HELPING THE PHILIPPINES BECOME COMPETITIVE THRU IMPROVED HYBRID RICE SEED PRODUCTION

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Responsibility for this publication rests with the Philippine Rice Research Institute and the International Rice Research Institute.

Suggested Citation:

Bordey FH, Beltran JC, Moya PF, Manalili RG, San Valentin MRL, Rebong DB II. 2016. Helping the Philippines Become Competitive Thru Improved Hybrid Rice Seed Production. Science City of Muñoz, Nueva Ecija (Philippines): Philippine Rice Research Institute, and Los Baños, Laguna (Philippines): International Rice Research Institute. 31p.

Published by:
Philippine Rice Research Institute
Maligaya, Science City of Muñoz, Nueva Ecija

ISBN: 978-621-8022-20-1

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The Philippine Rice Research Institute (PhilRice) is a chartered government corporate entity under the Department of Agriculture. It was created through Executive Order 1061 on November 5, 1985 (as amended) to help develop high-yielding, cost-reducing, and environment-friendly technologies so farmers can produce enough rice for all Filipinos.

It accomplishes this mission through research, development, and extension work in its central and seven branch stations, coordinating with a network that includes 57 agencies and 70 seed centers strategically located nationwide.

PhilRice has the following certifications: ISO 9001 (Quality Management), ISO 14001:2004 (Environmental Management), and OHSAS 18001:2007 (Occupational Health and Safety Assessment Series).

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Working with in-country partners, IRRI develops advanced rice varieties that yield more grain and better withstand pests and diseases as well as flooding, drought, and other harmful effects of climate change. More than half of the rice area in Asia is planted to IRRI-bred varieties or their progenies. The institute develops new and improved methods and technologies that enable farmers to manage their farms profitably and sustainably, and recommends rice varieties and agricultural practices suitable to particular farm conditions as well as consumer preferences. IRRI assists national agricultural research and extension systems in formulating and implementing country rice sector strategies.

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ABBREVIATIONS

ha - hectare
h - hour
yr - year
WS - wet season
DS - dry season
kg - kilogram
km - kilometer
L - liter
md - manday
sq.m - square meter
t - ton
M - million
PhP - Philippine peso
RMB - Chinese renminbi
INR - Indian rupee
US$ - United States dollar

ACKNOWLEDGMENT

We acknowledge the many individuals who have made possible the writing and publication of this hybrid seed production monograph.

We appreciate the DA National Rice Program formerly led by Assistant Secretary Edilberto M. De Luna; and the DA-Bureau of Agricultural Research headed by Dir. Nicomedes M. Eleazar for funding the project.

We recognize the support and encouragement provided by Dir. Edmund J. Sana of the DA National Rice Program. We also appreciate the institutional support in pursuing this project provided by Dr. Sailila E. Abdula, Dr. Eufemio T. Rasco, and Dr. Calixto M. Protacio, current and former executive directors of PhilRice.

Credit is also due to Dr. Samarendu Mohanty, head of IRRI-Social Sciences Division, and Ms. Rhemilyn Z. Relado, head of PhilRice Socioeconomics Division, who both fully and willingly supported the implementation of this project.

We are also grateful to Dr. Bruce Tolentino, IRRI deputy director general for communication and partnerships, for inspiring us to work harder to complete this important project.

We appreciate the enormous help provided by our international fieldwork partners: Dr. Fangming Xie of IRRI and Dr. Xianhua Shen and Mr. Wan Yong of the Rice Research Institute, Jiangxi Academy of Agricultural Sciences, China; and Rupendra Singh, Pankaj Malik, Yog Raj of Bayer Company in Hyderabad, India and also Aldais Janaiah.

Thanks to our experts from PhilRice, Ms. Joan D. Caguiat and Mr. Leonilo V. Gramaje, for lending their time and expertise to ensure that we present specific subject matters properly.

We also thank the staff members who helped us in data gathering, administrative matters, and coordination work to implement this project: Ms. Esther B. Marciano, Ms. Mary Grace Salabsabin, and Ms. Ma. Potenciana Caisip of IRRI; Ms. Charmaine G. Yusongco, Ms. Suennie Jane C. Paran, Ms. Teodora L. Briones, Ms. Anna Liza P. Labay, and Ms. Alfrelyn Gregorio of PhilRice; and Mr. Raymond Patrick Cabrera of DA-BAR.

Thanks to Mr. Constante T. Briones who did the language editing and Ms. Anna Marie F. Bautista who made the cover design and layout, both of PhilRice.

Our deepest gratitude we reserve for the hybrid rice seed growers in the various sites who willingly provided all the information that we needed to complete these studies.

Lastly, we thank and beg for the forgiveness of all those who helped us implement this project but whose names we have failed to mention.

PREFACE

In 2013, the Philippine Rice Research Institute (PhilRice) of the Department of Agriculture (DA) and the International Rice Research Institute (IRRI), with the participation of the Philippine Council for Agriculture and Fisheries (DA-PCAF) jointly planned, designed, and implemented the project *Benchmarking the Philippine Rice Economy Relative to Major Rice–Producing Countries in Asia*. The Philippine government, through the DA, provided the full financial support for this undertaking. One of the major features of this project is the development of a database on input use, level of output, prices, and detailed cost of hybrid rice seed production.

This monograph on the economics of hybrid seed production is one of the major outputs of the project. It is intended for a general audience who would like to learn about the current status of hybrid rice seed production in the Philippines relative to the two major hybrid seed producers in the world: China and India. In this monograph, the farm-level competitiveness of producing private hybrid seeds in Davao Oriental, Philippines is compared with those in Jiangxi, China and Andhra Pradesh, India. It also contains a detailed description of each country's hybrid seed management practices, input use, and labor-using and labor-saving practices. Data from each country were collected through face-to-face interviews using questionnaires tackling clean seed output, input use, cost of hybrid seed production for crop year 2014, and basic farm and household characteristics.

Results from this study can provide insights on how a country can further improve its competitiveness in hybrid seed production. We gain a perspective on the policies being implemented by our neighbors to make their respective hybrid rice industry competitive. By understanding the costs of producing hybrid seeds amidst different government policy frameworks in major hybrid seed-producing countries, agricultural policymakers can make appropriate decisions on how to best position the country's interest in terms of hybrid rice seed security. Policymakers and planners can use this information in crafting sustainable development programs for the hybrid rice industry.

Project Leaders

Flordeliza H. Bordey
Piedad F. Moya

ABSTRACT

Hybrid rice is one of the technologies identified to increase production and meet the growing demand for the staple food in the Philippines and Asia. The widespread commercialization of hybrid rice in the Philippines is stymied by the limited availability of F1 seeds at affordable price. The country produces hybrid seeds but not enough to meet the demand. Private companies have responded by importing cheaper hybrid seeds in addition to their local produce. The standing issue is whether the Philippines can produce hybrid seeds at a cost competitive with other hybrid seed-producing countries. This paper assesses the farm-level competitiveness of producing F1 seeds in the Philippines relative to China and India, the world's major hybrid seed producers. Specifically, yield and input-use in hybrid rice seed production were examined; costs of and returns to producing F1 seeds were estimated and compared; and policies on increasing hybrid seed availability and affordability in the Philippines were recommended.

China ranked first in terms of land productivity with an average F1 seed yield of 3.12 t ha^{-1} per cropping season, a superior yield advantage of 36% over the Philippines (1.98 t ha^{-1}) and 27% over India (2.29 t ha^{-1}). The high yield in China is attributed to their advances in biotechnology that overcome the biotic or abiotic pressures. The Philippines had the lowest F1 seed yield, as China and India are more familiar and experienced with the technology.

On average, China incurred the largest total hybrid seed production cost at US$4,959 ha^{-1}, hence the biggest unit cost at US$1.59 kg^{-1}, despite being the highest yielder. The Philippines has a total production cost of US$2,303 ha^{-1}. Despite its lowest yield of hybrid seeds, its unit cost of US$1.16 kg^{-1} was cheaper than in China and almost comparable to India. The cheapest cost of hybrid seed production was in India at US$2,294 ha^{-1}, with cost per unit estimated at US$1 kg^{-1}.

Results indicate that the Philippines can compete with other hybrid seed-producing countries in terms of cost. However, to reduce the local price, the supply of F1 seeds needs to be increased. This can be done by improving the seed yield through further research on parental lines, planting row ratio, fertilizer rates including splitting and timing, plant protection, and water management. Additional study is also needed in finding suitable areas for hybrid seed production in the Philippines.

Keywords: hybrid rice, F1 seed yield, cost competitiveness

INTRODUCTION

Hybrid rice is one of the technologies identified to increase production and meet the growing demand for the staple food in the Philippines and Asia. It was planted in about 20 million (M) hectares (ha) in Asia in 2013, of which 15.5 M ha were in China; the rest in India, Vietnam, Philippines, Indonesia, and others (Bui Ba Bong, 2014). Hybrid rice is to increase productivity without necessarily expanding the rice area. Bordey and Nelson (2012) saw that users of hybrid rice seeds (F1) had 18% higher production than users of inbred seeds from previous harvest. Gonzales *et al.* (2007) also found a yield advantage of hybrid over inbred of 8-13% in wet season and 11-14% in dry season.

Because of its potential in increasing rice production and in achieving self-sufficiency, commercializing hybrid rice became a component of several government agricultural programs in the Philippines such as the *Gintong Ani* in 1998, *Agrikulturang MakaMASA* in 2000, and the *Ginintuang Masaganang Ani* in 2001. The price of F1 seeds was subsidized up to 2010 to promote utilization and increase adoption (Bordey *et al.,* 2013). Since then, the commercialization of hybrid rice became private sector-driven where seed companies are more involved now in producing and marketing F1 seeds.

New evidence asserts that hybrid rice can not only increase yield but also reduce cost per unit. Hybrid rice users in irrigated ecosystem in Nueva Ecija average 7.20 t ha^{-1} with a cost of PhP 9.85 kg^{-1}; inbred farmers' seeds have only 4.13 t ha^{-1} and cost of PhP13.72 kg^{-1} (Bordey *et al.,* 2016). With its promising contribution to improving farm-level competitiveness, government's interest in hybrid rice promotion is being renewed.

The widespread commercialization of hybrid rice in the Philippines is stymied by the limited availability of F1 seeds at affordable price. The country produces hybrid seeds but not enough to meet the demand. Private companies have responded by importing cheaper hybrid seeds in addition to their local produce. Can the Philippines then produce hybrid seeds at a cost competitive with other hybrid seed-producing countries? Comparative data on hybrid seed productivity and costs are limited, hence the need for this study.

This paper assesses the farm-level competitiveness of producing F1 seeds in the Philippines relative to China and India, the world's major hybrid seed producers. Specifically, yield and input-use in hybrid rice seed production were examined; costs of and returns to producing F1 seeds were estimated and compared; and policies on increasing hybrid seed availability and affordability in the Philippines were recommended.

Trends in the Philippine hybrid rice seed industry

The Philippine government recognized the potential contribution of hybrid rice in attaining local self-sufficiency as early as the 1990s, hence its inclusion in national rice programs. Multidisciplinary research on development of hybrid rice varieties, seed production protocols, and associated crop management practices were supported during the *Gintong Ani* Program (GAP) in 1998 and were sustained through the *Agrikulturang MakaMASA* Program until 2000 (Casiwan *et al*., 2003). Promotion activities such as training, technology demonstration, and information campaigns were also carried out. However, it was the *Ginintuang Masaganang Ani* (GMA) through the Hybrid Rice Commercialization Program (HRCP) that catapulted hybrid rice into commercial-scale planting since 2001 (Sebastian and Bordey, 2005; Gonzales *et al*., 2006; Bordey *et al.*, 2013).

Initial government efforts generated interest among farmers but adoption was largely constrained by the limited availability of F1 seeds. Aside from the seed growers who ventured into hybrid seed production and the farmers who bought seeds directly from them, adoption was restricted to farmers in compact technology demonstration areas (Javier, 1999).

During those times, the National Seed Industry Council (NSIC, formerly Philippine Seed Board) released only three hybrid rice varieties: the International Rice Research Institute-bred PSB Rc26H or Magat, and PSB Rc72H or *Mestizo* 1; PSB Rc76H or Panay was bred by Cargill Inc., which was eventually merged with Monsanto (Redoña *et al*., 2002). Only *Mestizo* 1 was recommended for nationwide cultivation and had potential for commercial production of F1 seeds.

HOW IS HYBRID RICE SEED (F1) PRODUCED?

Since rice is naturally a self-pollinating plant, producing F1 is more complicated than inbred seed production (Virmani and Sharma, 1993). The three-line system of hybrid seed production involves the cytoplasmic male-sterile (CMS) A line or the female parent; the maintainer or B line which mass-produces the A line without losing its sterility; and the restorer R line or the male parent.

The complication starts during crop establishment when R line seedlings at different ages are transplanted along with the A line seedlings. Applications of fertilizer and plant protection chemicals need proper timing to ensure synchrony of their flowering stages. Additional activities such as application of gibberellic acid (GA3), flag leaf-clipping, and supplementary pollination are required to increase seed yield. GA3 is applied to synchronize the reproductive stages of male and female parents while flag leaf-clipping and supplementary pollination enhance the transfer of pollen to the female plant. Intensive roguing is also required to ensure purity of the F1. Finally, F1 from A lines should be harvested separately from R lines to avoid mixture. Due to its difficulty, hybrid rice seed is more expensive to produce than high-quality inbred seeds.

The use of the thermosensitive genetic male-sterile (TGMS) approach is another way of producing F1. This paper focuses on the CMS option.

A viable hybrid seed industry that can efficiently produce and distribute F1 to farmers needed to be established for its widespread adoption. To encourage engagement in the hybrid seed business, the government through Philippine Rice Research Institute (PhilRice) trained individual seed growers from Cagayan Valley (Region 2) and Southern Mindanao (Region 11) to produce F1 seeds of *Mestizo* 1. They were organized into cooperatives so they could consolidate volume and effectively market their seed produce. In addition, private companies such as HyRice and SL Agritech were also allowed to produce seeds of *Mestizo* 1 while they were doing research to develop their own hybrid varieties (Malabanan, 2001). Despite these efforts, the amount of *Mestizo* 1 F1 remained inadequate.

The Department of Agriculture imported 60 t of hybrid seeds from China (Jin You variety) to meet its target area for the dry season planting in 2001. The seeds were distributed to farmers in Cagayan Valley Region, but did not perform well under local conditions causing setbacks in farmers' adoption (Casiwan *et al.*, 2003).

To surmount the challenges during the early stages of hybrid rice promotion, the price of F1 seeds was subsidized at the farm level. The government procured F1 from seed producers and sold them to farmers at half the procurement cost (Bordey *et al.,* 2013). The government also implemented the plant-now-pay-later scheme wherein half of the subsidized price was paid upon receipt of seeds and the other half after harvest. Farmers were also allowed to avail of credit assistance from the Quedan and Credit Guarantee Corporation (QUEDANCOR), which paid for the seeds, payable by farmers after harvest. Farmers who planted F1 seeds could also avail of soil analysis services for their farms after attending a technical briefing on hybrid rice.

Recognizing the importance of seed availability to the success of the program, the government offered a guaranteed market for F1 seeds produced by seed growers and/or private companies. PhilRice conducted hybrid seed production trainings for seed producers and provided technical field assistance. To further spur F1 production, the government also provided free parental seeds, GA3, and low-volume sprayers to seed producers. Farm machinery such as seed cleaners, flatbed dryers, and bag closers were likewise provided to seed grower cooperatives as incentives for devoting more than 100 ha for hybrid seed production and attaining a seed yield of at least 750 kg ha^{-1}. Each seed producer was also entitled to a PhP 10,000 ha^{-1} cash assistance that can be used as supplementary working capital for seed production.

Private companies were also motivated to join in the hybrid rice seed business, including Bayer, SL Agritech, and HyRice corporations. The government allowed these companies to set the market price for their own hybrid varieties, and shouldered the marketing cost. For every kilogram of hybrid seeds they sold to farmers, they collected subsidy from the government.

These efforts led to a remarkable increase in the area harvested to commercial hybrid rice from only 5,371 ha in 2001 to its peak of 368,634 ha in 2005 (Figure 1). Hybrid rice production also increased from 29,223 t to 2.21 M t during the same period (Figure 2). Average hybrid rice yield also increased from 5.44 t ha^{-1} to 6.01 t ha^{-1}. Beyond 2005, however, the growth in area harvested to hybrid rice was not sustained.

Starting wet season 2005, the system of procurement and distribution of hybrid seeds was changed (David 2006; Bordey *et al*., 2013). The government no longer procured hybrid seeds but instead guaranteed to pay seed producers a portion of their selling price, thus shifting the marketing functions to them. PhilRice's role in the commercialization was clipped to monitoring, which was eventually assumed by the DA Rice Program.

Hybrid seed yield improved from an average of 335 kg ha^{-1} in 2002 wet season to 776 kg ha^{-1} in 2004 dry season (Bordey *et al.*, 2013) as seed growers sharpened their technical competence. Because of this, government support to seed producers was gradually removed starting 2004 DS. This dampened the interest of seed growers, escalated into limited availability of F1 seeds, and led to the decline in area harvested to hybrid until 2010.

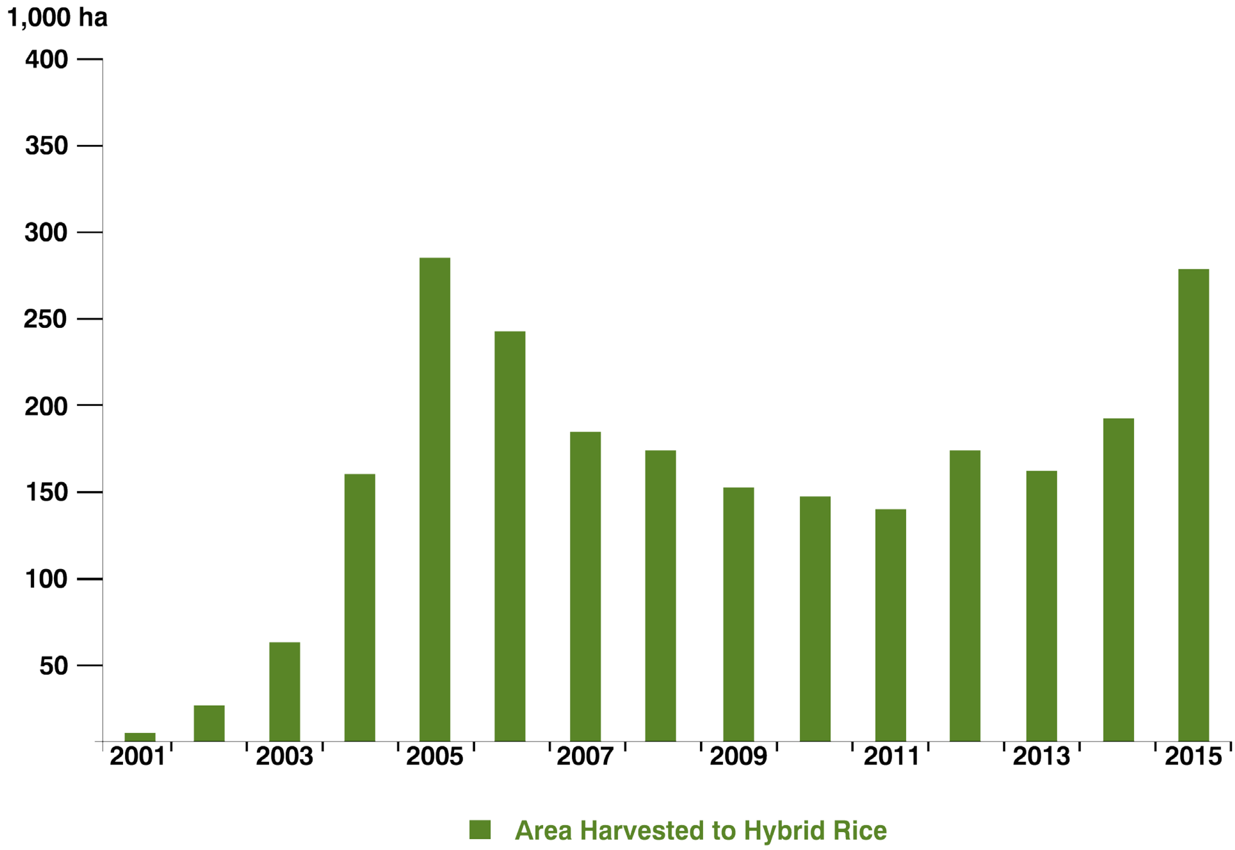

Figure 1. Area harvested to hybrid rice, 2001-2015.

Several problems stunted the early commercialization stages of hybrid rice (Bordey *et al.*, 2013). The limited F1 availability due to low seed yield constricted area expansion. Delays in government procurement and distribution of hybrid seeds also created inefficiencies, as farmers had to plant other seeds. This led to seed carry-over stocks but the quick deterioration in hybrid seed viability spelled wastage. The subsidy was also unsustainable because it drained government funds that could have been used for other purposes.

David (2006) also diagnosed problems in the design of HRCP: 1) government performing private sector roles; 2) anomalies in seed payments; 3) regulatory functions compromised; 4) questionable rationale of input subsidies; 5) effective cost of hybrid seeds much higher; and 6) excessive subsidies distort varietal choice of seed growers and farmers.

On the demand side, farmers' adoption was lukewarm because of more expensive hybrid seeds compared to inbred in spite of the subsidy. Early hybrid varieties were also perceived to be more susceptible to pests and diseases such as bacterial leaf blight and rice tungro virus (Redondo and

Castañeda 2002; Cabling and Malasa 2002; Catudan and Mataia 2002; Sebastian and Francisco 2002; Casiwan 2002). The use of hybrid rice technology also entailed new management practices which were alien to farmers at that time. These are: 1) use of 20 kilogram (kg) ha^{-1} F1 seeds; (2) use of 400 sq. m seedbeds; (3) incorporation of 10 bags organic fertilizer in the seedbeds; (4) sowing of 50g seeds per sq. m; (5) use of one seedling per hill during transplanting; and (6) use of new F1 seeds every cropping. These factors mired the adoption of hybrid rice.

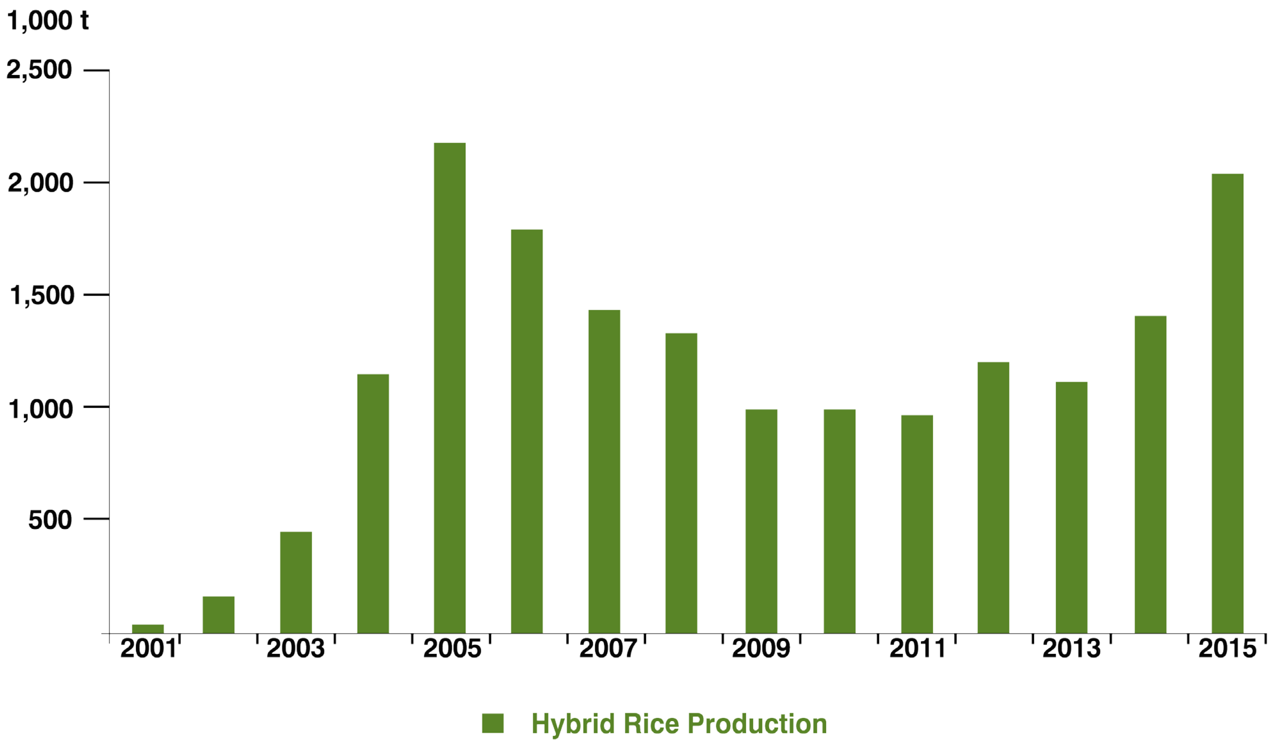

Figure 2. Hybrid rice production, 2001-2015.

Realizing that the problems on program implementation outweighed the benefits, the government decided to discontinue the subsidy program in 2010. As expected, area harvested to hybrid dropped to 177,484 ha in 2011. Despite withdrawal of seed subsidy, area harvested increased to 361,408 ha in 2015 approximating its peak in 2005. This hectarage produced 2.08 M t of paddy. Hence, from less than 8% of national area harvested, hybrid rice accounted for more than 11% of total production in 2015.

One of the key differences between the early commercialization experience and the post-subsidy period is the stronger private sector involvement in the latter, particularly in the development of hybrid varieties. From only three varieties prior to 2000, NSIC has by 2016 released 73 hybrid varieties, 62% of which were proprietary or bred by private companies (Table 1). Thirteen companies are active in hybrid rice breeding: Monsanto, Bayer, SL Agritech, Syngenta, Bioseed, Pioneer, Seedworks, Hyrice, Advanta, Beidahuang, Methahelix, DevGen, and Long Ping.

Despite the stronger involvement of private companies in hybrid rice breeding, IRRI bred the most with 15 NSIC-released hybrids. PhilRice has 10, two of which were developed in partnership with UPLB. However, commercialization of public hybrids is weak and wanting. Among the private companies, Syngenta leads with 11 varieties, and has acquired DevGen; Bayer has eight.

Table 1. Number of hybrid rice varieties released by NSIC in the Philippines, as of 2016.

Breeding Institute	Number of Varieties Bred
IRRI	15
PhilRice	10
PhilSCAT	3
Syngenta	11
Bayer	8
Bioseed	3
Seedworks	3
Advanta	3
Methahelix	3
DevGen	3
Long Ping	3
Monsanto	2
Pioneer	2
Hyrice	2
SL Agritech	1
Beidahuang	1
Total	**73**

The domination of private companies in the Philippine hybrid rice seed industry is a consequence of seed importation. Their hybrids have passed local field testing, hence the NSIC recognition, but their F1 seeds are produced abroad and imported into the country. India and China were the main sources of imported hybrid seeds although some companies also sourced from Bangladesh and Pakistan (BPI, 2016). Ideally, producing the seeds within the country could stimulate rural economy through employment or promote agribusiness through the contract growing scheme. Certain private companies produce seeds in the Philippines but majority of them only bring in seeds from their subsidiaries abroad, where cost of production is lower. This underscores the importance of understanding the cost structure of hybrid seed production and comparing it across the major hybrid seed-producing countries.

METHODOLOGY

This section describes the site selection process, sampling procedures, and analytical framework used in the study.

Site selection and description

This study compares hybrid rice seed production in the Philippines with the two major sources of imported hybrid rice seeds: China and India. China is the first country to use hybrid rice technology to its fullest. Research was pioneered by Prof. Yuan Longpin in 1964 and in 1976, the first hybrid was released in China for commercial production until it reached its peak area of 17.6 M ha or 54% of China's total rice area in 1991. The area then stabilized at about 15.5 M ha (Guohin, 2014). China is the most advanced in terms of productivity of commercial hybrid and seed production.

India is the second country in Asia to develop and commercialize hybrid rice. Since 1989, it implemented its Hybrid Rice Program coordinated by the Directorate of Rice Research in Hyderabad (Mishra *et al.*, 2002). They started a mission-mode project on hybrid rice with technical support and germplasm provided by IRRI. A national network approach was adopted by including all concerned research institutions, public and private seed agencies, and the Department of Agriculture of target states. In 1995, 10,000 ha were planted to hybrid rice, reaching about 1 M ha in 2006. It exceeded 2.5 M ha in 2013, which is roughly 5.6% of the total rice area in India (Prasad *et al.*, 2014).

Upon recommendations of a hybrid rice expert at IRRI (Dr. Fangming Xie, pers com) and site validation, Jiangxi province in China and Andhra Pradesh state (now subdivided into Telangana and Andhra states) in India were selected as study areas due to the concentration of hybrid seed production in these places. For the Philippines, the province of Davao Oriental was chosen due to presence of the hybrid seed contract growing system and suitability of the area for hybrid seed production.

Jiangxi in southeast China has a subtropical monsoon climate. It has an annual temperature of 18 °C ranging 6 °C in January to 29 °C in July. Its rainy season begins in April and peaks in May to June (http://www.chinahighlights.com/jiangxi/weather.htm). Changshen is the specific sample site in Jiangxi which has an average precipitation of 1631 mm per annum (http://en.climate-data.org/location/979835/).

Andhra Pradesh in southern India has a semi-arid (predominantly hot and dry) climate. Summer commonly starts in March and peaks in May with maximum temperature averaging at 42 °C. Monsoon season usually ensues in June lasting until September with about 755 mm annual rainfall. It has a dry, mild winter from November to early February with little humidity and average temperature range of 22–23 °C (https://en.wikipedia.org/wiki/Telangana). The specific sample locations in Andhra Pradesh are Karimnagar and Warangal districts.

Davao Oriental in southern Philippines has a tropical climate with rainfall more or less evenly distributed throughout the year, and has no distinct dry season (https://en.wikipedia.org/wiki/Davao_Oriental). The peak of rainy season occurs during November to January. The specific sample sites in Davao Oriental are Lupon and Banaybanay, which have an average temperature of about 27°C and annual rainfall of 1843 and 1877 mm, respectively.

Data were gathered during the seed production season in 2014 crop year. For India, planting started in December; harvest in April. Planting starts in January in the Philippines; harvest in April. In China, planting begins in April; harvest in August.

Sampling procedure

Sample farmers were selected purposively in consultation with local experts and private hybrid seed companies. A quota sample of 30 seed growers per country were interviewed personally guided by a structured questionnaire. In India and the Philippines, the sample respondents were contract growers producing seeds of proprietary hybrid varieties; those in China were individual seed growers.

Costs and returns analyses

To construct the costs and returns structure of hybrid seed production, data on seed yield, material inputs, labor and machine uses, crop management practices, and prices of inputs and outputs were obtained. Seed yield here is the amount of clean and dry (i.e., 14% moisture content) F1 seeds produced after postharvest processes. The volume of R line produced was also gathered to estimate the total income from hybrid seed production.

The material inputs include the cost of parental seeds, fertilizers, plant protection chemicals (e.g., insecticide, herbicide, and fungicide, among others), GA3 and other growth promoters, and tarpaulin or other plastic materials used as field barriers. In India and the Philippines, private companies provided contracted seed growers with "free" parental seeds, with cost deducted from the price of F1. In China, seed growers paid directly for the cost of parental seeds but generally got higher price of F1 seeds. To allow for better comparison, the price of F1 seeds in China was adjusted by subtracting the cost of seed to produce a kilogram (kg) of clean F1. The resulting cost of production per kg was therefore net of seed cost, and is an underestimate of the total unit cost.

Similarly, data on labor use in various farm activities were collected. To construct the total labor use for the whole cropping season, the number of persons was multiplied by the number of days they work in the farm, and the number of hours they work within each day. This was divided by 8 hours to construct a man-day (i.e., 1 md = 8 h work). The number of md was categorized according to source: (1) hired through daily rate or contract rate and (2) labor provided by the farmer, his family members, and exchange workers, where one family works for free on a neighbor's farm in exchange for the neighbor working an equivalent amount of time on the other family's farm.

Several major farm activities were considered in the study: (1) land preparation; (2) crop establishment; (3) crop care and management; (4) harvesting and threshing; and (5) postharvest. Land preparation includes sub-activities such as plowing, harrowing, rototilling, side plowing, cleaning and repair of dikes, and construction of water ditches in the field. Transplanting is used in crop establishment that includes seedbed preparation, raising, pulling, and hauling seedlings into the field.

Crop care and management constitutes fertilizer and pesticide applications, irrigating and draining the field, pest management practices such as manual weeding, supplementary pollination, and roguing to remove off-types. Harvesting and threshing includes labor required for cutting and gathering the rice stalks and separating the grains from the panicles. R lines are harvested first, then field-cleaning is done before harvesting the F1 from A lines. Postharvest activities such as bagging and hauling of outputs from the farm to the pick-up point were included in the analysis.

Since cleaning and drying are mostly done by the private companies, these were excluded from the farm labor.

Farmers were also asked about machinery use. For land preparation, the use of four-wheel tractors is common in India while the two-wheel tractor is customary in China. In the Philippines, the floating tiller is also popular aside from the use of the two-wheel tractor. After harvesting the R line, combine harvester was commonly used to reap F1 in China and India. In the Philippines, manual cutting is done before using an axial-flow thresher to collect the grains from the panicles.

Data about prices of material inputs, labor wages and contract rates, machine rent per season, imputed land rent, interest cost of borrowed capital, and selling prices of F1 and R line were collected as well. Other costs of production such as food, transport, and land tax were also determined.

The cost of each individual item was estimated by multiplying quantity by its acquisition price:

$$Ci = Qi \times Pi \tag{1}$$

where C is cost, Q is quantity, and P is the price of input i.

To assess the profitability of rice production, the following formula was used:

$$NR = GR - TC \tag{2}$$

where gross revenue (GR) is the sum of proceeds from sales of F1 and R line produce per hectare. Total cost (TC) refers to the cost of production per hectare, and net return (NR) is the difference between GR and TC.

To allow comparison across countries, the costs and returns were expressed in United States dollar using the exchange rates in Table 2. For better comparison, the costs were also presented in terms of expenses required to produce a kilogram of F1 by dividing cost per hectare by clean F1 yield. The lower the cost of production per unit of output, the more cost-competitive a hybrid rice seed production system is.

Sensitivity analysis determined the responses of F1 cost and net income per kg as the seed yield improves.

Table 2. Exchange rates used in the conversion of local currencies to US$, 2013.

Country	**US$**
Philippines (PhP)	42.45
China (RMB)	6.20
India (INR)	58.60

Source: IMF, 2013

Data gathering through personal interview guided by a structured questionnaire and aided by a translator. *(Photos by JC Beltran)*

Data limitations

While data in this study provide insights about the status of hybrid rice seed production (HRSP) in selected areas in Asia, limitations should be considered in the interpretation of results. First, the findings of the study were generated from small samples and cannot be generalized to represent the whole HRSP setup in each country. Second, the generated costs and returns only reflect those of proprietary hybrids. Third, the accuracy of the gathered information is subject to the farmers' ability to recall their production practices and expenditures. Finally, the reliability of the information also highly depends on the capability of the translators to accurately interpret the responses of farmers from the local language to English. In spite of these limitations, the dataset generated by the project is the most recent source of comparable input-output data on HRSP across selected countries in Asia and can be useful for planners, policymakers, and rice researchers in these areas.

RESULTS & DISCUSSION

Farmers' profile

Table 3 summarizes the profile of hybrid seed producers in the study sites. Respondents in China were the oldest at an average age of 55, the Philippines at 50, and India at 40. Their ages can have implications on their ability to do farm work. Older farmers may tend to rely more on hired workers than their own labor.

In general, labor-intensive hybrid seed production remains to be a male-controlled occupation. All sample seed producers in China and India are male, but women (19%) in the Philippines are actively engaged. Household compositions in China and India were male-dominated; Philippines had more female household members. Interestingly, household size was largest in China with seven family members despite the country's one-child policy. This could be partly explained by the extended family nature prevalent in rural China. The Philippines had six and India had only five members. The size of the household generally affects the availability of family labor for seed production. The bigger household size in China is consistent with their use of family labor in seed production activities.

Table 3. Socioeconomic characteristics of hybrid rice seed producers in Philippines, India, and China.

Item	Davao Oriental, Philippines (n=31)	Andhra Pradesh, India (n=30)	Jiangxi, China (n=30)
Age (years)	50	40	55
Sex (% male)	81	100	100
Household size	6	5	7
Male	3	3	4
Female	4	2	3
Education (years)	10	8	9
Rice production (years engaged)	22	22	34
Hybrid production (years engaged)	6	8	26
Inbred production (years engaged)	18	1	11

Educational profile of farmers decides their relative exposure to latest technologies. They need a basic level of education to enhance their ability to derive, decode, and evaluate useful information from various knowledge products and tools that would increase their farm productivity. Filipino hybrid seed producers had an average of 10 years of formal schooling, having finished up to secondary education. Chinese and Indian farmers had only 9 and 8 years, respectively.

The number of years a farmer has spent in the rice farming business could size up his acquired practical knowledge on how to overcome certain production and adoption problems. The Chinese are the most experienced having spent 34 years in rice production, 26 years of which were into hybrid seed production. Indian and Filipino farmers had been into rice farming for 22 years, 8 and 6 years of which were respectively into hybrid seed production. In terms of inbred seed production, the Filipino farmers had the longest experience with 18 years; the Indians had a 1-year experience.

Farm characteristics

Table 4 characterizes farms in the three countries. Area devoted to hybrid rice seed production was biggest in the Philippines at 1.86 ha, India at 1.76 ha, and China at only 0.23 ha that necessitates optimizing their hybrid rice technologies. The smaller farm size in China could be attributed to increasing competition in land use among agricultural, industrial, and residential purposes because of the fast economic development of the country (Bordey *et al*., 2016).

Chinese farmers had the most accessible input and output markets, which were only 1.83 km of concrete farm-to-market road away. Hybrid rice seed areas in India are 7.23 km of asphalt and concrete roads away from markets. Some farm-to-market roads in the Philippines are made of concrete (16%) and sand and gravel (16%), 45% are dirt roads, making rural transportation quite more difficult.

Manual transplanting of parental seedlings in the Philippines.

Table 4. Characteristics of farms in the study sites.

Item	Davao Oriental, Philippines (n=31)	Andhra Pradesh, India (n=30)	Jiangxi, China (n=30)
Rice cultivated area (ha)	1.86	1.76	0.23
Distance from farm to market (km)	2.38	7.23	1.83
Major transport structure (%)			
Asphalt	6	33	0
Concrete	16	43	93
Sand and Gravel	16	3	0
Dirt road	45	7	0
Others	16	13	7
Primary source of water (%)			
State irrigation canal	100	13	70
Communal irrigation canal	0	3	13
Rivers/streams/ free-flowing sources	0	3	13
Bore/open/dug/tube wells	0	80	3
Tenure (%)			
Owned	39	100	90
Leased	3	0	0
Rented	55	0	10
Mortgaged	3	0	0

All hybrid seed producers in the Philippines obtained water from national irrigation canals. Some 70% of the Chinese relied on irrigation canals built by the government, on communal irrigation canals (13%), and on rivers, streams, and free-flowing sources (13%). Up to 80% of the Indians depended on bore, open, dug, and tube wells; on state irrigation canals (13%).

Indians owned the farms where they produced hybrid seeds; 90% of the Chinese were owner-cultivators, and 10% rented land. More than half of the Filipinos were renters, 39% were owners, and others were leaseholders and mortgaged owners.

Input uses and costs

This section describes parental seeds, fertilizers, plant protection chemicals, GA3 and other growth promoters, labor, irrigation and drainage, land, interest cost on capital, and other inputs used.

Parental seeds

Figure 3 shows parental seeds (A x R) utilization in the study sites where average seeding rates varied considerably due to the A x R planting row ratios that were adopted. Since Filipinos and Indians were contract growers of their respective seed companies, they just followed recommended seeding rates and A x R planting row ratios, which were both 12: 2; the Chinese used 18: 2. China has strong CMS lines because of their good flowering behavior and receptiveness, relative to the Philippine lines.

Seeding rate of A line was lowest in India with only 13 kg ha^{-1}; Philippines with 26 kg ; China had the highest at 28 kg , but also had the lowest seeding rate of R line with only 5 kg . India (9 kg ha^{-1}) and the Philippines (10 kg ha^{-1}) had much higher rates. Estimated seeding rates of A x R per hectare were 28 x 5 in China, 26 x 9 in the Philippines, and 13 x 10 in India.

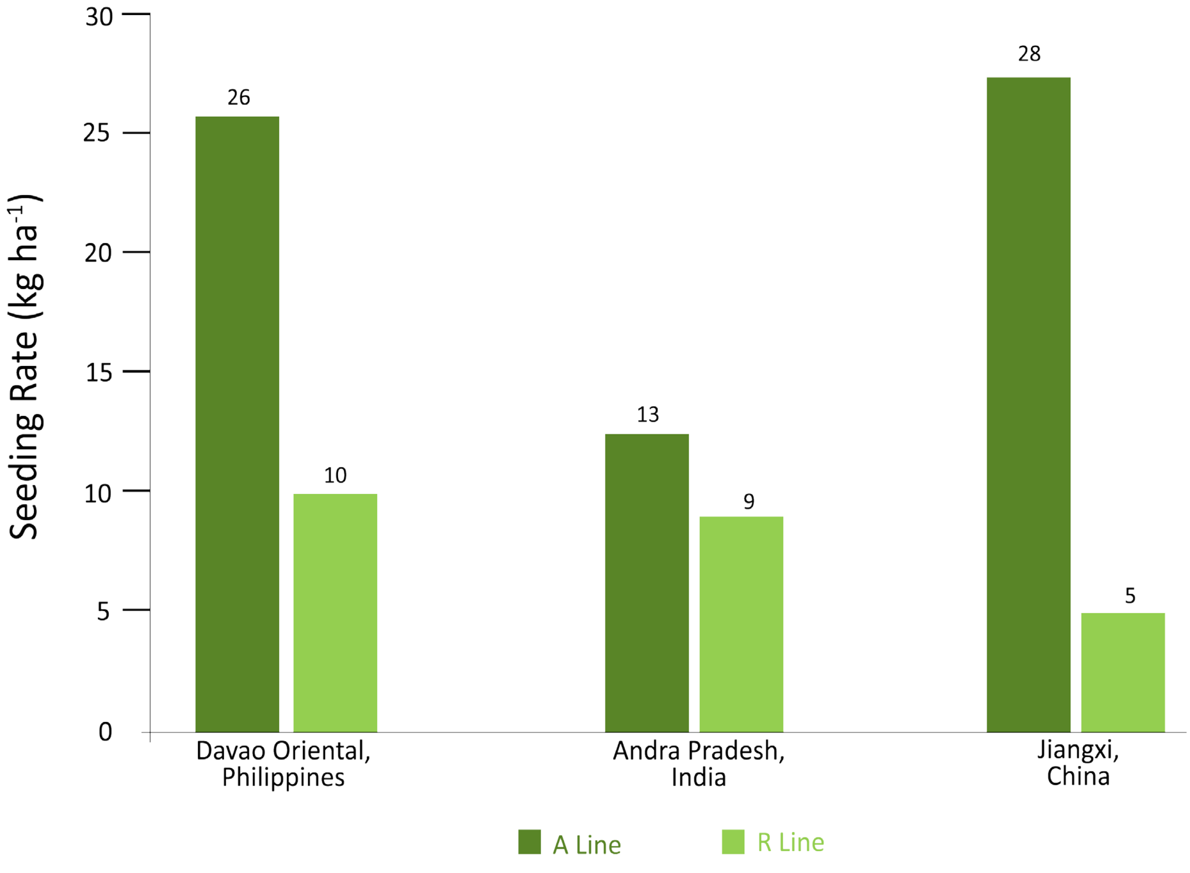

Figure 3. Seeding rates (kg ha^{-1}) of A and R Lines, by study sites.

No parental seed costs are presented here because seeds were provided "free" by the private seed companies in the Philippines and India. China's actual cost is deducted from the price of F1 seeds for comparison purposes (see Methodology).

Fertilizers

Different rates of fertilizer application in the study sites were observed (Figure 4), with China having the highest Nitrogen (N) at about 300 kg ha^{-1}; Indian seed producers at 170 kg ha^{-1}; and Filipinos at only about 142 kg ha^{-1}. The high N usage in China and India is probably due to their cheaper prices than in the Philippines (Manalili *et al.,* 2016).

Phosphorous (P) fertilizer was moderately used in all study sites (Figure 4), with the Chinese using the highest at 56 kg ha^{-1}; Filipinos the least at 16 kg ha^{-1}; the Indians at 41 kg ha^{-1}. Potassium (K) fertilizer had the same trend: 110 kg ha^{-1} for China; India at 55 kg ha^{-1}; and 40 kg ha^{-1} for the Philippines.

Seed growers applied less P and K fertilizers than N because these can be stored in the soil from one season to another, while N is mostly used by the current crop or is lost to the surrounding water and atmosphere (Moya *et al*., 2004).

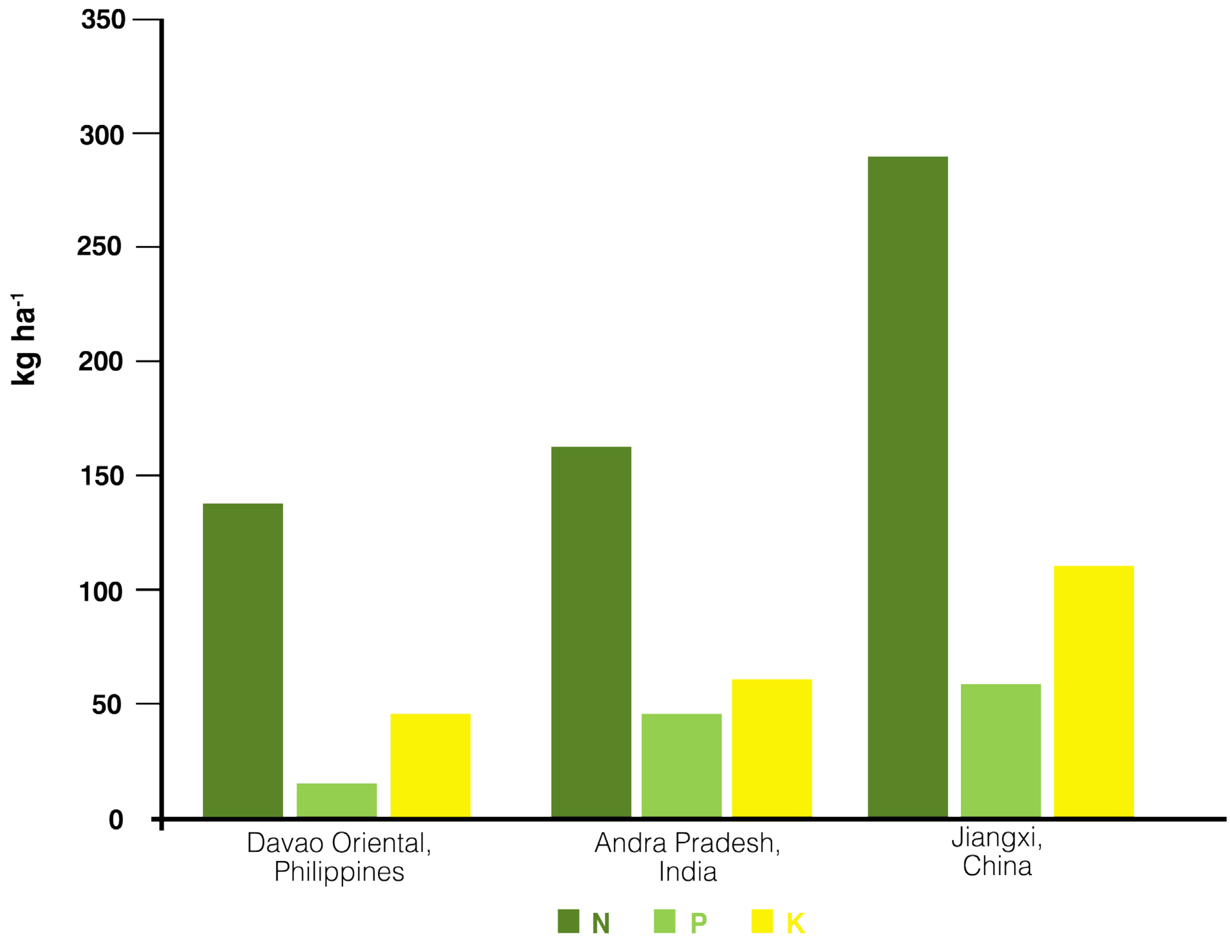

Figure 4. Fertilizer use (kg ha^{-1}), by study sites.

Since China had the highest rate of fertilizer application, it also incurred the biggest fertilizer cost at US$467 ha^{-1} (Table 5). The Philippines at US$288 ha^{-1} was still higher than India with only US$215 ha^{-1}

Table 5. Cost of hybrid seed production per hectare (US$ ha^{-1}), by study sites.

Item	**Davao Oriental, Philippines**	**Andra Pradesh, India**	**Jiangxi, China**
Seeds	*	*	*
Fertilizers	288	215	467
Pesticides	166	130	329
GA3	*	*	*
Other chemicals	10.61	0.42	0.00
Hired labor	802.13	918.71	763.46
OFE** labor	64.63	352.00	2,440.69
Power cost***	166.36	201.63	185.92
Land rent	659.99	417.22	633.15
Irrigation	52.77	2.22	15.89
Others	93.29	57.02	93.72
Total	2,302.93	2,294.00	4,958.80
Irrigation	52.77	2.22	15.89
Others	93.29	57.02	93.72
Total	**2,302.93**	**2,294.00**	**4,958.80**

**- no cost indicated as seeds were given free by the companies in the Philippines and India. For China, costs are deducted from F1 price for comparison purposes.*
*** OFE - operator, family and exchange labor*
*** Power cost - animal and machine rent*

Plant protection chemicals

All subject seed growers relied heavily on pesticides for their pest and disease problems, with the Chinese spending most at US$329 ha^{-1} (Table 5); Indians the least at US$130 ha^{-1}; Filipinos at US$166 ha^{-1}, indicating that they are not major users of chemical inputs. Studies have shown that Indian and Filipino farmers generally used less pesticides than other farmers, particularly insecticides (Rola and Pingali, 1993; Moya *et al*., 2004; Dawe 2006; Moya *et al.*, 2015; Beltran *et al*., 2016). Looking at total pesticide cost sees that seed producers in all study sites spent mostly on insecticides and herbicides.

Gibberellic acid (GA3) and other growth promoters

Gibberellic acid (GA3) was heavily used by hybrid seed growers for panicle exsertion, longer duration for stigma receptivity, increased duration of floret opening, adjusted plant height for proper pollination, and enhanced outcrossing ability of the parental lines. GA3 costs are not presented here, as the private companies provided it free in India and the Philippines. In China, seed growers paid directly for GA3 but generally got higher price of F1. To facilitate comparison, the per kg price of clean F1 seeds in China was adjusted by subtracting the cost of GA3.

The use of growth promoters in hybrid seed production was popular among Filipinos, spending US$10 ha^{-1} on average (Table 5). Only few seed growers in India used them, spending less than a dollar per ha. Not a single seed grower in China used them.

Labor

Hybrid seed production is labor-intensive. Seed growers commonly incur huge labor cost for major activities such as land preparation, crop establishment, crop care and maintenance, harvesting, threshing, and postharvest operations. These activities can be done by an operator, family members, and exchange (OFE) and hired labor.

Supplemental pollination

Table 6 shows labor utilization in hybrid seed production in the study sites. Labor input was highest in China that employed 241 labor man-days per hectare (md ha^{-1}); 221 md ha^{-1} in India; and 137 md ha^{-1} in the Philippines. In China, family labor contributed more than two-thirds of the total md per cropping season because of its small farm size and limited supply of hired labor due to high off-farm employment opportunities (Mataia *et al*., 2015). In contrast, 80% and 91% of total labor-use were respectively done by hired laborers in India and the Philippines.

Among labor components, crop care and maintenance was the most labor-intensive, requiring an average of 129 md ha^{-1} in India, 101 md ha^{-1} in China, and 58 md ha^{-1} in the Philippines (Table 6). Crop care and maintenance activities in hybrid seed production became more laborious than inbred seed production and rice farming because of the supplementary pollination and roguing to remove off-types. These activities were mostly done by OFE in China; by hired labor in India and the Philippines. Next was crop establishment, which required an average of 60 md ha^{-1} in India, 52 md ha^{-1} in China, and 38 md ha^{-1} in the Philippines (Table 6). As hybrid seed production uses manual transplanting, it requires more labor because of the separate planting of A and R parental lines. It also includes seedbed preparation, raising, pulling, and hauling seedlings into the field. The same trend on labor requirement was observed: OFE in China, and hired labor in India and the Philippines.

Harvesting and threshing hybrid seeds were also labor-intensive. On average, about 46 md ha^{-1}

Table 6. Labor requirement in hybrid seed production, by study sites.

Item	Davao Oriental, Philippines	Andra Pradesh, India	Jiangxi, China
Hired labor (md ha^{-1})	**124.5**	**174.0**	**55.4**
Land preparation	8.8	3.9	4.2
Crop establishment	37.0	58.0	15.1
Crop care and maintenance	47.6	89.2	20.4
Harvesting and threshing	29.4	20.9	11.8
Postharvest	1.8	2.0	3.9
OFE* labor (md ha^{-1})	**12.0**	**46.5**	**186**
Land preparation	0.9	2.4	11.1
Crop establishment	1.1	2.4	37.2
Crop care and maintenance	10.5	39.5	80.6
Harvesting and threshing	0.0	0.2	33.9
Postharvest	0.5	1.9	22.6
Total labor (md ha^{-1})	**137.5**	**220.5**	**240.9**
Land preparation	9.6	6.4	15.3
Crop establishment	38.1	60.4	52.4
Crop care and maintenance	58.1	128.7	101.0
Harvesting and threshing	29.4	21.1	45.8
Postharvest	2.3	4.0	26.4

** OFE - operator, family and exchange labor*

were employed in China; 21 md ha^{-1} in India; and 29 md ha^{-1} in the Philippines (Table 6). R line was manually harvested in all countries. The relatively lower labor-use in India is because of the use of combine harvester to harvest F1 seeds after harvesting the R line. Seed growers in China also used the combine harvester, but the labor that harvests the R line puts the country on top of the list of labor-intensive harvesting and threshing. In the Philippines, the axial-flow thresher is still used in threshing F1 seeds. These activities were mostly done by OFE in China; by hired labor in India and the Philippines.

High labor-use necessitates higher labor cost, which is magnified by the prevailing wage and contract rates. In-kind payments for laborers were practiced as R line harvests were commonly collected by harvesters as payment in all study sites.[1] Table 5 estimates total labor cost in hybrid seed production. China being the most labor-intensive country, incurred the highest average labor cost at US$3,204 ha^{-1}; India at US$1,271 ha^{-1}; the Philippines at US$867 ha^{-1}.

[1] This includes free cost of harvesting R-line which is lumped with the cost of harvesting F1 from the A-line. This results in overestimated cost of harvesting and threshing.

Irrigation

Irrigation cost comprises irrigation fees paid to the government and water pump rentals, inclusive of fuel used for irrigating the field and seed nursery. The Philippines had the highest cost of irrigation at US$53 ha^{-1} as farmers paid government-imposed irrigation fees (Table 5). Chinese and Indian farmers obtained water from state-owned irrigation canals free of charge. In China, their main cost of about US$16 ha^{-1} represents the minimal amount incurred for fuel and oil to pump water in the fields. In India, they used electricity instead of fuel for water pump and incurred a negligible cost of about US$2 ha^{-1}. Electricity in India is subsidized (Bordey et al., 2015). Some of the respondents used water pumps to supplement their primary sources of water. India provides free electricity for pumps that draw water from bore wells for agriculture purposes.

Land

Land cost consists of rent or, if owned, the opportunity cost of renting out the land, and taxes levied by the government. Land arrangement in China is unique in that the government has full ownership of the land. Farmers merely secure land rights through a contract with the government and exercise full control over all production decisions (Mataia *et al.*, 2015). Thus, China does not impose tax on agricultural land, and their farmers have zero costs, unlike the Philippines and India that impose a minimal tax payment scheme for agricultural land.

Land rent eats up the bigger share of land cost. Land rent here refers to the amount paid by the share tenant or lessee to a landowner for the use of land in rice production. For farmers who own their cultivated land or "mortgagers," land rent was calculated using the average rent of the share tenants or lessees. The Philippines had the highest land rent at US$660 ha^{-1} (Table 5). The growing scarcity of productive rice land suitable for hybrid seed production could be the driving force behind the high land rent in the area (Bordey *et al.*, 2013).

Land rent in China (US$633 ha^{-1}) is the second most expensive, also due largely to the increasing scarcity of productive rice land (Mataia *et al.*, 2015). This is supported by the small farm size observed in the survey area, which is less than half a hectare on average. Interview of key informants also indicated that land conversion for non-agriculture purposes is common. Crop diversification is also customary, with former rice areas now planted to fruit trees, vegetables, and ornamental plants used for landscaping.

India had the lowest cost of land at US$417 ha^{-1} as all respondents there were landowners. Cheap land rent in India could be influenced by the low rental rate for temple land used for agricultural purposes. The government of India sets a fair rent for properties that belong to religious institutions (Bordey *et al.*, 2015.)

Other inputs

The cost of other inputs covers transportation, food, and other materials such as sacks, twine, mats, and ropes. On average, this cost item was highest in the Philippines at US$64 ha^{-1} where farmers customarily feed field workers, especially during major activities such as crop establishment, crop care and maintenance, harvesting, and threshing (Launio *et al.*, 2015). China and India had smaller cost on this item because of zero food cost. China incurred more expenses on materials at US$ 24 ha^{-1}, while India spent more on transportation cost at US$21 ha^{-1}.

Clean seed yield

F1 seed yields varied considerably across study sites (Table 7). China ranked first in terms of land productivity with an average F1 seed yield of 3.12 t ha^{-1} per cropping season, a superior yield advantage of 36% over the Philippines (1.98 t ha^{-1}) and 27% over India (2.29 t ha^{-1}). The high yield in China is attributed to their advances in biotechnology that overcome the biotic or abiotic pressures, including ever-decreasing water supply and more severe drought from global warming (Li *et al.*, 2009). It is also due to the continued success of their hybrid rice program through government policies, standards, and investments in human resources and necessary infrastructure (Li *et al.*, 2009).

The Philippines had the lowest F1 seed yield, as China and India are more familiar and experienced with the technology. Nevertheless, yield performance in the Philippines increased from 700-800 kg ha^{-1} in 2002-2004 to 1200-1900 kg ha^{-1} in 2012 (Bordey *et al*., 2013), and now to almost 2000 kg ha^{-1}. For the Philippines to continue its yield growth, a more advanced seed production system is necessary. High-yielding and pest and disease-resistant hybrids are needed, coupled with seed production protocols adapted to farmers' fields.

Table 7. Clean seed yields, output prices, and returns, by study sites.

Item	Davao Oriental, Philippines	Andra Pradesh, India	Jiangxi, China
Yield			
Processed F1 Seeds (kg ha^{-1})	1,984.36	2,288.51	3,122.98
Processed R Line (kg ha^{-1})	1,773.31	2,093.42	1,816.61
Price of Output			
Price of F1 (US$ kg^{-1})	1.71	1.20	1.64
Price of R line (US$ kg^{-1})	0.42	0.19	0.40
Returns			
F1 seeds (US$ ha^{-1})	3,396.16	2,735.04	5,127.60
R line (US$ ha^{-1})	745.94	402.17	720.79
Gross revenue (US$ ha^{-1})	4,142.09	3,137.21	5,848.38
Cost of production (US$ ha^{-1})	2,302.93	2,294.00	4,958.80
Cost per unit (US$ kg^{-1})	1.16	1.00	1.59
Net returns per hectare (US$ ha^{-1})	1,839.17	843.21	889.58
Net returns from F1 seed (US$ kg^{-1})	0.55	0.19	0.05

Seed cleaning and processing

Cost of hybrid seed production

On average, China incurred the largest total hybrid seed production cost at US$4,959 ha^{-1}, hence the biggest unit cost at US$1.59 kg^{-1}, despite being the highest yielder (Table 7). The imputed cost of OFE labor constituted almost half (49%) of China's total production cost (Table 8), which asserts that farming in this country relies on family labor. Material inputs accounted for the next big item at 18%. Cost for hired labor got a 15% share from the total cost; land rent at 13%, indicating scarce but productive land.

The Philippines was in the middle in terms of total production cost with US$2,303 ha^{-1}. Despite its lowest yield of hybrid seeds, its unit cost of US$1.16 kg^{-1} was cheaper than in China and almost comparable to India. Hired labor cost and land rent are the main items that contribute to high production cost in the Philippines, while material inputs constituted 21% of total cost. If yield continuously progresses in this country, the cost of producing a kilogram of hybrid seeds will become cheaper than in other countries.

The cheapest cost of hybrid seed production was in India at US$2,294 ha^{-1}, with cost per unit estimated at US$1 kg^{-1}. Similar to the Philippines, hired labor cost, land rent, and material inputs captured the biggest share in total cost in India.

Returns to hybrid seed production

Proceeds from F1 seeds constituted the biggest share of the total returns to hybrid seed production. The price of F1 seeds varied across study sites (Table 7), highest in the Philippines at US$1.71 kg^{-1}; China at US$1.64 kg^{-1}; India at only US$1.20 kg^{-1}. Due to higher yield and price levels, China enjoyed the highest gross returns at US$5,128 ha^{-1}; Philippines at US$3,396 ha^{-1}; India had the lowest at US$2,735 ha^{-1}.

Additional returns came from the sales of R line harvests, with India producing 2.09 t ha^{-1}, China with 1.82 t ha^{-1}, and the Philippines with 1.77 t ha^{-1} (Table 7). Due to higher price of R line in the Philippines at US$0.42 kg^{-1}, it collected the highest returns at US$746 ha^{-1}; China got US$721 ha^{-1} at a price of US$0.4 kg^{-1}; India only got US$402 ha^{-1} at US$0.19 kg^{-1}. With combined proceeds from the sales of F1 seeds and R line produce, China grossed US$5,848 ha^{-1}, US$4,142 ha^{-1} for the Philippines, and US$3,137 ha^{-1} for India.

Considering the total cost of producing hybrid seeds, the Philippines garnered the highest average net income at US$1,839 ha^{-1} (Table 7). Net income from F1 seeds was US$ 0.55 kg^{-1}, owing to lower cost of production and higher price of F1 seeds. China had the highest yield but it also had the most expensive cost of production, thereby netting only US$890 ha^{-1} or a per unit net income from F1 seeds of US$0.05 kg^{-1}. The low price of F1 seeds in India resulted in its lowest net income of only US$843 ha^{-1}. However, India's net income from F1 seeds of US$0.19 kg^{-1} was higher than China's because of India's lower cost of production.

Table 8. Cost share (%) of inputs from the total cost of hybrid seed production, by study sites.

Item	Davao Oriental, Philippines	Andra Pradesh, India	Jiangxi, China
Seeds	*	*	*
Fertilizers	12.49	9.35	10.03
Pesticides	7.19	5.68	6.63
GA3	*	*	*
Other chemicals	0.46	0.02	0.00
Hired labor	34.83	40.05	15.40
OFE** labor	2.81	15.34	49.22
Power cost***	7.22	8.79	3.75
Land rent	28.66	18.19	12.77
Irrigation	2.29	0.10	0.32
Others	4.05	2.49	1.89

** - no cost indicated as seeds were given free by companies in the Philippines and India.*
For China, costs are deducted from F1 price.
*** OFE - operator, family and exchange labor*
*** Power cost - animal and machine rent*

Sensitivity of cost per kg and net income to yield changes

Sensitivity analysis determined the cost per kilogram of F1 seeds and the net income for seed growers at various yield levels (Table 9). Results showed that if the Philippines could equal the current F1 seed yield level of India at 2.29 t ha^{-1}, the production cost per kg of hybrid seeds in the Philippines would be reduced to the India level at US$1.0 kg^{-1}. Consequently, the net income of Filipino seed growers will increase from US$0.55 kg^{-1} to US$0.71 kg^{-1}. This value is higher by US$0.51 kg^{-1} relative to the current net income of Indian seed growers.

Attaining the current yield of China at 3.12 t ha^{-1}, the Philippines' cost of producing hybrid seeds would drop to just US$0.74 kg^{-1}, which would be cheaper by US$0.81 kg^{-1} than in China. At these projected yield and cost levels, the net income that Filipino seed producers could earn would be almost a dollar per kilogram. This income would be higher by US$0.78 and US$0.92 kg^{-1} than India and China, respectively.

Overall, results suggested that as yield would improve in the Philippines the cost per unit of hybrid seed production would decrease, while net income would increase. This implies that if hybrid yield would continuously improve, the country would have an advantage in terms of cost competitiveness at the farm level compared with exporting countries India and China. Hence, the Philippines needs to continue improving its competitiveness by intensifying long-term investment in R&D to look for future sources of hybrid seed yield growth.

Some of the hybrid varieties sold in the Philippines.

Table 9. Sensitivity of cost and income of F1 seeds to yield changes in the Philippines.

Yield level (kg ha^{-1})	Cost of F1 seeds (US$ kg^{-1})	Cost difference PH vs IN	Cost difference PH vs CH	Net income from F1 seeds (US$ kg^{-1})	Net income difference PH vs IN	Net income difference PH vs CH
2289*	1.01	0.00	-0.58	0.71	0.51	0.65
2500	0.92	-0.08	-0.67	0.79	0.60	0.74
3123**	0.74	-0.26	-0.85	0.97	0.78	0.92
3500	0.66	-0.34	-0.93	1.05	0.86	1.00
4000	0.58	-0.43	-1.01	1.14	0.94	1.08

Note:

PH - Philippines

IN - India

CH - China

** Current F1 seed yield of IN; ** Current F1 seed yield of CH*

At current yield, cost of hybrid seed production in the PH (US$ kg^{-1})	*1.16*
At current yield, cost of hybrid seed production in IN (US$ kg^{-1})	*1.00*
At current yield, cost of hybrid seed production in CH (US$ kg^{-1})	*1.59*
At current yield, net income of F1 seeds in the PH (US$ kg^{-1})	*0.55*
At current yield, net income of F1 seeds in IN (US$ kg^{-1})	*0.19*
At current yield, net income of F1 seeds in CH (US$ kg^{-1})	*0.05*
Price of F1 seeds in PH (US$ kg^{-1})	*1.71*

SUMMARY & IMPLICATIONS TO THE PHILIPPINES

The Philippines has lower F1 seed yield than India and China, but its costs of producing hybrid seeds per kilogram is lower than China and almost comparable to India. The Philippines will even be more cost-competitive if yield will continuously improve. Research on hybrid seed production must be continued and strengthened to increase yield. High-yielding and pest and disease-resistant parental lines/hybrids, coupled with seed production protocols adapted to farmers' fields, must be developed and identified. Research should also look for means to save labor-use in seed production like mechanized harvesting and threshing of F1 seeds.

Characteristics of parental lines, planting row ratio of A x R, fertilizer rates, including splitting and timing, application of pesticides, and water management need to be examined to benefit Filipino seed growers. The Philippines could adopt some of the practices of Chinese hybrid seed producers as follows: use of parental lines resistant to local pests and diseases; raising healthy seedlings using appropriate plant protection chemicals and early fertilizer application at the seedbed. Chinese seed producers do basal fertilizer application at 60-70% of their recommended rate one to two days before transplanting. They dry water out of their fields starting from 15-20 days after transplanting until small cracks are observed in the soil. This favors the development of only productive tillers. In addition, further training of local F1 seed growers should be conducted to enhance their knowledge, particularly in fertilizer application and water management.

Filipino seed growers likewise need to understand and evaluate their own experiences in the field. Knowledge on flowering synchronization of the parental lines and the skills acquired from trainings on flowering adjustments (in possible cases of non-synchronization) are vital in reducing the cost of GA3 application and manual labor in hybrid seed production.

Given the relative comparability of locally produced F1 seeds to imported hybrid seeds from India in terms of production cost per unit, why then is the price of hybrid seeds in the Philippines way more expensive than India? This could be partly due to differences in available total supplies of hybrid seeds in the two countries. Hence, the price of locally produced F1 seeds could be reduced if the total supply can be increased. Aside from yield improvement, expanding the area for hybrid seed production other than in Davao Oriental can help. However, this requires research on optimum characteristics of suitable location.

To further augment the seed supply, the government can encourage public-private partnership in producing seeds of publicly bred hybrid varieties. Public research institutions like PhilRice can partner with private investors to mass-produce and commercialize seeds of its hybrid varieties. It may also consider contract growing with seed cooperatives and provide them with technical support. In the end, hybrid seed importation should not be feared as long as we continuously improve the competitiveness of local hybrid seed producers.

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ISBN 9786218022201

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