



Philippine Institute for Development Studies
Surian sa mga Pag-aaral Pangkaunlaran ng Pilipinas

Rice that Filipinos Grow and Eat

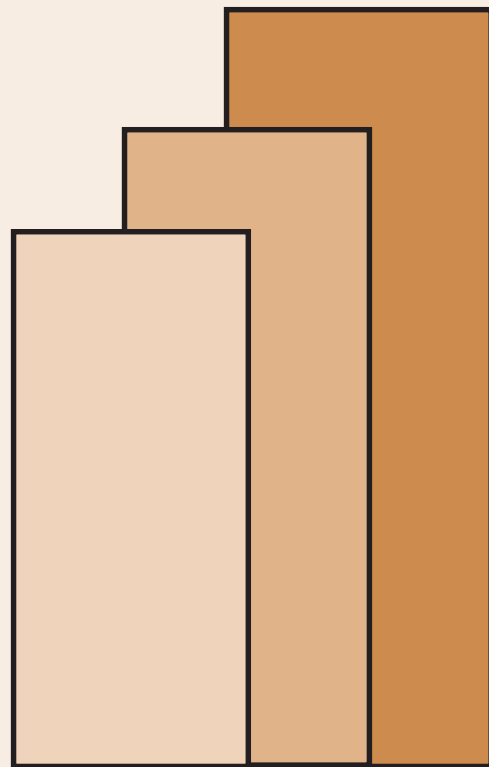
John C. de Leon

DISCUSSION PAPER SERIES NO. 2005-11

The *PIDS Discussion Paper Series* constitutes studies that are preliminary and subject to further revisions. They are being circulated in a limited number of copies only for purposes of soliciting comments and suggestions for further refinements. The studies under the *Series* are unedited and unreviewed.

The views and opinions expressed are those of the author(s) and do not necessarily reflect those of the Institute.

Not for quotation without permission from the author(s) and the Institute.



July 2005

For comments, suggestions or further inquiries please contact:

The Research Information Staff, Philippine Institute for Development Studies
3rd Floor, NEDA sa Makati Building, 106 Amorsolo Street, Legaspi Village, Makati City, Philippines
Tel Nos: 8924059 and 8935705; Fax No: 8939589; E-mail: publications@pidsnet.pids.gov.ph
Or visit our website at <http://www.pids.gov.ph>

Rice that Filipinos Grow and Eat

A discussion paper by John C. de Leon, Ph.D., for the
Rice and the Filipinos: the Last 100 Years

PhilRice
Philippine Rice Research Institute

PIDS
Philippine Institute for Development Studies

Table of Contents

| | |
|--|----|
| Abstract | 3 |
| List of Keywords | 3 |
| Rice in the Philippines (Introduction) | 4 |
| A melting pot of many fabulous varieties | 5 |
| Current varieties | 6 |
| Most popular varieties to farmers | 7 |
| IR64 and the myth of ramble varieties | 9 |
| Dramatic changes (postwar) | 9 |
| IR8 and the modern plant type era | 10 |
| Plateauing yield and some countermeasures | 11 |
| A thousand years in the making | 13 |
| Intensive land use strategy | 14 |
| Rice that we eat | 15 |
| Scented varieties and their export potential | 16 |
| Micronutrient dense rice | 18 |
| Medicine called rice | 19 |
| Future Challenges | 20 |
| Conclusion | 21 |
| Bibliography and endnotes | 22 |

Abstract

This paper introduces rice to the reader and analyzes the changes it has gone through these past 100 years in the shaping hands of varietal improvement science. Here, the richness of the crop as a genetic material and resource is revealed. Landrace rice, pureline selection rice, crossbred rice, semidwarf rice, hybrid rice, new plant type rice, designer rice - from the traditional to modern to futuristic - rice becomes all of these while traversing time in the Philippines. There is rice for the lowlands, uplands, the cool elevated; the irrigated and rainfed; the saline prone, drought prone, the flood prone - each kind serving as a wonderful display of dexterity from a tiny seed. Rice for full season farming and rice for double or relay cropping also exist. Of course, there must be rice for daily consumption and rice for important occasions. There is non-sticky rice or the glutinous opposite; well milled or brown rice; red rice; aromatic rice; micronutrient dense rice; golden rice; the generic fancy or specialty rices; even rice with healing wonders or medicinal properties. Harnessed by purposeful R&D, rice ably provides for the multiplicity of our needs. And though very much transformed already rice remains culture-friendly, like the science that does not tire molding it. Viewed in these sense, rice becomes very precious and unabandonable to many.

Keywords: Rice, Filipinos, rice as essential crop, rice as essential food, rice culture, cultivated species, varieties, varietal improvement, yield, rice sufficiency, opportunities besides high yield

Rice in the Philippines

The culture of dryland rice in the Philippines, as in the case of mainland Southeast Asia, is believed to be older than the wetland system of cultivation. Rice was originally grown under upland condition as a component of shifting and subsistence farming. Not long after, lowland rice culture began to spread along coastal areas and riverbanks.

Archaeological evidence unearthed in 1978 at the Andarayan site in Solana, Cagayan Valley suggested a dryland rice strain in use as early as 3400 ± 125 years before present (BP) in the province.¹ A previous determination of the recovered rice husk and stem fragments indicated a sample age of 3240 ± 160 BP. These extremely concordant dates are equivalent to the periods 1522 B.C. to 1077 B.C., suggesting the presence of rice in the Philippines as early as the second millennium B.C. Other records similarly indicated that rice arrived in the Philippines sometime after 1500 B.C.² The initial construction of the famous rice terraces in the Cordillera region is also believed to have taken place some 2,000 to 3,000 years ago.

The cultivated rice species in Asia and the Philippines (see Figure 1), called *Oryza sativa* Linn., is an annual grass that natural and human selection transformed to become an important food crop of the world. A wild perennial rice called *O. rufipogon* and a wild annual known as *O. nivara* were its successive progenitors following evolutionary time. Cytogenetic evidence on the close affinity between these ancestors and the annual cultivated forms of rice is well established.^{3,4} Another cultivated species of rice grown in some parts of West Africa is called *O. glaberrima* Steud. Recently, promising upland selections from numerous crosses between *O. sativa* and *O. glaberrima* varieties have been reported. This breakthrough was achieved through a multi-institutional research undertaking called NERICA or the “New Rice for Africa”. The project aimed to combine the hardiness of the local African rice species with the high-productivity of the Asian variety.⁵ There are 20 other species of rice that remain undomesticated or wild.

There is a great diversity of form within the cultivated species of rice in Asia. Each form followed a different pathway of evolution and dissemination. An extensive dispersal of this species occurred in places with tropical, subtropical, and temperate climates. The process

ultimately produced the so-called eco-geographic races of *O. sativa* - referred to as Indica, Japonica, and Javanica. Varieties grown by our farmers mostly belong to the indica classification, although some farmers purposely cultivate a few japonica varieties from Japan or Korea for the high-end consumer market. Javanica or 'bulu' type rice is still being grown in the mountain provinces of northern Philippines.

At present, more than 100,000 accessions of cultivated and wild species of rice from at least 100 countries are conserved in the Genetic Resources Center (GRC) of the International Rice Research Institute (IRRI). The GRC serves as the main "bank" for all the known rice seeds of the world, including all the genes that these different collections carry, hence the "genebank" terminology. Old varieties that have been out of circulation for a long time are kept in the GRC. The Philippine Rice Research Institute (PhilRice) maintains a duplicate collection of Philippine traditional rice varieties in its genebank facility in the Science City of Muñoz in Nueva Ecija.

A melting pot of many fabulous varieties. Despite the numerous cultivars spawned by homeland climate and preferences, rice in the Philippines is also a melting pot of many varieties from abroad. Alien variety documentation, especially of the more adapted and fabulous ones, can be gleaned from the pages of scientific and popular literatures. The University of the Philippines College of Agriculture (UPCA, established in 1909) and the Bureau of Plant Industry (BPI, created in 1930) contributed immensely in perpetuating these seeds and knowledge. Among the successful cosmopolitan varieties were Ramai from Cantho, Saigon, Vietnam, introduced to us in 1919; Kra Suey from Thailand and Malagkit Sungsong, a glutinous or sticky variety from China, both introduced in the 1920s; Peta from Indonesia and introduced in 1930; Seraup Kechil 36 and Seraup Besar 15, both from Malaysia and introduced in 1936; and Fortuna from the USA, introduced into the country after the Second World War.⁶

Of the endemic traditional varieties, on the other hand, the more popular names include Elon-elon which was already being grown in 1914; Apostol and Milagrosa in 1915; Wagwag in 1936; Buenavista or Kasungsong in 1939; and some products of cross-breeding developed from the late 1930s like Raminad Strain 3, selected from the progenies of Ramai and Inadhica cross or Ramai x Inadhica; Ramelon from Raminad x Elon-elon; Buenketan from Buenavista x

Ketan Koetok; Milketan from Milagrosa x Ketan Koetok; and Milfor from the Milketan x Fortuna cross. A few retail and grocery stores today in the cities of Muñoz and San Jose in Nueva Ecija still sell Milagrosa-and Wagwag-labeled rices regularly.

After the war, the BPI and UPCA led the effort to retrieve many prewar varieties left physically mixed in the field. Panicles of the aforementioned varieties and those from Azucena, Dinalaga, Guinangang, Khao Bai Sri, Macan I, Macan Bino, Macan Tago, Macan Sta. Rosa, Mangarez and Thailand were secured and carefully sorted in the laboratory. Foundation seeds of the following varieties were also produced: Agoyor, Binirhen, Calwis, Canoni (Red), Carreon, Carti 42, Caydaog, Criollo la Fria, Dinitaan, Dorado Agulha, Gumuyod, Inabaca, Jaguari, Kaawa, Kinanda, Kinandang Pula, Kinandang Nagpulot, Kinawayan, Lady Wright, Lubang Puti, Lubang Pula, Luteang, Magsanaya, Macapilay Pusa, Mangarez, Moratuto, Nagdami, Nira B, Palawan, Pilit Kalabao, Pinulot, Portoc, Remelletes, Rexoro, Salog, Salumpikit, Suacong, Tapukoy and Twalibon for the uplands; Cotsiam, Guinata, and Sinaba for the elevated areas; Baiang, Ballatinao, BE-3, Bengawan, Brondal Putih, Bulao, Bulastog, Concejala, Inumay, Intan, Khew Khao, Macaraniag, Macan Compol, Macaneneng, Malaman, Mas Java, Milfor 6, Nagadhan, Salak, Skrijmankote, Tjahaja and Tjere Mas for transplanted lowland.⁷

Traditional rice varieties gave low but dependable yields under minimal input and management practice. Many were tolerant to variations in water level and competed reasonably well with weeds. Some varieties were fairly resistant to insect and disease attacks, while others possessed excellent cooking and eating qualities besides being aromatic. Among the traditional varieties mentioned, Apostol, Azucena, Binirhen, Delhlinla, Elon-elon, Fortuna, Kasungsong, Macan I, Macaraniag, Magsanaya, Makapilay Pusa, Milagrosa, Milbuen, Milfor, Milketan, Palawan, Raminad Strain 3, Seraup Besar 15, and Wagwag were reported to have very good to excellent table qualities (see Figure 2).

Current varieties

The formal system of rice varietal release in the country is preceded by rigid selections done by the Rice Technical Working Group (RTWG) of the National Seed Industry Council (NSIC) through the National Cooperative Testing (NCT) project. In the NCT, test entries

nominated by different public breeding institutions and private seed companies are evaluated over several combinations of test locations and seasons for yielding ability and general agronomic performance. All test entries are compared to so-called check or standard varieties identified by the NCT. The same entries are also evaluated for resistance to major insect pests and diseases, physical and physico-chemical properties of the grain, milling potential, preference and acceptability by trained and consumer panels.

Entries with combined superiority for the different traits and parameters examined relative to the standard varieties are recommended by the RTWG to a Technical Secretariat for review and submission to the NSIC. The NSIC convenes its members as a final screening committee that will deliberate and approve the commercial release of new varieties. The history of the NCT can be traced to the cooperative undertaking initiated by the UPCA, BPI and the Bureau of Agricultural Extension (BAEX, now the Agricultural Training Institute or ATI) between 1952 and 1954 that eventually led to the establishment of the Philippine Seed Board (PSB) in 1955. The PSB was superseded by the NSIC under R.A. 7308 or the Seed Industry Development Act of 1992.

From 1991 up to 2004 the NSIC, erstwhile the PSB, approved the release of 77 varieties of rice for commercial production. Of this total, 42 varieties were intended for the irrigated lowlands, 15 for the rainfed lowlands, 6 for the uplands, 8 for the saline prone irrigated lowlands, and 6 for the cool elevated areas. Among the varieties approved for the irrigated lowland ecosystem 8 were F₁ hybrid varieties.

Most popular varieties to farmers. In 2002, the Rice Program of the Department of Agriculture conducted an informal survey to verify the top 5 varieties planted by farmers in the 79 provinces of the country.⁸ An analysis made on the dataset generated indicated that some 34 varieties of rice constituted the top 5 choices by our farmers. Interestingly, these varieties represented a mix of old and new official cultivar releases by the NSIC. IR42, the oldest of the varieties, was approved for commercial cultivation by the PSB in 1977. The other varieties were released in 1983, 1984, 1985, 1988, 1991, 1992, 1994, 1995, 1997, 1998, 2000, 2001 and 2002.

Based on this survey PSB Rc82, PSB Rc18, PSB Rc80, PSB Rc78, PSB Rc28, IR64, PSB Rc74, PSB Rc64, PSB Rc14, and IR60 were the ten most frequently grown varieties by

our farmers (Table 1). PSB Rc82 and PSB Rc18 are among the check varieties for grain yield and general performance in the NCT. On the other hand, IR64 has remained as the standard variety for grain and eating quality since 1985. IR64 replaced the well known variety C4-63G from UPCA, which was released in 1968.

Using the 34 varieties as reference and plugging in the information on variety release year, it was possible to analyze the tendency of farmers in trying out new seeds or varieties. This probing showed a 'variety replacement rate' of 3.1 years across the 15 regions surveyed with a range of 1.7 to 5.3 years. In some regions or its constituent provinces, therefore, variety replacement rate by farmers can be as fast as the rate of releasing new varieties, estimated in this case to be every 1.8 years sans IR42. In other words, the reaction of our farmers to new seed technologies can vary from immediate adoption to one that gives ample time for observation (may be related to the 'wait and see attitude') and variety diffusion.

Breeder and foundation seed production and distribution records at the PhilRice-Central Experiment Station (PhilRice-CES) until the third quarter of 2004 showed that the demand by seed growers and farmers for PSB Rc82, PSB Rc18, PSB Rc28, IR64, PSB Rc14, IR60 and IR42 has not waned. However, other varieties released in 2002 and 2003 like NSIC Rc110, NSIC Rc112, and NSIC Rc122 have also started to attract attention in the field. Seeds of these varieties, along with other cultivars, were requested by and distributed in the dry season of 2005 to members of the Rice Seed Production Network (SeedNet) situated in the provinces of at least ten different regions. For NSIC Rc122 alone, more than 800 kilos of breeder seeds were disposed by PhilRice-CES between January and September of 2004.⁹ This variety is more popularly known as 'Angelica'.

PhilRice established the SeedNet in 1994 to facilitate the seed distribution of new varieties to more farmers in the country. In the wet season of 2004, the SeedNet had 70 members located in our major islands as follows: 27 in Luzon, 21 in the Visayas, and 22 in Mindanao. On the other hand, PhilRice was created in 1985 to be the national agency to undertake and coordinate rice research in the Philippines (see Table 2). Since 1990, the institute's central experiment station in Muñoz, Nueva Ecija has completely modernized and

expanded the former Maligaya Rice Research and Training Center (MRRTC), the famous rice breeding station of the BPI, established originally as Maligaya Experiment Station in 1931.

IR64 and the myth of ramble varieties. The variety IR64 commands a premium price almost exclusively in the local rice trading scene. In 2004, Roferos, Juliano and Felix reported the result of their study comparing the grain quality of IR64 with the other commercial varieties known until 2002.¹⁰ They employed the method of cluster analysis to classify these varieties based on the head rice, physical attributes, and physico-chemical characteristics of their grains. Physico-chemical characteristics, which include moisture content, gelatinization temperature, gel consistency, amylose content, and crude protein, are known indicators of cooking quality and texture in rice.

Their findings suggested that many varieties, including several of those that our farmers prefer to grow, are very similar to IR64 in grain quality. PSB Rc78, PSB Rc18, PSB Rc80, PSB Rc54, PSB Rc64, PSB Rc14 and PSB Rc72H or Mestizo 1 hybrid (Figure 3) are among the notable examples of such varieties that rice traders and millers should be buying from farmers at a premium price as well. In other words, traders have little basis to classify these other varieties as “ramble” or inferior to IR64 in terms of their translucency, milling properties, and texture of cooked rice.¹¹ Currently in Muñoz, farmers can sell their newly harvested palay at P11.00-11.20 per kilogram. This is a welcome departure from previous prices that really make our farmers “cry”. An interesting study on the rice marketing chain and how it affects farmers’ profitability was made by Yorobe and his group in 2004.¹²

Dramatic changes (postwar)

Of the palpable elements of rice varietal changes in the Philippines these past 100 years, the most dramatic were undoubtedly those on yielding ability, plant stature, maturity duration and the weakening or elimination of photosensitivity. The utilitarian shift from tall rice varieties to semidwarf cultivars started in the mid 1960s in the country. Unlike the tall traditional varieties that were prone to lodging or toppling over, the shorter selections responded favorably in terms of harvestable yield formation to higher rates of nutrient applications, i.e. more than the

usual prewar rate of 30 kg of nitrogen fertilizer per hectare. Consequently, these were recognized as the new high yielding varieties of rice, the so-called HYVs or modern varieties.

The same HYVs were also early maturing and no longer limited by sensitivity to photoperiod. Such improvements therefore permitted the growing of more than one crop of rice per year, especially in irrigable and drainable fields, and bestowed fuller control of planting time to the farmer adopter. Modern varieties of rice particularly selected for the less favorable environments - those often stressed by salinity or brackish water intrusion; by drought due to insufficient amount of rainfall; and by low temperature spells - also started to spread in affected localities. High yielding varieties and intensified cropping therefore boosted the gross productivity of rice cultivation in many parts of the country.

In relation to lodging, the bending moment and breaking strength of the culm and sheath are normally considered in determining a variety's resistance to this problem. Bending moment increases with increments in panicle and grain weights. The breaking strength of a tiller is related to the length of lower internodes, the thickness of the culms, the tightness of the leaf sheath, and the rate of senescence of older leaves. Interestingly, prewar studies concerning this subject in rice in the Philippines missed plant height as an important attribute that affected lodging.¹³

The pleiotropic or associated effect of genes responsible for plant height on leaf length is known and the correlation is positive. Long and wide, drooping leaves in the plant canopy, typical of most traditional rice varieties (Figure 4), decrease the efficient interception of light due to mutual shading. Mutual shading at the reproductive and ripening growth stages of the rice plant can cause noticeable reductions in the number of spikelets developed and filled. This somewhat mimics the observation of decreased number of grains in rice plants during the rainy or wet season cropping, when overcast clouds "shade" the crop from the incident solar energy, thereby lowering the crop's production of dry matter and grain yield.

From the establishment of the insular Bureau of Agriculture in 1901 until World War II broke out in 1941, our farmers were able to choose from the following general types of rice varieties: traditional endemic, traditional introduced, strains selected from endemic varieties, strains selected from introduced varieties, and improved, uniform selections following

hybridization. Many prewar varieties were still released by the PSB for the cultivation of our farmers until the late 1960's. Regarding the use of rice hybridization for varietal improvement in the Philippines, the one reported by Torres and Borja in 1920 at the defunct Alabang Experiment Station is among the pioneering works on record.¹⁴

IR8 and the modern plant type era. The first semidwarf variety of rice that became well known to Filipino farmers was formally released by the PSB in 1968. The pedigree line IR8-288-3 was simply called IR8 following the designation given by the International Rice Research Institute (IRRI) in 1966 to cross number IR8 made by its breeders in 1962. (Plant breeders at IRRI achieved another milestone in 2002 by completing and designating cross number IR80000). IR8 came about by crossing the tall local variety Peta and the short-statured variety Dee-geo-woo-gen (DGWG), an early maturing semidwarf indica from Taiwan. Taiwanese farmers have known the variety DGWG since 1939.

Considering that plant breeding in practice is also propelled by artistic imagination, the creative stroke behind IR8 may be drawn from the thinking that IR8 is actually the tall but high yielding Peta variety made smaller.¹⁵ IR8 is considered as the first high yielding and semidwarf indica rice variety adapted to tropical climates. It “initiated the era of modern plant type for irrigated rice”. Tests at IRRI showed this variety yielding 6 t/ha in the wet season and up to 9 t/ha in the dry season. Its yield occasionally exceeded 10 t/ha during the dry season.¹⁶

IR8's novel plant type, positive reaction to fertilization, and ability to produce high economic yield without lodging made it attractive to plant breeders. Consequently, this variety and other selections derived from it were extensively used as parent materials in the breeding programs of the BPI, UPLB and PhilRice in addition to IRRI. For example, a published study in 1995 showed that 92% of all the 67 official varieties released in the Philippines from 1960 to 1994 were related directly to IR8 as one of their parents, or to IR8 through the variety Peta as a common ancestor.¹⁷ This study revealed that about 57 common donor parents, the sources of important genes for successful adaptation, acceptable agronomic performance, and plant features, made these particular varieties developed by the different breeding programs in the country related. At the core of this consanguineous ancestry were 19 landraces that provided the basic template - the “genetic design” to breed these varieties.

Plateauing yield and some countermeasures. The yield potential of inbred cultivars that succeeded IR8 have not significantly departed from the 6-9 t/ha level originally demonstrated by this variety (Figure 5). The high genotypic and morphological similarity of these varieties to the IR8 ancestry may be the fundamental cause of “plateauing yields”. In this regard, the implementation of alternative strategies in breeding new rice varieties can be appreciated. They are important countermeasures to break what seemed like a “yield barrier” that has developed in the last two decades. These alternative ideas currently include the exploitation of the phenomenon of heterosis through hybrid rice breeding and the development of a new plant type (NPT) of rice.

NPT will bolster the productive capacity of rice for direct seeding and rainfed culture through plants with very different architecture from the IR8 idiomorph and the so-called “Green Revolution” varieties. Contrasted to existing HYVs, NPT rice has fewer number of tillers, but all its tillers are productive or panicle bearing. In addition, tillers of NPT rice are bigger and more robust since NPT plants also produce bigger panicles that are more densely packed with grains (Figure 6). Experiments and simulation tests using the NPT model indicated a yield potential improvement of about 25% over the typical semidwarf varieties.

Heterosis in rice has been locally reported as early as 1938.¹⁸ The “5th invention,” as one noted writer perceives hybrid rice to be (and in the mold of the great Chinese tradition of inventing, like the gunpowder; paper; printing; and compass), is indeed an idea whose time for productive use by the Filipino farmer has finally come.¹⁹ In 1981, the success of the development and extension of indica hybrid rice was ranked as one of the most important achievements in science and technology of China.²⁰ Hybrid rice technology was developed in China in 1974 following the initiation of concerted research on hybrid rice in 1964.

Reports of more than 10 t/ha yields (about 200 cavans of threshed palay per hectare) from farmer cultivation of hybrid rice in the Philippines are now being repeatedly heard. In fact, a report from the field that came in as of this writing indicated that a farmer in Brgy. Tondod, San Jose City, Nueva Ecija, has already breached the 300 cavans per hectare mark with the hybrid varieties he planted.²¹ The highest hybrid rice yield recorded so far in the country stands at 258 cavans of dried weight palay from one hectare. On the other hand, trials of NPT rice in

China have also reportedly hit the 12 t/ha target. In the Philippines, however, no NPT variety has so far been released. Promising NPT prototypes were first harvested at IRRI in 1994.

A thousand years in the making. The historical development of high yielding rice varieties of the present kind spans more than a thousand years already if its scattered “parts” are finally pieced together like a jigsaw puzzle. Current HYVs could be associated with the early maturing varieties called *Champa* that were popular to Vietnamese and Chinese farmers even before 1000 A.D. In East Asia, particularly in Japan, the selection of high yielding, fertilizer responsive varieties, though generally not of the semidwarf type yet, began in the 1800’s with the introduction of fertilizers. The earliest known semidwarf rice was recorded in 1871 in Taiwan. It was called Woo-gen. In the Philippines, dwarf plants of rice resulting from mutation experiments were reported in 1959 and 1960. The breeding of day-length and temperature-insensitive japonica rices also started in Taiwan in the early 1920s (see Table 3). Rice as our Asian heritage becomes obvious even in this aspect of rice’s technocomplexity.²²

Progress attained in improving the yield performance of our varieties from the early 1900’s up to the present can be shown to be in the vicinity of a fourfold increase in average productivity. Average yields increased from about 15 cavans/ha in the early 1900s to 17 cavans/ha in 1920; 22 cavans/ha in 1940; 24 cavans/ha in 1960; 41 cavans/ha in 1980; and 59 cavans/ha in 2000. The FAO reported that the average yield of rice grown in the Philippines and in its neighboring countries until 1958 was only around 1.4 t/ha or about 28 cavans/ha.

The growth of rice production in the Philippines can be attributed chronologically to the following developments: opening of new rice lands; cultivation of varieties with higher grain yields; use of high yielding and early maturing varieties that promote rice double cropping; and expansion of rice areas with reliable irrigation and drainage. The dramatic increments in yield after the 1960’s onward have been well attributed to the increase in area planted to semidwarf varieties or HYVs.

In 1970, the area harvested for rice in the Philippines was 3.1 million hectares. About 1.5 million hectares of this were planted to modern varieties. The national output from rice cultivation that year reached 5.32 million metric tons. In 2003, the rice area harvested, modern variety coverage, and aggregate production reached 4.06 million hectares, 3.7 million hectares

(91%), and 14.2 million tons, respectively. Comparing with the 1970 data, the total harvestable area for rice, area planted to modern varieties, and overall production had increased by 30.9%, 146.6% and 166.9%, respectively.²³

The shift in strategy from one which is land frontier based to another that emphasized high yielding varieties became necessary when competition for human settlement spaces in lands considered as agricultural intensified in the country. The closing out of the land frontier became apparent after 1960 in the Philippines. Today, it is not only to human settlements that the cultivation of rice must give room to. Rice lands in the countryside are slowly being cemented or concretized. These are being planted to a variety of commercial business establishments instead, which increase the pressure on the rice R&D sector to produce more rice from a shrinking rice land that must be carefully nourished and sustained.

Intensive land use strategy. Unlike our experience in the Philippines, other countries pursued from the beginning the strategy of intensive land use to induce growth in the production of rice and other crops. The wide adoption of early maturing rice varieties promoted multiple cropping in the same piece of land, which was consistent with the overall policy of cultivating the arable lands intensively. In the country, a reference to locally grown varieties that reached maturity in only three months dates back to 1893.²⁴ Late maturing varieties face the danger of yield loss when the seasonal rainfall ceases as early as September or October. Rice is traditionally a wet season crop in the Philippines. It is normally grown starting in June and is typically harvested in late November or December, when rainwater in the fields start to recede. Short duration varieties increase the chance of escaping such drought problem, especially in rain-dependent ecosystems.

In the past, however, farmers tended to believe that early maturing varieties do not produce as much yield as the late maturing ones. Umali and Tepora showed in 1955 that early maturing rice types could outyield late maturing varieties.²⁵ Early varieties were those that matured in 100-150 days after sowing based on the 1914 classification by Crisostomo.²⁶ Nowadays, early maturity implies growth duration of up to 115 days from sowing date.

Modern HYVs of rice are attractive because many possess the combined traits of earliness and non-sensitivity to photoperiod. Improvement made on the latter trait prevents the

occurrence of yield penalties on the crop due to untimely planting. If flowering occurs before the sensitive variety has accumulated adequate carbohydrates, then grain yield may be reduced. Conversely, if flowering is delayed due to early planting, then the sensitive crop will be exposed to biotic and abiotic hazards in the field, thereby destabilizing its expected yield.

Rice that we eat

The presence of rice defines the seriousness of a given meal in the Philippines. This is the psychology behind our resilience to produce rice sufficiently every year. Rice as food contributes to the correlation of taste, cooking, and material culture of the various ethnic groups in the country.²⁷ As one historian vividly pointed out, rice is the balancer of taste in the Filipino meal. It is a bland background for the main dish.²⁸ For table rice, Filipinos prefer the type that is long grain, translucent, white, well milled, high in head rice, aromatic, and soft on cooking.²⁹ Rice for normal consumption is simply boiled till it is cooked dry and fluffy. Fried rice is often resorted to and is equally satisfying, especially if prepared from rice that does not harden upon cooling, storage, and reheating.

Studies on the physico-chemical properties of Philippine rice varieties as well as the sensory properties of their raw and cooked forms suggested that breeding for milled rice quality should target intermediate amylose content (AC) of 20% to 25% and intermediate gelatinization temperature (GT) of 70°C to 74°C.³⁰ AC refers to the linear fraction composition of starch, in contrast to the branched fraction called amylopectin. AC of non-waxy rice ranges from a low of 5-12% to a high of 25-33% based on a dry milled sample and measured by iodine colorimetry. On the other hand, GT is the temperature at which more than 90% of the starch in the grain has irreversibly swollen in hot water. This temperature ranges from 55°C to 80°C. The increase in hardness of cooked rice during storage has been attributed to amylopectin staling. Regardless of AC, lower GT cooked rice showed less staling (and therefore more suitable for fried rice preparation) than the intermediate and high GT cooked rice.

Traditional rice varieties like Peta and Wagwag have been analyzed with high AC and intermediate GT. This quality of high AC-intermediate GT combination produces rice that is soft

upon cooking. On the other hand, IR8 and other early semidwarf rices were analyzed with high AC also but low GT. The resulting cooked rice from this high AC-low GT combination is hard.³¹

Most rice in the market now belongs to the intermediate AC classification to satisfy the dominant consumer preference for soft textured cooked rice. Rice that is “more filling” (high AC) is still available, however, in many retail stores and supermarkets. For waxy or glutinous rice (1-2% AC), pure opaque grains with low GT are the preferred grain characteristics because of the tendency of cooked high GT waxy rice to harden fast.³² Glutinous or sticky rices of either the white or brownish varieties are utilized in preparing native rice cakes and sweets. Incidentally, the allele genealogy of the waxy gene controlling the glutinous endosperm appearance indicated a probable Southeast Asian origin.³³

In evaluating the quality of glutinous rice, Malagkit Sungsong remains as the standard variety for comparison. Malagkit Sungsong or its improved plant version is still being grown today. Among the numerous HYVs made available to our farmers, IR29, UPL Ri-1, BPI Ri-1, BPI Ri-3, IR65, NSIC Rc13 (Malagkit 1), NSIC Rc15 (Malagkit 2), and NSIC Rc17 (Malagkit 3) have been released as glutinous varieties until 2004. The three new NSIC varieties were found superior to the check variety IR65, which was released in 1985.

Scented varieties and their export potential. Historically, rice is not an export crop of the Philippines, although reports that describe the prior abundance of rice in our islands and the export of its excess to China (c.1842) or of local varieties to Sevilla, Spain (c.1855) could be found.³⁴ Sugar cane, coconut, tobacco, and abaca became major export crops while “rice had to be imported in large quantities every year.”³⁵ In contrast, India, Thailand, and Vietnam have developed export-winners from their rice - which they anchored essentially on the scent trait and its strong expression in the grain. The FAO forecast in 2003 showed that prices continued on a steady upward trend for the aromatic rice market.

Published accounts on Philippine aromatic varieties of rice are scanty. Aromatic or fragrant rice belong to the so-called specialty type rices that can be sold at more expensive prices in the market. Usually, the aroma of such varieties is better recognized when the grain is boiled. Guinata and Kinandang Pula have been reported to be scented or aromatic. Other

traditional varieties described in passing to be aromatic are Azucena, Binicol, Milagrosa, Milfor 6, Mimis, and Sinampablo.

In cooking non-aromatic varieties, aroma is commonly introduced before steaming is done using a few leaves of the *pandan* (screw pine) plant, which also acts as a flavor enhancer. The presence of the major aroma compound 2-acetyl-1-pyrroline (AcPy) in 18 Philippine rice germplasm accessions³⁶ that represented 12 traditional varieties (see Table 4) was confirmed in a study conducted in 2004. The laboratory analysis made utilized the GC-MS technique. The aroma compound concentration in these traditional varieties exceeded the AcPy concentration in the aroma standard variety Burdagol by up to 150% (Figure 7). Compared to the renowned KDML105 (Jasmine) rice of Thailand, however, the 18 accessions analyzed had lower AcPy concentrations, less than 50% of the Thai variety aroma in general.³⁷ IR841 is another improved rice selection recognized locally for its aroma.

AcPy is the primary odorant in popcorn and has also been associated with the potent pandan smell.^{38, 39, 40} Several methods have been developed to quantitatively analyze AcPy formation during cooking and in discriminating the potency of this flavor/odor compound in different varieties. Using a combination of techniques, it has been shown that the concentration of AcPy is higher in brown rice than in milled rice. Moreover, the concentration of AcPy appears to be higher still in the husk or hull and shoot.⁴¹ In addition to aromatic rice, waxy varieties and the red and black varieties or colored rices (which have more protein, crude fiber, lysine, vitamin B1, and other minerals) also belong to the so-called specialty rices. Specific varieties used for rice wine and wild rices like *Zizania aquatica* are considered as specialty rices as well - clearly distinguished by a substantial price difference in the rice market.

At present, the aggregate area under aromatic rice cultivation in the country is uncertain. Extensive information on the status of research and development on specialty rices around the world has been compiled by the FAO in 2001.⁴² No report from the Philippines was included in this very important publication. But by training our sight on exportable rice, we realize that excess rice from HYV cultivation is not our only hope. Aromatic rices exist among the modern inbreds, hybrids, and traditional varieties of the Philippines. Some of these only require valuation for market competitiveness. A comprehensive rice program should be able to assess

the potential of this genetic resource and formulate a strategic plan for its integration to mainstream research, production, and commercialization.

Micronutrient dense rice. The nutritional value of rice is mainly determined by the protein content and micronutrients left in the grain after it is milled. The heritability of protein content in rice varieties is generally low and environmental factors significantly affect this character. The demonstration of considerable genetic variation for iron (Fe) and zinc (Zn) content in brown rice samples suggested that conventional plant breeding approaches could be used to improve the amount of these micronutrients (empirical results show doubling) in the rice grain.

Increasing further the Fe content of rice through conventional breeding appears to be more feasible compared to the experience with vitamin A. The reason for this is the discovery of the naturally existing high-Fe rice and aromatic line IR68144-3B-2-2-3 selected by plant breeders at IRRI from the cross of IR72 x Zawa Bonday. The brown rice grain of IR68144 has a reported iron concentration of about 21 mg/kg. This line can be certainly used to expand the strategy of food-based improvement of human nutrition, especially in high-risk communities or countries. An interesting clue that led to its discovery was that aromatic varieties like Jalmagna, Zuchem, and Xua Bue Nuo consistently exhibited higher grain Fe concentrations than non-aromatic materials.⁴³

Existing information suggest that rice does not contain any vitamin A, C or D. In the endosperm of rice, for example, the precursor of vitamin A (retinol) called β -carotene is not naturally present. This inherent limitation in the nutritional value of rice was the basis for a seven-year genetic engineering research that introduced to the world in 1999 the prototype of a β -carotene-producing japonica rice. This was dubbed as the "golden rice" (see Figure 8). The development of the prototype golden rice as potential donor for pro-vitamin A biosynthesis in the rice plant system is truly important for achieving future breakthroughs. The usual cross breeding approach followed by rigid selection can now be utilized to transfer this important trait to popular commercial rice varieties. Historically, developing countries solved the vitamin A deficiency problem through periodic dosing, education on food selection, and food fortification.⁴⁴

Medicine called rice. Philippine flora is medically enriching. At least 1,500 of the 13,000 plus plant species are medicinal plants. A little over 800 of these have already been described in a book. However, only around 120 have been validated for safety and efficacy, while only 5 species have found business applications.⁴⁵ (These are the untapped potentials of our genetic resources). You may not believe it, but the very crop and grain we so causally eat has also been cited for its healing properties. There are claims of medicinal varieties of rice.

Though slow in being thoroughly proven scientifically, rice is believed to have components with medicinal properties that play a key role in health maintenance and the prevention of diseases. We are already familiar with the rice bran-derived B vitamin called tiki-tiki. We take it to prevent or cure beri-beri. A more sophisticated product called stabilized rice bran has been found to have promising uses against diabetes, arthritis, peripheral neuropathy, high cholesterol, liver abnormalities and cardiovascular disease.⁴⁶ It is considered that many of these chronic conditions have their indirect origins from oxidative damage.

Rice bran is better known as a milling fraction in the rice polishing process. But rice bran in the health and medical research realms enjoys close association with anti-oxidants, phytonutrients, nutraceuticals, and food supplements. IP6 (inositol hexaphosphate or phytate), the major form of phosphorylated inositol, a water-soluble alcohol often grouped with vitamins present in foods, is another rice-based product drawing much attention in biomedical researches for its disease prevention contributions like in kidney stone formation, cholesterol deposition, even anti-cancer actions, among others. It occurs at 9.5-14.5% by weight of the rice bran.⁴⁷

In one place in India, over 50 rice varieties are reportedly known for their medicinal properties. Particular varieties are given to women after delivery to make them strong again in a very short period. A different variety is recommended for lactating mothers. There is even a variety that is best given to a cow and mixed with other seeds after parturition or calving.^{48, 49, 50} In the Philippines, the variety Annanaya is believed to have extra-energizing effect on the body, while the variety Minaangan is considered useful in easing-up ulcer problems and dizziness.⁵¹ The existence of rice varieties believed to possess striking medicinal properties is an engaging

information worth verifying, exploring, and opening our rice research and development activities to if necessary.

Future challenges

At least 90% of all rice production and consumption in the world continues to take place in Asia. This foretells that the breeding of new varieties of rice shall pre-occupy many more generations of plant breeders and researchers from countries in this part of the world, including the Philippines. This endeavor will continue to challenge the technical skills and creative faculties of those who will be involved. Variety development will only end when rice breeders and farmers who retire are not properly replaced. It will also cease in the Philippines when the essentiality of rice in the Filipinos' idea of a meal drastically changes or simply fades away.

The challenges related to yield remain manifold, considering the following. Between the years 1901 to 1970, rice was sufficiently produced in the Philippines only in 1953 and 1968. Here we can find another “tragic contradiction”⁵² - the ironies of history that one could probably call. For the very year the Bureau of Agriculture was created (it was insular), the Philippine Islands imported some 170,648 metric tons of rice worth 10.217 million pesos. As per record, the total volume of rice hauled annually into the country up to 1923 reached 3,753,049 metric tons with a combined value of 280.761 million pesos.^{53, 54} And over the twenty years that followed, i.e. from 1971 to 1990, the import-export scene was something like thirteen years of milled rice importation to seven years of limited rice exports - realized from 1978 through 1984 and again in 1987. The volume of rice we exported from these surplus years ranged from 10,000 to 236,000 metric tons.⁵⁵ Instances of disastrous cropping years also took their toll in our production front - as in the 1971, 1972 and 1973 lashings of our fields by typhoons, floods, drought, and tungro disease. Quite understandably, this period had been described as “a century of very low productivity levels and of recurring shortages, importations, and annual crises.”⁵⁶

One challenge we must face, thus, is that of repeated realization of yield potential of existing varieties in as many farmers' fields as possible. Varieties can be in the form of the modern inbred HYVs or the F₁ hybrids, which are starting to increase in number. In less

productive provinces or regions, the attainment of the yield potential of these varieties may not be possible due to several factors including the inherent limitation of the soil. But it may be more reasonable to expect an improvement over prevailing yields in such places through the widespread adoption of the most appropriate HYVs, including those for rainfed, upland and adverse environments that clearly show superiority in yielding ability. Ultimately, the increased productivity in the customarily low yielding localities will contribute in upping the baseline yield and average rice yield of the country.

Another challenge is to sustain the current yield potential under conditions of reduced water regimes in many farms. Water availability in the irrigated fields is increasingly becoming difficult to guarantee even on a seasonal basis in many provinces. The success of current HYVS is partly attributed to the expansion of areas with improved irrigation and drainage facilities. Thus, varieties that cannot perform well under upland-like management of irrigated lowland fields in the future may be eliminated, and the breeding of so-called aerobic rices may be expanded. Varieties with shorter growth durations also become more suitable under conditions of looming water shortages in a cropping season. In relation to this, high yielding and early maturing varieties that continue to do well under direct seeding culture will be desirable, since direct seeding can reduce further by several days the cropping duration of early maturing varieties.

The need to again raise the yield potential of upcoming varieties beyond current improvement projections for conventional inbreds, hybrids, and new plant type selections is a looming challenge. Strategic R&D must be strengthened and invested on to empirically show how much more yield can be practically added to the current potential given the local cultivation conditions, the crop management practices of our farmers, and the genetic resources available to breeders and researchers. This challenge essentially constitutes the “Malthusian dilemma”⁵⁷ whose partial solution will rely on measures that could “curb and stabilize population growth.”

The recent popularization of practices like the integrated crop management (ICM) system and the palaycheck model (an adaptation of the Australian RiceCheck) highlight the many different ingredients that will make rice farming successful - which could mean achieving the yield target for a particular farm or location. In Europe, for example, varietal choice only

appears in more than 50% of the observed ICM practices. Fertilization and plant protection are virtually more universal, appearing in 95% and 93% of the schemes, respectively. Farming measures related to soil management, tillage practices and crop rotation appear in more than half of the examples while more than one-third refer to harvest, post-harvest, and irrigation.⁵⁸

It cannot be entirely due to seeds, therefore, that the sufficiency of our rice needs will be met. But good seeds are essential to good crop production. And good rice production must be sustained because rice, our most important food item, can only be eaten if it is there.⁵⁹

Conclusion

Superior varieties of rice are important contributors to our productivity and sufficiency objectives. Area expansion, cultural management, and intensive cropping help achieve these goals given the initial input of selected varieties. The contribution of modern variety development to the higher growth rate of rice output of the country, particularly over the last 30 years, is well documented. The battle for rice sufficiency, the Filipinos' essential crop and food, is still a raging encounter to be completely won in a ricefield with a changing landscape. A dynamic system of rice varietal improvement and R&D will help us cope with such change and enable us to pursue other opportunities from rice besides high grain yield.

References and Endnotes

1. Snow B.E., R. Shutler Jr., D.E. Nelson, J.S. Vogel, and J.R. Southon. 1986. Evidence of early rice cultivation in the Philippines. *Philippine Quarterly of Culture & Society* 14:3-11.
2. Teubner, C., E. Witzigmann, T. Khoo, S.G. Schonfeldt, and K. Lampe. 1997. *The Rice Bible*. Viking Studio. pp.240.
3. Watanabe Y. 1997. Phylogeny and geographical distribution of genus *Oryza*. In T.Matsuo, Y. Futsuhara, F. Kikuchi, H. Yamaguchi (eds.) *Science of the Rice Plant Vol.3. Genetics*. Tokyo: Food and Agriculture Policy Research Center. p.37-39.
4. Chang, T.T. 1975. The origin, evolution, cultivation, dissemination, and diversification of Asian and African rices. *Euphytica* 25:425-441.
5. Tokyo International Conference on African Development-TICAD. In <http://www.ticad.net/nerica.html>.

6. Masajo T.M., J.C. de Leon, and J.E. Hernandez. 2004. Breeding: Variety Apostol to Hybrid Mestizo. In B.S. Vergara (ed.) Philippine Rice Centennial-Research and Development. PhilRice. pp.107-166.
7. Octubre, F.P. 1956. Purification of standard lowland rice varieties. In Two And A Half Decades of Public Service to Philippine Agriculture. Bureau of Plant Industry, Manila. pp. 231-238.
8. Data from this survey were obtained from Dr. Frisco M. Malabanan, the DA Rice Program Director.
9. Data, which served as basis for this information, were obtained from Engr. Ricardo F. Orge, head of the Seed Production and Health Division of PhilRice.
10. Roferos, L.T., B.O. Juliano, and A.dR. Felix. 2004. Improving Grain Quality Beyond IR64. Plenary Paper, 17th National Rice R&D Conference, PhilRice, Muñoz, Nueva Ecija.
11. Juliano, B.O., R.R. del Rosario, O.M. del Rosario, and L.T. Roferos. 2004. Rice Quality: Kanin to Kakanin. In BS Vergara (ed.) Philippine Rice Centennial, Research and Development. PhilRice. pp. 341-396.
12. Yorobe, J.M., M.M. Elauria, J.M. Cabling, G.C. Cataquiz, and A.B. Mataia. 2004. Rice Marketing in the Philippines: Performance and Policy Implications. Plenary Paper, 17th National Rice R&D Conference, PhilRice, Muñoz, Nueva Ecija.
13. *Ibid.* Masajo T.M. *et al.*
14. Torres, J.P. 1923. Some notes on rice hybridization work. Philippine Agric. Rev. 16:46-48.
15. This idea cropped up in a discussion with Mr. Hilario C. dela Cruz, former rice breeder of the MRRTC and former head of the Plant Breeding Division of PhilRice.
16. In Yoshida, Shouchi. 1981. Fundamentals of Rice Crop Science. p.216.
17. de Leon, J.C. and A.L. Carpena. 1995. Pedigree-based genetic diversity analysis of improved rice (*Oryza sativa* L.) varieties in the Philippines. Philipp.J.Crop Sci.20(1):1-12.
18. Capinpin, J.M. and K. Punyasingh. 1938. A study of varietal crosses and hybrid vigor in rice. The Philippine Agriculturist 27:255-277.
19. Hilario, Frank A. 2005. The 5th invention or, the multiplier effects of an idea whose time has come. PhilSCAT Newsletter (Jan-June): 21-22.
20. In China National Hybrid Rice Research and Development Center. 1999. Yuan Longping. p.17
21. This information was shared to me firsthand by Engr. Rogelio Malunay, the Agricultural Officer of the San Jose City, during the farmers' field day conducted last April 18, 2004.
22. I wanted to add this dimension to the "legions of commonalities" and "varied items of technocomplexes of rice," alluded to by Dr. F.H. Hornedo as our Asian heritage in his Overview (p.8) for the wonderful ARF publication Rice in the Seven Arts edited by Dr. Paul B. Zafaralla.
23. PhilRice-Bureau of Agricultural Statistics. Rice Statistics Manual (1970-2002).
24. This old reference was cited in Uichanco, I.B. 1952. A history of rice and corn improvement in the Philippines. The Philippine Agriculturist 36:283-289.
25. Umali, D.L. and J.N. Tepora. 1955. Early rice types yield more. UPCA Monthly Bull. 20:3.
26. Crisostomo, M.S.1914. Upland rice in the Philippines. The Philippine Agriculturist and Forester 3:8-10.

27. In Fernandez, Doreen G. 2002. Palayok: Philippine Food Through Time, On Site, In The Pot. Makati, Metro Manila: Bookmark.
28. In Veneracion, Jaime B. Philippine Agriculture During the Spanish Regime. Diliman, Quezon City: University of the Philippines, 2001.
29. *Ibid.* Juliano, B.O. *et al.*
30. *Ibid.*
31. *Ibid.*
32. *Ibid.*
33. Olsen, K.M. and M.D. Purugganan. 2002. Molecular evidence on the origin and evolution of glutinous rice. *Genetics* 162:941-950.
34. *Ibid.* Veneracion, J.B.
35. In Constantino, Renato. 1975. The Philippines Revisited (Pre-Spanish-1941). Vol.1. Manila.
36. Seeds of 355 traditional varieties noted down from an extensive review of literature were obtained from the GRC of IRRI through a Material Transfer Agreement under IRGC Request No. 20030901.
37. de Leon, J.C., C.DC. del Rosario, E.C. Arocena, and T. Yoshihashi. 2005. Re-discovery of several aromatic traditional varieties from the Philippines. Poster Paper, 18th National Rice R&D Conference, PhilRice, Muñoz, Nueva Ecija.
38. Buttrery, R.G. and L.C. Ling. 1982. 2-Acetyl-1-pyrroline: An important aroma component of cooked rice. *Chem. Ind. (Lond.)* pp.958-959.
39. Schieberle, P. 1991. Primary odorants in popcorn. *J. Agric. Food Chem.* 39(6):1141-1144.
40. Buttery, R.G., B.O. Juliano, and L.C. Ling. 1983. Identification of rice aroma compound 2-acetyl-1-pyrroline in Pandan leaves. *Chem. Ind. (Lond.)* p.478.
41. Yoshihashi, T., N. Huong, and N. Kabaki. 2003. Quality evaluation of Khao Dawk Mali 105, an aromatic rice variety of northeastern Thailand. JIRCAS Working Report No. 30. pp. 151-160.
42. Tran, D.V. and R.C. Chaudhary. 2001. Specialty rices of the world: a prologue. In R. Dufy (ed.) Specialty rices of the world: breeding, production and marketing. Science Publisher, Inc. FAO. pp.3-14.
43. In Gregorio, G. 2001. *Seeds of Health* 1(1):6.
44. In Murphy, P.A. 1995. FAO Consultation on Food Fortification: Technology and Quality Control.
45. In Highlights of the Seminar-Workshop on the "State of the Art of Medicinal "State of the Art of Medicinal Plant Research and Business Plant Research and Business Opportunities". UP Los Baños. 2003. <http://www.pchrd.dost.gov.ph/>
46. In Betty Kamen. *Alternative Medicine. Stabilized Rice Bran, The Perfect Polish for Your Diet.* <http://www.supergoodstuff.com/>
47. In Raxit J. Jariwalla. 2004. *Advances in Rice-Based Products with Potential Benefits to Health.* <http://www.thehormoneshop.com>
48. In Pankaj Oudhia. 2003. Research note. <http://www.botanical.com/>
49. In Meena Menon. 2003. *Rice Varieties.* <http://www.flonnet.com/>.
50. In Ulpotha Heritage Rice. 2004. <http://www.ulpotha.com/>

51. This information was sourced from T.F. Padolina of the Plant Breeding Division of PhilRice in 2004 through her personal communications with Dr. M. Cadatal and F. Buyayo.
52. I share the opinion of F. Sionil Jose in this sense. In *Rice in the Seven Arts. Ibid.*
53. In Wester, P.J. 1924. Food Plants in the Philippines. Bu.Agr.Bull. 39:155-172
54. Torres, J.P. 1956. The choice varieties of rice. In *Two and a Half Decades of Public Service to Philippine Agriculture*. Manila, Bureau of Plant Industry. pp. 215-216.
55. In PhilRice. 1992. Rice Production Technoguide (Introduction. pp.xii-xiv).
56. Castillio, G.T. 1983. The other sides to Masagana 99. In *How Participatory is Participatory Development*. Philippine Institute for Development Studies. pp.184-185.
57. In Ricardo M. Lantican. 2005. Food, population, & environment: How do we manage? Manila Bulletin 13 March.
58. de Leon, J.C. 2004. High yielding varieties and seed classes for different rice ecosystems. In ED Redoña, AP Castro, and GP Llanto (eds.) *Rice Integrated Crop Management: Towards a RiceCheck System in the Philippines*. Proceedings of the First National Workshop on Rice Integrated Crop Management. pp.36-41.
59. Modified from the 'Food and the Filipino'. In Fernandez, D.G. *Ibid.*

Other readings

- Chandler, Jr. R.F. 1979. *Rice in the Tropics: A Guide to the Development of National Programs*. Westview Press.
- Barker, R., R.W. Herdt, and B. Rose. 1985. *The Rice Economy of Asia. Resources for the Future-IRRI*.
- Dalrymple, D.G. 1986. *Development and Spread of High-Yielding Rice Varieties in Developing Countries*. US Agency for International Development.
- Huke, R.E. and E.H. Huke. 1990. *Rice: Then and Now*. IRRI.
- Vaughan, D.A. 1994. *The Wild Relatives of Rice, A Genetic Resources Handbook* . IRRI.
- Hayami, Y. and M. Kikuchi. 2000. *A Rice Village Saga, Three Decades of Green Revolution in the Philippines*. Barnes and Noble-IRRI.