hybrid rice technology,
- On the other hand, hybrid rice technology can play a crucial role in increasing rice production and productivity in Asia and thus reduce food insecurity and hunger.

5. ADOPTION OF RECOMMENDATIONS FROM REGIONAL EXPERT CONSULTATION

1. It is recommended that governments consider hybrid rice technology development and its adoption as a priority thrust area for capacity building in their efforts to increase rice production and hence strengthen food security of their respective countries. Policy options should be focused on improving national capacity in hybrid rice technology-related innovations and commercialization.

2. Governments should allocate sufficient resources for human resource development, and strengthening infrastructure including R&D facilities in order to enhance hybrid rice breeding efficiency and capacity at national level.

3. Research objectives should cover selection of hybrids and their parents possessing high outcrossing ability, identification of suitable locations/growing seasons, suitable growth duration, genetic purity of parental seeds and crop management practices in which flowering synchronization of parental lines is critical.

4. Considering that hybrid rice production is a knowledge-intensive technology, it is recommended to organize regular training on hybrid rice technology for a large number of farmers and farm women and seed producers to support rapid expansion of this technology to farmers. Hybrid rice seed production also requires skilled manpower; therefore, training of researchers, technicians, and seed growers should be conducted intensively both by public extension systems and private companies. Trained personnel could serve as resource persons for new training programmes.

5. Non-availability of appropriate parental materials at national level is one of the major constraints to developing hybrid rice at country level. But developing local germplasm is expensive and

time consuming. Taking this into consideration, governments should assist research organizations in accessing foreign germplasm to strengthen local breeding programmes.

6. It is unanimously recommended to enhance the level of heterosis for large scale adoption of hybrid rice by two-line breeding and inter sub-specific hybridization with high and stable heterosis, high general combining ability, high outcrossing potential, good grain and cooking quality, and resistance to diseases and pests. Priority should be given to inclusive research on two-line breeding based on TGMS in the years to come.

7. Proper crop management practices should be followed for realization of heterosis and maximizing the genetic yield potential of rice hybrids. Crop management practices should be suited to the rice ecosystems, production systems, local conditions, and specially the F1 hybrid varieties and should follow the principles and good agronomic practices of sustainable crop intensification. Dissemination of the package of practices of hybrid rice cultivation is extremely important. Developing crop management practices for hybrid seed production is also recommended.

8. Hybrid seed production is a key component in bringing success in the adoption of hybrid rice technology. Although the member countries are at different stages of seed production in terms of its productivity but irrespective of the countries, the productivity levels of seed production in all member countries are poor. In view of that all efforts should be directed at increasing the productivity of seed production and hence reducing the cost of its production.

9. It is strongly recommended that private seed industry be more involved and strengthened through public-private partnership arrangement in order to expand the role of the seed industry in hybrid seed production and thus popularize cultivation of hybrid rice. An effective partnership would bring together the distinct strengths of public and private sectors to attain the common goal.

10. Hybrid Rice Development Consortium (HRDC) could be an effective platform for key academies, institutions, and private companies from China to participate actively in it by becoming members. New policies under HRDC-China engagement should help in mobilizing the hybrid rice materials from China to Asia and Africa with proper agreements and licenses.

11. The availability of hybrid seeds at affordable price to farmers is the most important determinant to expanding the planting area of hybrid rice. Therefore, governments should provide favorable environments and incentives to attract the private sector to invest in hybrid seed industry and advocate PPP in capability building.

12. Considering that a vibrant extension system is a prerequisite to expansion of hybrid rice technology to farmers' fields, both government extension organizations, national and international NGOs and CBOs and other concerned stakeholders should work together to bring this technology farmers' level within shortest possible time. PPP arrangement for expansion of hybrid technology could be a viable option.

13. It is recommended that countries undertake a range of measures to create awareness about the benefits of hybrid rice technology among the farmers that will accelerate dissemination of hybrid rice technology. This includes frontline demonstrations, regular field days, giving awards to most successful farmers, use of mass media such as radio talks, video films, newspaper articles publications in local languages on hybrid rice cultivation and hybrid seed production.

14. Crop management practices should be devised to suit rice ecosystems, production systems, and local socio-economic conditions. Innovative approaches in integrated management practices applicable to hybrid rice should be established following the principles and practices of sustainable crop production intensification as promoted by FAO under the banner of *"Save and Grow"* and *"Climate Smart Agriculture".*

15. It is recommended to foster a value chain approach to ensure the sustainability of this technology and attract more young farmers to engage in hybrid rice production or seed business.

16. It is stressed that a national platform for hybrid rice development would provide a mechanism to synergize the activities of various stakeholders in hybrid rice industry including public and private agencies, NGOs and civil organizations, local communities, and farmers. At the international level, hybrid rice R&D cooperation and networking should be maintained and strengthened through international platform for hybrid rice development.

17. It is recommended to deepen the mechanism of coordination among various partners at national and international levels mainly with China and IRRI through HRDC as an important vehicle for successful development and adoption of this technology.

18. South-South cooperation under the assistance of FAO should be effectively harnessed to disseminate hybrid rice between countries in Asia because such kind of cooperation has shown effectiveness in the past and is becoming a rising trend in the future.

6. CLOSING SESSION

In the closing session, Ms. Lin Huifang expressed her satisfaction with the outcomes of the consultation and thanked all participants for their active and fruitful participation in the last three days which ended with 18 recommendations. She hoped that after returning to their respective countries they will submit these recommendations to their high officials for follow-up action at country level with a goal of expanding this technology in more areas. She committed Chinese government willingness to assist Asian countries in developing their hybrid rice technology under south-south cooperation. Finally, she again thanked all participants and experts for their participation and wish them save return to their country.

Dr. Du Van Pham, on behalf of FAO, thanked all participants for their hard work over the past three days to make the programme a success. He expressed satisfaction with the sincere efforts they devoted to charting the future course of development of hybrid rice technology to facilitate its rapid expansion in Asian region. He expressed optimism that fruitful discussions, debates and interactions among the participants sharing both positive and negatives issues in adopting this technology in their countries will provide important lessons for mutual learning. He expressed hope that FAO would do its best to help the member countries in this regard ensuring that FAO will also give due importance to the recommendations of this consultation and will seek to include these in the programmes of Regional Rice Initiative.

APPENDIX 1: PROGRAMME

"REGIONAL EXPERT CONSULTATION ON HYBRID RICE DEVELOPMENT IN ASIA **under FAO-China South-South Cooperation**: CONSTRAINTS AND OPPORTUNITIES"

"**中国-联合国粮农组织南南合作计划亚洲杂交水稻发展研讨会：机遇与挑战**" 日程

1-3 November 2016, Changsha, People's Republic of China

中国，长沙 2016年11月1日至3日

第一天 Day 1 2016年11月1日 1 November 2016	
时间Time	日程Programme
08:30-09:00	注册Registration
第一部分：开幕式 Session I: Opening session 主持人：湖南杂交水稻中心齐绍武主任 Chair: Mr. Qi Shaowu, HHRRC	
09:00-09:15	农业部国际交流服务中心副主任蔺惠芳致辞 Remark by Mrs. Lin Huifang, DDG, CICOS,MOA
09:15-09:30 09:30-09:45	粮农组织驻中国朝鲜代表文森特·马丁先生致辞 粮农组织亚太区域代表处Pham Van Du先生致辞 Remark by Mr. Vincent Martin, FAOCH Remark by Mr. Pham Van Du, FAORAP
09:45-09:55	介绍代表 Introduction of participants
09:55-10:15	合照 Group photo
10:15-10:30	茶歇 Tea/coffee break
第二部分：主旨研讨：区域杂交水稻发展 Session II: Key notes on Regional Hybrid Rice Development 主持人： 粮农组织亚太区域代表处Pham Van Du先生 共同主持人：湖南杂交水稻研究中心廖伏明 报告人：隆平高科；菲律宾国际水稻研究中心；粮农组织亚太区域代表处 Chair: Mr. Du Van Pham, FAORAP Co-Chair: Mr. Liao Fuming, HHRRC Rapporteur: Longping High-tech; IRRI; FAO RAP	
10:30-10:50	隆平高科谢放鸣教授：亚洲各地杂交水稻研发 Hybrid Rice Research and Development across Asia Prof Xie Fangming, Longping High-Tech
10:50-11:10	杂交水稻：振兴杂交水稻发展联盟满足亚洲杂交水稻市场需求 菲律宾国际水稻研究中心Jauhar Ali博士 Hybrid Rice: Meeting the Market Needs of Asia through a Revitalized Hybrid Rice Development Consortium (HRDC) Dr. Jauhar Ali, International Rice Research Institute (IRRI), Philippines

11:10-11:30	亚洲杂交水稻可持续发展: 粮农组织亚太区域代表处Pham Van Du先生 Sustainable Development of Hybrid Rice in Asia: Constraints and Opportunities Mr. Du Van Pham, FAORAP
11:30-12:00	讨论General Discussion
12:00-14:00	午餐Lunch
第三部分：知识经验分享 Session III. Sharing knowledge and experiences 主持人：湖南杂交水稻研究中心张玉烛研究员 共同主持人：粮农组织亚太区域代表处Pham Van Du先生 报告人：粮农组织亚太区域代表处；孟加拉国；柬埔寨；中国；印度尼西亚；老挝；缅甸 Chair: Mr. Zhang Yuzhu, HHRRC Co-Chair: Mr. Du Van Pham, FAO RAP Rapporteur: FAO RAP; Bangladesh; Cambodia; China; Indonesia; Lao PDR; Myanmar	
国别报告：杂交水稻发展现状 **Country reports on Current Status of Hybrid Rice Development (20 minutes for presentation and 10 minutes for the discussion)**	
14:00-14:30	杂交水稻技术发展的瓶颈 Barriers in the Development of Hybrid Rice Technology **Mr. Subash Dasgupta** FAORAP
14:30-15:00	• 孟加拉国BANGLADESH **Dr. Md. Kamal Hossain** 孟加拉水稻研究所杂交水稻处高级科研官员 Senior Scientific Officer (SSO) from Hybrid Rice Division Bangladesh Rice Research Institute
15:00-15:30	• 柬埔寨CAMBODIA **Mr. Neak Thon** 农林渔业部农业水稻作物司高级水稻专家 Senior Rice Expert from the Rice Crop Department of Ministry of Agriculture, Forestry and Fisheries
15:30-16:00	• 中国CHINA 湖南杂交水稻研究中心党委书记马国辉研究员 **Mr. Ma Guohui**, HHRRC
16:00-16:30	茶歇Tea/coffee break
16:30-17:00	• 印度尼西亚INDONESIA **Dr. Satoto** 水稻研究中心研究员 Researcher from Indonesian Center for Rice Research
17:00-17:30	• 老挝LAO PDR **Mr. Saykham Volachith** 农林业部国家农林研究所农业经济处处长 Head of Agronomy Unit from National Agriculture and Forestry Research Institute (MAFRI), Ministry of Agriculture and Forestry

17:30-18:00	• 缅甸MYANMAR **Ms. Daw Hmwe Hmwe** 农业研究司水稻处杂交水稻科副科长 Deputy Director from Hybrid Rice Section, Rice Division Department of Agricultural Research
18:30-22:00	**欢迎晚餐Welcome dinner**
第二天 Day 2 2016年11月2日 2 November 2016	
国别报告：杂交水稻发展现状（继续） **Country reports on Current Status of Hybrid Rice Development (continue)** 主持人：湖南杂交水稻研究中心赵炳然研究员 共同主持人：粮农组织亚太区域代表处Pham Van Du先生 报告人：尼泊尔；菲律宾；斯里兰卡；泰国； Chair: Mr. Zhao Bingran, HHRRC Co-Chair: Mr. Du Van Pham, FAO RAP Rapporteur： Nepal; The Philippines; Sri Lanka; Thailand	
09:00-09:30	• 尼泊尔NEPAL **Mr. Dilaram Bhandari** 农业司作物发展处项目负责人 Program Director at Crop Development Directorate, Department of Agriculture
09:30-10:00	• 菲律宾PHILIPPINES **Ms. Joanne Domingo Caguiat** 水稻研究所高级科研专家 Senior Science Research Specialist from Philippine Rice Research Institute
10:00-10:30	• 斯里兰卡 Sri Lanka **Mr. Darsha Manjula Withanawasam** 区域水稻研发中心农业（研究）助理主任 Assistant Director of Agriculture (Research) from Regional Rice Research Development Centre
10:30-11:00	茶歇Tea/coffee break
11:00-11:30	• 泰国THAILAND **Mrs. Bang-On Thammasamisorn** 水稻研发厅国家水稻科学研究所农业研究官员（高级专业职称） Agricultural Research Officer, Senior Professional Level from National Rice Science Institute, Bureau of Rice Research and Development
11:30-12:30	国别报告问答（小组讨论待定） Panel Discussion Chair: Dr. Jauhar Ali, IRRI Panellist: • Mr. Liao Fuming, China • Ms. Daw Hmwe Hmwe, Myanmar • Dr. Susan R. Brena, Philippines • Mr. Darsha Manjula Withanawasam, Sri Lanka Rapporteur: Sri Lanka and Thailand
13:00-14:00	午餐Lunch
第二天2016年11月2日下午 Day 2 (Afternoon)	

实地考察 FIELD TRIP		
	参观隆平水稻博物馆 Visit LONGPING RICE MUSEUM	
第三天 Day 3 2016年11月3日 3 November 2016		
第四部分：关于各国/各地区的杂交水稻合作项目 Session IV: Towards a collaborative programme on of Hybrid rice in countries-/region 主持人：粮农组织亚太区域代表处Pham Van Du先生 共同主持人：湖南杂交水稻研究中心张玉烛研究员 Chair: Mr. Du Van Pham, FAORAP Co-Chair: Mr. Zhang Yuzhu, HHRRC		
09:00-09:30	湖南杂交水稻研究中心袁隆平院士：超级杂交稻研究进展 Progress in Breeding Super Hybrid Rice **Prof Yuan Longping, HHRRC**	
09:30-10:00	茶歇Tea/coffee break	
10:00-12:30	国家/地区按主题重点分组讨论 •杂交水稻研究 —湖南杂交水稻中心符习勤 研究员 •杂交水稻种子生产和推广服务 —湖南杂交水稻中心张玉烛研究员 •种质资源的获得和交换 —李继明 •杂交水稻发展在亚洲:局限和潜力 —谢放鸣 —10个成员国的代表们/受邀代表们按以上主题依照自身兴趣分成4个小组 —准备国家间和国际机构间双边/多边合作大纲草案 Breakout session per Thematic priorities of countries/region: • Hybrid rice research — Mr. Fu Xiqin, HHRRC • Hybrid rice seed production and extension services — Mr. Zhang Yuzhu, HHRRC • Access and exchange of germplasm — Mr. Li Jiming, HHRRC • Hybrid rice Development Across Asia: Limitations and potentials — Mr. Xie Fangming, HHRRC – Participants from 10 member countries/invited participants will work as they wish in 4 groups/themes – Preparation of draft outline of bilateral/multilateral collaboration among countries and international institutions	Each group has to appoint Chair and Rapporteur 每组应指定主席和报告人
12:30-13:30	午餐Lunch	

13:30-15:30	各参与国（包括中国在内）展示提议大纲草案（每个国家10-15分钟） • 孟加拉国 • 柬埔寨 • 中国 • 印度尼西亚 • 老挝 • 缅甸 • 尼泊尔 • 菲律宾 • 斯里兰卡 • 泰国 Presentation draft outline collaborative activities for each participating country and China (10-15 minutes each) • Bangladesh • Cambodia • China • Indonesia • Laos • Myanmar • Nepal • Philippines • Sri Lanka • Thailand
15:30-16:00	茶歇Tea/coffee break
16:00-16:30	全体讨论（小组待定） Panel discussion Chair: TBD Panellist: • Dr. Jauhar Ali, IRRI • Dr. Md. Kamal Hossain, Bangladesh • Dr. Satoto, Indonesia • Ms. Joanne Domingo Caguiat, Philippines
16:30-17:00	采纳建议 Adoption of Recommendations Mr. Du Van Pham, FAORAP Mr. Subash Dasgupta, FAORAP
17:00-17:30	闭幕致辞 农业部国际交流服务中心/粮农组织Closing remark CICOS, MOA FAORAP

APPENDIX 2: LIST OF PARTICIPANTS

REGIONAL EXPERT CONSULTATION ON HYBRID RICE DEVELOPMENT IN ASIA* Under FAO-China South-South Cooperation*: CONSTRAINTS AND OPPORTUNITIES

中国-联合国粮农组织南南合作计划亚洲杂交水稻发展研讨：机遇与挑战

代表名单

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APPENDIX 3: GROUP PHOTO