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Eulito U. Bautista and Evelyn F. Javier

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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
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The Evolution of Rice Production Practices

by Eulito U. Bautista and Evelyn F. Javier
Scientist III and Senior Science Research Specialist
Philippine Rice Research Institute

[Keywords: paddy, rice production, farmers' practices, traditional varieties, Green Revolution technologies, modern varieties, direct seeding, integrated nutrient and pest management, mechanization, postharvest]

In this chapter, a summary of the evolution of major practices in rice production over the last 100 years in the country is presented. These practices essentially evolved out of the changes in the varieties introduced and planted by Filipino farmers, which have to change the manner by which production and postharvest operations have to be done in order to maximize productivity and reduce costs. Varieties were introduced in three major periods: the pre-Green Revolution era dominated mainly by traditional varieties which were planted once a year, the Green Revolution period of 1966 to 1988 which was characterized by the diffusion of modern high-yielding varieties which are planted for two seasons per year, and the post-Green Revolution period from 1989 to the present times. As varieties changed over time, farmers' practices also changed to attain maximum yield potential of the varieties as well as in response to goals of higher productivity, greater efficiency, and, for the present period, environmental sustainability.

From preparing the rice plots to rice milling, operations evolved out of the need for greater efficiency and higher productivity. Although the first period has been characterized by single rice crop per year and field operations were not necessarily done efficiently, farmers were already looking for better alternatives to conduct field tasks that were done either manually or with the use of carabaos. Much of these practices have been romanticized mainly because the social life of farmers and their communities evolved within the conduct of these tasks, often done with the assistance of relatives and neighbors. There were less inputs needed as yield from the traditional cultivars was limited by the plant itself so that labor productivity and time as well as efficiency were of less concern compared to the drudgery in the conduct of manual tasks.

The period spanning the introduction and diffusion of short-statured, non photo-sensitive and early maturing high yield varieties, coupled with the availability of irrigation water from newly constructed irrigation systems, were quite different. Demands for efficiency and time became of greater importance to attain the high yield and double crop potential of these modern varieties. Tasks which formerly were not given attention to, such as fertilizer management, chemical control, threshing and drying suddenly became important to small farmers who suddenly found themselves tillers and managers of their own land due to newly passed land reform law. Techniques and equipment to accomplish these tasks were developed or improved upon so that this period revolutionized the whole rice production system. Research on land preparation, planting, fertilizer management, pest management, harvesting and threshing as well as drying and milling were actively pursued and promoted although farmers were selective in adopting only a few of these new breakthroughs. The International Rice Research Institute led in both the development of these varieties, management practices as well as machinery to answer the needs of farmers at this time.

After the Green Revolution, concerns on costs and productivity including sustainability continued to become important as Filipino farmers struggle to sustain productivity gains over the past period while pursuing cost reduction measures as well. While neighboring farmers in Southeast Asia adopt modern practices and big machinery to attain economy of scale, our farmers continue to be selective of technologies that are efficient, inexpensive and with high potential for income generation from the neighboring fields. At this time, the Green Revolution technologies continue to be practiced while some crop care measures such as the integrated pest and nutrient management are further refined. We also see old practices becoming relevant again as the need for more efficient management of the decreasing amount of water becomes vital. Direct seeding, a rainfed area practice brought about by the early maturing varieties and the development of herbicides during the previous period, also continues to be increasingly popular due to less costs to farmers. The use of high quality seeds and the introduction of hybrid rice cultivars both from the public and private sectors are also pursued by government programs that continue to seek rice self-sufficiency levels enough to feed the increasing population of the country.

Rice production practices is expected to continue to evolve to the changing challenges and needs of the times, when both the Filipino scientists and the rice farmer will come up with innovations that seek to pursue rice self-sufficiency and global competitiveness for the Filipino farmer. Direct seeding, mechanization and integrated nutrient and pest management will continue to be refined and practiced on wider scale. As new high yielding inbred and hybrid varieties that cater to new environments and conditions are developed and introduced, farmers will continue to adapt improved methods to plant rice and to maximize their benefits from producing it. Research institutions like PhilRice, the International Rice Research Institute and other research institutions will continue to lead in developing these innovations for more productive, profitable and sustainable rice production for the country.

Chapter 2: The Evolution of Rice Production Practices

I. Introduction

Rice production practices and technologies either directly increases yield or affect production costs. The use of modern high-yielding varieties and the management of nutrients, pest and disease management, and water are technologies that directly contribute to higher yield. On one hand, farm mechanization and direct seeding do not directly affect production but significant contributes to costs coming from labor.

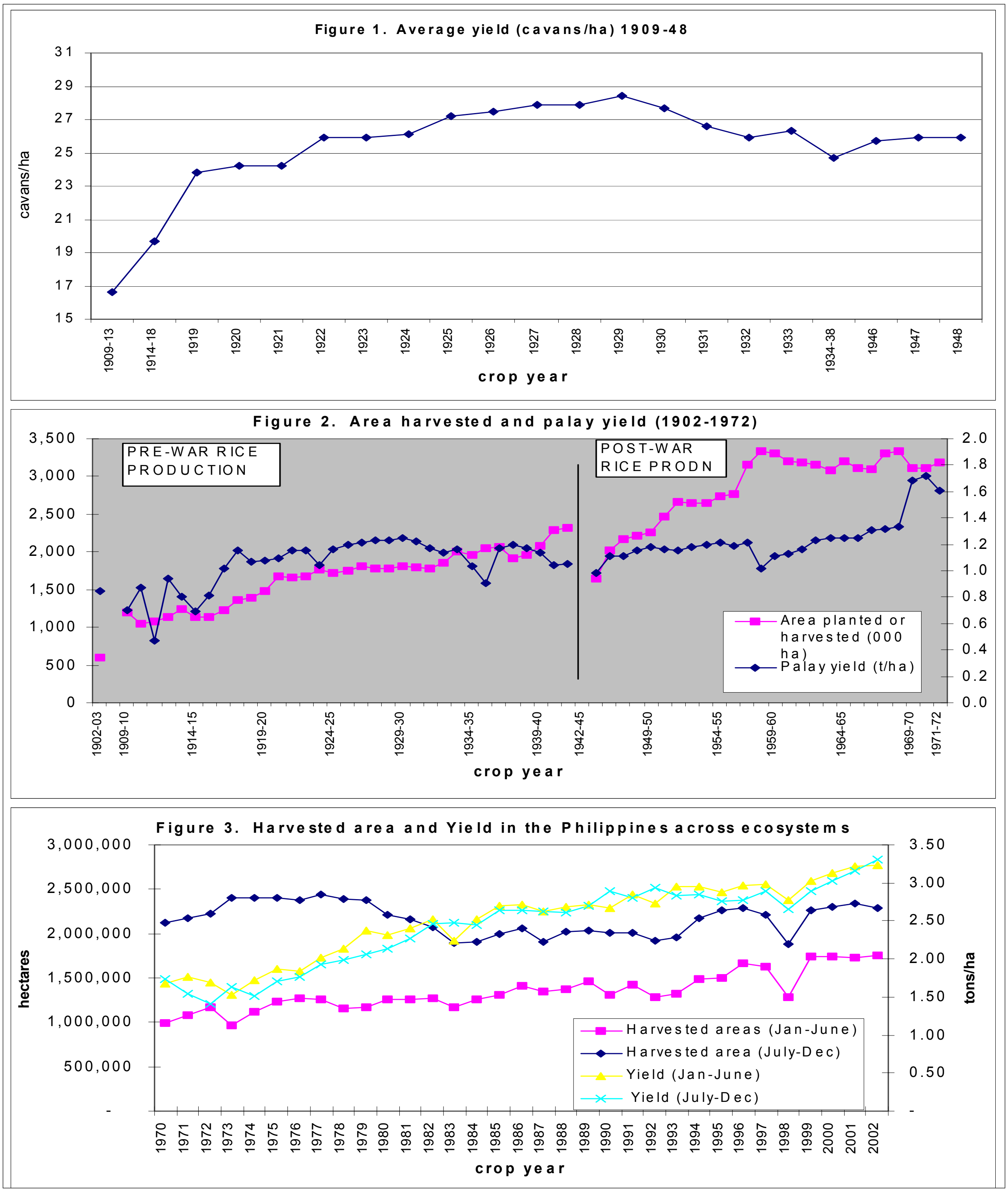
Rice production practices in the Philippines have been continually changing over time mainly due to technologies and government programs envisioned to respond to the dynamic challenges and needs of the Filipinos. The most pressing of these needs are the continuing growth of population that has to be fed with the staple food and the clamor for cost-reduction measures to make rice farming profitable to most farmers.

Over time, tremendous progress have been made in improving the yield and reducing the cost of producing rice in the countryside. Rice was being produced at 16 cav/ha in 1909 compared to the 2002 production levels of 70 cav/ha, an improvement of almost 340 times! This attainment, although still lacking to attain full self-sufficiency for the rice needs of the country, has been attributed to the technological breakthroughs in rice science and the promotion of improved technologies and practices to the Filipino farmers.

Rice production before Green Revolution

In the years before the war, rice farmers managed their rice production through their experiences and direct observations. Changes in total rice production over time involved changes in yield with relative proportion of irrigated, rainfed and upland areas, the change of seasonal harvesting pattern, and variety planted (Gonzalo, 1952). In 1909-1913, average rice production was only16 cavans per hectare. With new and superior varieties and planting of better seeds, yield increased to 24 cavans per hectare in 1919 to 28.4 cavans per hectare in 1929 and became constant up to 1948 at the level of 28.4 cavans/ha (Fig. 1, Serrano, 1952). There was no increase in yield since 1955 despite the increasing harvested areas, until it reached 28 cavans/ha (1.20t/ha) in 1966 (Fig 2). In 1968, the yield reached an average of 30 cav/ha but the highest increase was observed in 1970 at an average of 40 cav/ha (Fig 2 and 3).

The increase of rice production was also attributed to the construction of irrigation canals in 1920's and the further expansion of irrigated areas in 1946 with the construction of big dams and concrete canals. Likewise, when chemical fertilizer was introduced in 1951, coupled with better rice varieties and irrigation, production was increased to 28.3 cavans/ha or 7,273,294 cavans in fertilized 257,046 hectares of rice field compared to 25.1 cavans per hectare of unfertilized areas.



Figures 1-3. Area harvested of palay (hectares) and average palay yield (cavans or tons/ha) from 1902 to 2002 (Serrano,1952;Venegas and Ruttan,1964)

With intensive campaign for planting better varieties of rice during 1946-51, the cultivated areas increased to 3.092 M ha, 4.093M ha in 1949 and back to the original 5.07M hectares in 1950. (In 2002, the total harvested rice area is only 2.293M hectares (1.42M ha irrigated, 0.775M rainfed and 0.098M upland rice areas.)

In the early years, several schools for agriculture like the University of the Philippines College of Agriculture, Central Luzon Agricultural School and other provincial agricultural schools in the country were established in support of agriculture. Agricultural (rural) high schools were also created to boost agricultural knowledge and capabilities. Agencies related to the promotion of agricultural development were also established to cater irrigation systems, fertilizer administration, land settlements, weather, and soil conservation.

Despite these initiatives, however, the progress of the Philippine rice industry during this period was slow compared to other rice producing countries like Japan, China and Korea. Serrano (1952) attributed this to the lack of support and facilities for rice research and organizations by the Philippine government. The support given then concentrated on mechanization and price control but not for rice research. Several proposals for the development of varieties and production technologies had been forwarded to the government but any change of production techniques or management technologies was not much documented as the varietal improvement. It was assumed that as new varieties are introduced, development of production technology for these new varieties would be tackled also through intensive research and development.

Rice production in the Green Revolution period

Generally, the development and adoption of new and modern varieties seemed to have more impact to the rapid yield growth from 1965 to 1980 than to any change in the production technology. Likewise, with the advent of the Green Revolution and the scarcity of and increasing cost of labor, research and development of mechanization technologies was vigorously initiated and the adoption of mechanized farming became eminent in the rice field. Before 1967, the increase of yield was more attributed to the increase of production area (53%); after 1967, the total production was due to the yield (76.5%) apparently due to the high yielding capacity of the newly introduced varieties. With proper seeds and cultural practices improved, the yield was boosted in 1975 from 1.75 tons/ha to 3.2 t/ha yield in 2002.

Rice production during this period is considered as most progressive because of tremendous growth in crop productivity and significant changes in terms of rice production techniques and management. In this period, IRRI spearheaded in changing the landscape in rice, from the development and introduction of modern high yielding varieties to the intensive use of chemical inputs and machines to sustain high yields and double cropping system.

II. Yield enhancing technologies

Rice production in the Philippines was significantly affected by three major periods: the period of the so-called traditional varieties that characterized the years before 1960s prior to the establishment of the Los Banos-based IRRI, the period between 1960s to 1988 when IRRI and other breeding institutions introduced the co-called modern, high yielding varieties (HYVs) that are mainly for irrigated fields, and the present period when other rice ecosystems such as rainfed and fragile rice environments were recognized and given attention to.

Rice Varieties

Traditional systems. The rice production system at the early times prior to the introduction of modern varieties and technologies is characterized by single cropping per year, with yields ranging from 16 cavans in 1900-1913 to 28 cavans/ha in 1966 (Serrano, 1952). During this period, rice management is less influenced by technology or chemical inputs but only by the farmer's direct experiences and field observation.

Before the spread of modern rice varieties, Filipino farmers used to plant traditional varieties that are photoperiod sensitive. The leading varieties then include the Milagrosa (which is now one of the leading indica varieties being patronized in the US), Wagwag, Buenavista (Kasungsong) and those introduced from abroad, notably Ketan Koeteok from French Indo-China (now Vietnam), Fortuna from Formosa, Celery Sticks and others. These varieties, although resistant to most pest and diseases and have excellent eating quality, yields only 20-30 cavans per hectare, matures late at around 150 days, and grows by as much as 160 cm tall.

At that time, Milagrosa was the best quality variety but it is not a good yielder and its grains were the smallest among other varieties. Wag-wag, named by old farmers of Muñoz, Nueva Ecija from the Tagalog word "*wagwagin*" meaning to shake off, is another leading variety for almost three decades because of its superior quality and relatively good yields.

The Bureau of Plant Industry (BPI) in 1928 to 1937 successfully crossed the Ramai and the native Inadhica varieties and introduced it as Raminad Strain 3 (also known as Quezon Rice), which was dispersed for commercial cultivation before and even after World War II. BPI also came up with a set of improved varieties that includes Buenkitan (from Buenavista and Ketan Koetek), Milketan and artificial hybrids like the Milfor and Milbuen series (from Milagrosa-Formusa and Milagrosa-Buenkitan crosses).

IRRI's establishment and its "miracle rice". In 1962, the International Rice Research Institute (IRRI) was established by a group of scientists from the Rockefeller and Ford Foundations in recognition of the concern for the increasing world population and the availability of sufficient food to forestall massive starvation. The initial breeding objective of IRRI was to create a plant type that would be lodging-resistant, non-photo period sensitive, and efficient in using solar energy and fertilizer to achieve high yields. IRRI immediately started crossing Philippine-grown Indonesian variety Peta with Taiwan's semi-dwarf Dee-gee-won and came up with IR8 (International Rice-8), the first of the IRRI's modern high-yielding varieties.

IR8 was short and sturdy, tillered well, had great seedling vigor, responded very well to fertilizer, had moderate seed dormancy and a reasonable degree of resistance to tungro virus, and was essentially insensitive to photoperiod. Unfortunately, it also had a bold and chalky appearance, was subject to considerable breakage during milling, and the amylose content of its starch was so high as to cause hardening after cooking and cooling. It was also susceptible to bacterial blight and to several races of rice blast. However, it was capable of yielding as high as 273 cav/ha at shorter duration of only 125 days.

While IRRI was starting breeding new varieties, the BPI and UPCA were already making breakthroughs in rice breeding. The Rice Production Contest conducted by BPI in 1958/59-64/65 furnished clear evidence that a yield of as high as 250-300 cav/ha (11-13 tons.ha) of palay could be obtained with BPI and UPCA's varieties when combined with appropriate culture techniques. These yields were obtained in Leyte, Laguna, Albay, Iloilo, Vizcaya, Mindoro and others, and were not limited to a particular location, thus, can be regarded as showing a very high potential for rice production in the Philippines.

At the same time that IR8 is being handed out in 1-kg packs and multiplied through the Rice and Corn Production Coordinating Council, two Filipino bred varieties developed in the mid-1950s, the BPI-76 and the C4-63 were also released for multiplication and demonstration. The yield capacity of BPI-76 and C-18 is lower than IR-8 but still much higher than local varieties. BPI-76 yields as high as 150 cav/ha, has medium in height (125cm tall), matures in 120 days, responds to high N fertilization, is resistant to lodging, moderately resistant to rice blast, stem borer, and yellow dwarf virus but maybe seriously affected by bacterial blight, is non-seasonal, dormant in 4-6 weeks, its grain is slightly colored and fairly non-shattering with flinty kernel, high MR, and of very good eating quality. On one hand, C-18 yields 65-195 cav//ha, matures within 4-4.5 months from seed germination, is best suited for moderately fertilized fields, has strong seedling vigor, 110 cm tall, produces 12 productive tillers, is resistant to lodging under normal spacing, moderate resistance to common diseases and stem borers, grain is flinty and eating quality is very good. However, because of higher yield potential in farmers' fields. Filipino farmers preferred IR8.

At the time of release in 1966, IR8 was yielding as much as 10 t/ha in the dry season and 6 t/ha in the wet season at IRRI's farm in Laguna while farmers in the neighborhood were getting 2-2.5 t/ha yield from traditional rice. This outstanding yield difference has practically "legitimized itself", according to IRRI. Its performance during the first year of introduction was its "own advertisement" while increasing adaptability to different areas dispelled farmers' doubts in fully adopting the "miracle rice" together with its package of improved practices that included seedbed preparation, fertilization, spraying against pest and diseases, straight-row planting, weeding, etc.

The combination of broad exposure and a series of government policies like organized extension effort, fertilizer subsidy and support for farm gate price led to rapid adoption of IR8 and succeeding varieties from IRRI. By the third year of seed availability, more than 40% of the Philippine rice land was planted with HYVs (Fig. 15). Of this, roughly 80% was in IR8 or IR5, while only 20% was distributed among recommended varieties from UPCA and from the BPI.

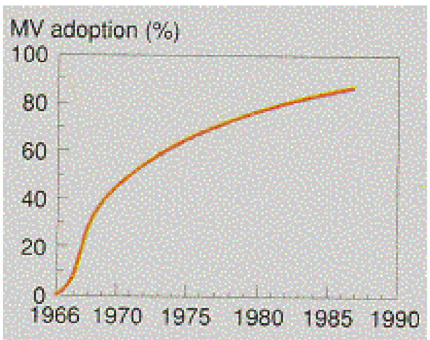


Fig. __. Adoption of HYVs in the Philippines (Huke and Huke, 1990).

Filipino-bred varieties from the Philippines, however, has found their way in other countries that were slow in adopting IR varieties. In Myanmar, the UPCA's C4-63 found its way in limited volume to farmers' fields in late 1960s. Thailand is now exporting Milagrosa in developed countries. Even traditional varieties like Dinorado, Wagwag and Buenkitan are still planted in some provinces like Nueva Vizcaya, Mindoro and Palawan while retailers in urban areas brand their rice using these varieties owing to their excellent eating qualities, a characteristic that is now given premium price by Filipino consumers.

Modern-day varieties. In 1987, the national program for rice varietal development was taken over by the newly established Philippine Rice Research Institute (PhilRice) and all local-bred lines (from IRRI, UPCA, and PhilRice) goes into a collaborative field screening at the national scale under PhilRice's leadership. Following PhilRice's establishment is the change in focus by IRRI research and development , from emphasis on favorable rice environments to ecosystems approach where other ecosystems were given attention to, such as rainfed, upland, and fragile rice areas.

Since release, however, the yield of IR8 and other HYVs have been on a declining trend mainly due to the increased insect and disease pressure to which these varieties are not resistant although IR varieties continue to be planted in massive scale in the Philippines at present. In 1987, the national program for rice varietal development was taken over by the newly established Philippine Rice Research Institute (PhilRice) and all local-bred lines (from IRRI, UPCA, and PhilRice) goes into a collaborative field screening at the national scale under PhilRice's leadership.

Enter the PSB (Philippine Seed Board) Rc and the NSIC (National Seed Industry Council) Rc series. These are varieties that came out of the collaborative undertaking among breeding institutions like IRRI, PhilRice, and partner agencies and state colleges/universities along with a few private companies also into breeding work. However, the most common rice variety planted at present is still IR-64 which was commercially released by IRRI in 1985. This variety has an average yield of 5.3 tons/ha, matures in 113 days, is 1m tall and resistant to pests and diseases except tungro. Filipino consumers have developed the taste for IR-64 so that it commands higher price from rice traders and millers than any other variety, even after newer, more disease-resistant and similarly high eating-quality varieties have been introduced later. Every year, PhilRice, UPLB and IRRI continue to release new and improved rice varieties but IR-64 remains as the most popular among Filipino farmers and consumers.

Hybrid rice. Hybrid rice has been successfully introduced in China for nearly a quarter of century now. Many Asian countries including the Philippines recently recognize the potential of hybrid rice to increase local rice production and the profitability of rice farming. A hybrid rice cultivar is a product of naturally cross-pollinating two genetically different parents with superior qualities that are passed on to the seed. This results in a phenomenon called "hybrid vigor" or "heterosis". The seed produces long roots and broad leaves that enable it to take up more nutrients and thus, produce more grains. These factors result in higher yields than ordinary rice cultivars, called inbreds. IRRI and PhilRice researchers estimate a yield increase with hybrids of at least 15% over the conventional inbred cultivars. With proper management and favorable environment, farmers can raise yields by up to 240 cavans per hectare per season or 12 tons/ha/season.

When planted, the cultivation procedure of hybrid cultivars is basically the same as inbreds; reproduction is also thru self-pollination; and the harvest (palay) looks the same as that with inbreds (i.e., not partially filled, etc.) but it cannot be used for replanting because hybrid vigor is lost resulting in lower yield and non-uniform crop stand.

At present, there are six commercial hybrids that are being promoted by the government starting 2000. PhilRice and IRRI developed three Mestizo hybrids while three private seed companies have produced their own hybrid rice varieties whose seeds are also being promoted through a government hybrid rice program being spearheaded by the Department of Agriculture. Because of aggressive government support, hybrid rice cultivation in the country is increasing, starting in 2000 with 5,000 ha to some 250,000 ha targeted in 2005-2006 to be planted in selected provinces, with targeted yield of 5.15-6.75 t/ha.

Soil and nutrient management

Traditional practices. Basically, lowland rice is best grown in easily drained heavy clay soils with not much nitrogen content while upland rice is best in loamy soils not too rich in nitrogen as high nitrogen content in the soil produce little grain and too much straw. With high N content, rice plants also become prone to lodging; this particularly occurs with tall varieties planted before as these were easily beaten by strong winds during the wet season (Camus, 1921). Thus, as early as 1920, the best rice producing areas were identified in the Central Luzon, with Nueva Ecija as the highest producing province.

Planting of rice in the early times was done only once a year thus allowing the field to fallow during the dry season. This was believed to preserve the fertility of the soils since rice could not exhaust the soil with nutrients continuously. However, farmers are aware of some cases in the past where rice was grown continuously with good yield for at least one hundred years without the use of fertilizers and this was attributed to the effect of sun and air on the soil during the dry season.

In 1910, rice was found to consume only 13 kg nitrogen, 19 kg phosphorous and 57 kg potassium per hectare; at this rate, the country produced 43.6 million kg of rice (Kelley and Thompson, 1910). Thereat, several studies were conducted on fertilizers commonly available in the farm or market, e.g. cogon and bamboo soils extracts which had acidifying effect but, when added with sodium nitrate, enhances rice growth (Villegas,1912); the use of lime in "worn-out" soils or "old" fields to increase rice yield, use of 250 to 350 petroleum boxes/ha horse manure or the use of 100-200 petroleum boxes of horse manure combined with 100-200 petroleum boxes of ashes and 100 kg of double superphosphate to the hectare (Balangue,1916); combination of ammonium sulfate-KCl-double superphosphate or horse manure+ash+double superphosphate to promote rice growth at later stages of development (Goco, 1918); the use of ammonium sulfate increased yield by 9.6x, ammonium nitrate by 6.5 x, calcium nitrate by 3x and sodium nitrate by 3.2x (Trelease, and Paulino, 1920). Other chemical or organic fertilizers were also tried like the Kainit™ (a natural mixture of KCl, MgCl, and NaCl) but were found to be more detrimental to rice when applied singly or in combination with other fertilizers (Vibar, 1926).

Studies on the use of rice straw and rice straw ash on paddy soils have been found to cause detrimental effect or “injury” to the young seedlings caused by the temporary loss of N. Addition of straw to the soil stimulated the reproduction of bacteria that use the straw as a source of C and used the nitrates as source of N. The N was lost as available plant food while the nitrates were transformed to organic nitrogenous materials after they had been utilized by the bacteria (Muray, 1921; Waksman,1924). However, soil scientists found some methods to mitigate these “injurious” effects of rice straw application to the young seedlings with the application of carbon disulfide (Collison and Conn 1922) and calcium bicarbonate; however, these did not help plant recovery from the damage (Chirikov and Shmuck, 1913). With these reasons in mind, the farmers might have opted to burn their rice straw and incorporate it later, not realizing that more potential nutrients from the rice straw are lost. (At present, inoculants have been found effective in hastening the decomposition of rice straw before incorporation into the soil. This retained and efficiently released the nutrients present in the rice straw into soil for the subsequent rice crops. Besides, proper timing of application of the rice straw could avoid the “injury” caused by the organic acids produced and the temporary immobilization of nitrogen during the decomposition *in situ*).

With the tremendous increase of the price of palay in the 1930’s, rice farmers resorted to the use of commercial fertilizer to increase production. Commonly used was ammonium sulfate and other fertilizers like the Hoz™(13-6-2), Corona™ (10-6-2), Corona Arroz™ (9-9-4), Nitrophoska™ (15-15-18), ammonium phosphate (20-20-0), or the Nin-Plus-Ultra™(17-20-0) [Calma et al, 1952]. Other fertilizers used since 1933 that are still existing to date are the Superphosphate (0-18-0) or Solophos™, and the sulfate of potash (0-0-50), the latter lately improved to give higher percentage of potassium (Muriate of Potash™, 0-0-60).

When commercial fertilizers were introduced with better rice varieties in 1950s, the production was 28.3 cav/ha in fertilized 257,046 hectares compared with 25.1 cav/ha from unfertilized areas (Galang, 1952). Because of this increase, fertilization became common in rice fields.

Crop year	Hectares	Production (cav)	Ave. yield (cav/ha)
1946-47	396,770	12,313,683	31.03
1947-48	389,397	10,926,135	28.06
1948-49	81,187	1,262,853	15.56
1949-50	131,767	3,054,826	23.18
1950-51	135,226	3,837,395	28.38

Source: FG Galang.1952. The Agricultural Extension Service. pp147-153. In: A half-century of Philippine Agriculture. BA Golden jubilee committee. Graphics house. Manila. 463 pp.

From 1933 to 1941, several fertilizer rates and fertilizer sources were tested for varieties Elon-elon and Ramil. Although fertilizer rates used were low, palay yield was increased 91% to as high as 100 cavans (Calma et al, 1952). This have encouraged farmers to use commercial forms and also organic manures such as guano, copra cake, dried lye or algae and compost with a little amount (40 kg/ha) of commercial nitrogen fertilizer (Aquino and Subido,1952).

Green Revolution soil and nutrient management package. The Philippine Masagana 99 packaged and implemented a fertilizer management that also included basal fertilizer application (Box 2; Ferre, 1986). Several studies at IRRI showed that the basal incorporation of fertilizer, done during the last harrowing and puddling prior to transplanting, is more efficient than broadcast. Adoption of the basal application, however, was very low since farmers have been traditionally applying their fertilizers several days after transplanting. However, if basal application is done, fertilizer application at two weeks after transplanting is to be employed.

The Masagana 99 Packaged Technology on Fertilizer Rate and Management

Dry season	Wet seaso
1. 4 bags 14-14-14 2 bags Urea 10-15 kg ZnSO4 (73-28-28 kg NPK/ha)	1. 4 bags 14-14-14 1 bags Urea 10-15 kg ZnSO4 (51-28-28 kg NPK/ha)
2. 3 bags 16-20-0 1 bag 21-0-0 2 bag Urea 1 bag 0-0-60 10-15 kg ZnSO4 (80-30-30 kg NPK/ha)	2. 3 bags 16-20-0 3 bag 21-0-0 1 bag Urea 1 bag 0-0-60 10-15 kg ZnSO4 (57-30-30 kg NPK/ha)
3. 1.5 bags 18-46-0 2 bags 21-0-0 2 bags Urea 1 bag 0-0-60 10-15 kg ZnSO4 (80-35-30 kg NPK/ha)	3. 1.5 bags 18-46-0 2 bags 21-0-0 1 bags Urea 1 bag 0-0-60 10-15 kg ZnSO4 (57-35-30 kg NPK/ha)

Notes:

a. Application method: 2/3 N and all P and K were incorporated during the final harrowing.
b. 1/3 N 5-7 days before panicle initiation
c. Apply ZnSo4 into the soil, in the seedbed or in the paddy field, foliar spray or dipping seedlings in ZnO
d. In the upland, no fertilizer application was done. It is suggested that 90 kg N/ha can be applied at 10, 35 and at 65 days after seeding.
e. Organic fertilizer is also recommended.

Azolla was highly recommended then in irrigated lowland rice areas but the production of azolla in some part of the country is very low due to its environmental growth specificity.

Modern soil and nutrient management. With the development of irrigation facilities and continuous supply of irrigation water to the farm, intensive rice monoculture (2-3 rice cropping systems) started to be practiced. However, rice monoculture itself contributes to the degradation of paddy resource base and hence declining productivities. The consequences of intensification on the paddy resource base vary by agro-climatic and management factors and can be observed only over the long term. Thus, despite the influx of high yielding varieties and increased on fertilizer rates, there was a declining trend of rice yield during the late 1980's (IRRI, 1998). IRRI in collaboration with PhilRice initially found out partial productivity can be increased by improving the supply of nitrogen with plant demand through dynamic adjustment of nitrogen doses with optimum amount and timing of split applications. More balanced NPK nutrition was also considered including larger potassium application.

Several diagnostic tools were subsequently developed to increase nutrient use efficiency. A practical and farmer-friendly tool is the leaf color chart (LCC) that could guide farmers when rice plants demand nitrogen supplement. This chart has several shades of green numbered from 1 to 5, with the numbers 3 and 4 signifying the need to apply N fertilizer. Another diagnostic tool is the Minus One Element Technique (MOET) to be set-up 45 days before transplanting. This is a kit where 7 sachets, each containing the necessary elements for rice except one element purposely omitted in the formulation. If the rice plants show symptoms of nutritional disorder, then that particular missing element in a sachet needs to be applied into the farmer's field following full recommended fertilizer rate. The SSNM (site-specific nutrient management) soil fertility assessment method is another practical tool to predict the amount of NPK fertilizer to be applied to a specific location or site. This is an element (NPK) omission technique done on site, with the goal of reducing the gap between the potential and nutrient limited yield.

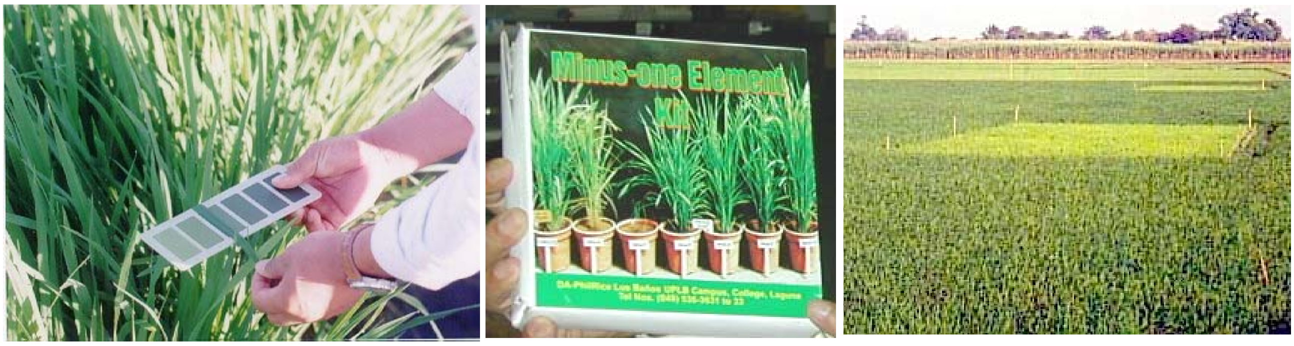


Fig. __. The nutrient-deficiency assessment methods: leaf color chart (LCC), minus-one element technique (MOET) and site-specific nutrient management technique (SSNM).

Water Management

Since 1521, rice has been documented to had been under cultivation in different parts of the Philippines. Since rice is basically an aquatic crop one needing much water for its growth and development, its cultivation took place only during the rainy season where water is plenty while leaving most of the land idle during the dry season.

To produce more rice in water-deficient areas, the government started to construct several irrigation systems. In 1840, the Spanish government started construction of irrigation systems and succeeded in irrigating 27,798 hectares during the dry season. Under the American administration, the first irrigation system in Tarlac, San Miguel Irrigation System, was built in 1913 (Camus, 1929). Subsequently, the Irrigation Act (Legislature Act No 2152) authorized construction of more irrigation systems all over the country. During that time, 16 irrigations systems were completed and distributed in 15 rice-producing provinces. Additional areas were irrigated by these systems reaching as many as 100,000 hectares. This development also prompted the rice breeders to work on varieties that can tolerate the heat during the dry season as most of the existing varieties at that time were adopted to the low heat and solar radiation during the rainy season.

Intermittent irrigation. The development of water resources directly contributed in the increase of areas devoted to rice and to rice production. However, in 1939, only 30% of the total acreage planted to rice was served with irrigation system, the remaining 70% was still totally dependent on rainfall. Out of the 30%, only few farms have sufficient supply of water to support two rice croppings per year (Alfonso and Catambay, 1948). This may have explained why most of the farmers in the irrigated areas practiced intermittent irrigation.

Surveys done in 1930 (Aragon, 1930) showed that as early as the 1920s, the practice of some of farmers in the irrigated areas of Nueva Ecija was to let the rice field dry up for 1 to 2 weeks after transplanting to encourage development of roots.

At the research farm of the Central Luzon Agricultural School, the usual practice was to saturate the soil at transplanting. Water was to be

The intermittent irrigation scheme
(Teodoro and Bataclan)

1. Soon after the seedlings are transplanted, the field is drained for a period of 2-5 days.
2. The first irrigation comes as soon as the surface shows sign of cracking from dryness. The water is admitted to a depth of 5-10 cm. This lasted for 1-2 days. Continuous and slow irrigation is done to wash the mud from the seedlings and remove any surface trash. The fields are again drained for about 3-4 days.
3. Second irrigation is 1-2 cm deeper than the first irrigation (6-12 cm). This lasts 3-5 days. This is followed by a period of drainage from 3-5 days.
4. In the third irrigation, the depth of water in the field is again increased by 2-3 cm. The field is kept drained from 3-7 days after irrigation.
5. Where the field receives 8irrigations, the depth of water applied in the 4th, 5th, and 6th is usually increased by about one centimeter over the preceeding irrigation depth. The period of irrigation is about 4 days for the 4th and the fifth. The fields are kept drained for almost the same length of time. The 6th drainage lasts for about a month and the 7th about a week. A constant depth of water (16 cm) is maintained from 3-4 weeks in the 7th and in the 8th irrigations. The fields are kept drained until the grain is harvested.

When irrigation water was perceived not sufficient, the number of irrigations was reduced to 7 or less:

6. Approx 15-16 cm of water was used for each irrigation starting on the 5th. The fields were drained for about 30-35 days in the 5th and from 6-11 in the 6th. The 6th irrigation lasted from 2 to 3 weeks, and the 7th about 4 weeks.
7. Another approach was that the farmers generally use a longer period for irrigation and for drainage from the time the seedlings are transplanted till the 3rd or 4th irrigation. The depth of water applied is gradually increased up to the 3rd irrigation and is gradually decreased to the 5th or 6th. The fields are irrigated from 10-20 days in the last irrigations and are kept drained 5-8 days longer.

re-introduced into the field a week after transplanting and maintained at 4-5 cm depth; afterwards water level is increased and maintained at 8-15 cm during the 1st to 2nd month of the rice plants and gradually increased to a maximum of 25 cm at booting stage. The last irrigation was reduced to 5-8 cm only and let dry up at ripening stage. This was practiced on lowland varieties that tolerate flooding like the *Ramai* to preventgrowth of some noxious weeds like the *Cyperus*, *spp*.

In the southern part of Luzon where water supply is sufficient, intermittent irrigationwas also employed in Calauan, Laguna, where 4-8 irrigations are made during the entire rice-growing season (Teodoro and Bataclan. 1931*) (see box 1*).

Pump introduction effect to crop establishment. In 1951, in response to the insufficiency of rice production, the Irrigation Service Unit (ISU) was launched as the pump irrigation program (Sta Iglesia and Lawas, 1959) and installed 211 pumps from 1952 to 1957 in which an organized farmer irrigation association paid the installed pumps in 10 equal annual amortizations with 6% interest. Upon introduction of water pumps, the method of planting rice also changed. Out of 216 farmers in 1954-55, 16 % were transplanting rice while 84 % were practicing hand broadcast seeding directly into the paddy field. In 1956-57, 72% had shifted to transplanting method while broadcast farmers dropped to 11% and the rest combined transplanting and direct seeding in their farms.

The combined method of planting is still observed at present mainly due to reduction of costs than any other reason. Rice transplanting is done during the wet season where risks of poor crop establishment is higher in broadcast seeding method due to unpredictable rain occurrence. Broadcast or direct seeding is done during the dry season where water is more controlled and pests and disease seldom occur during the hot summer days. Besides, more labor is required in transplanting than in the direct seeding as seed bedding and seedling pulling are eliminated while establishment time was lesser with direct seeding. It is also common in irrigated areas during the wet season for farmers nowadays to direct seed than to transplant as a result of less labor and less cost with the former method.

Water management and weeding practices. The weeding practices also changed with the manner of water management in the rice field. About ninety percent of the total rice production management was formerly devoted to weeding (92% to transplanted, 99% in direct seeded, and 97% for the combined methods). With the availability of water, weeds were controlled and labor for weeding was also reduced to 52.5% for direct seeded rice, 13.5% for transplanted rice, and 35.8% for combined methods of establishment. With the advent of the new and selective herbicides, manual weeding became supplementary to chemical control. The high labor cost of weeding was reported to have been compensated by the relatively lower price of herbicides applied in the direct seeded area.

With these improved and more efficient production management, an increase in yield of 36.4% was observed in the fully irrigated areas while 5% in partially irrigated area although yield reduction of 19.8% was observed in the non-irrigated areas (average of the 2 barangays).

Water management during the Green Revolution period. A remarkable change in rice production brought about by irrigation during this period was the second cropping of rice during the dry season. In as early as 1955-56, a second crop was already considered but was only given greater importance after 1967-68 when irrigation systems were increased and old systems were rehabilitated, coupled with the availability of non-photoperiod sensitive high yielding varieties, the 40% increase in irrigated area, large increased use of fertilizer and improved cultivation practices. However the rate of yield increase (3.6% annual rate) from 1962-71 has grown rapidly while area harvested declined. The decline was reversed only in 1967-68 when profitable possibilities of high yielding seeds along with the large expansion of irrigated areas induced increased plantings (Mears et al., 1974).

Massive investments in irrigation infrastructure in the late 1960's became essential for the success of the Green 'Revolution and for rapid growth productivity. With the construction of the Pantabangan Dam or Angat Irrigation Project in the late 1960's, rehabilitation of old irrigation canals, and the establishment of the National Irrigation Administration-Upper Pampanga River Integrated Irrigation System (NIA-UPRIIS) in the late 1970's, irrigation water became abundant in Central Luzon.

Presently, however, the increase in population, urbanization and industrialization competed with agriculture for water resources. At the same time, the supply of irrigation water started to decline due to reduced spending on irrigation infrastructure, degradation of existing infrastructure and over exploitation of groundwater resources (Pingali etal, 1997).

In 1997, the El Niño-La Niña phenomena greatly affected rice production. The National Irrigation Administration could not supply water to service areas because of scarcity or low of water supply, either due to decrease of watershed or due to the El Niño phenomena. Thus, alternative water management is being studied nowadays. The intermittent irrigation scheme being done way back in 1920's and 1930's are now re-introduced to farmers. Another technology being developed by the Los Banos-based IRRI is the aerobic rice technology (Bedder, 2003) to be adopted in the irrigated lowland rice areas. Dry seeds of suitable varieties are directly seeded in an unpuddled soil with no standing water condition and no permanent soil saturation; instead the soil is aerated or maintained below field capacity at most times. Bunds could be optional. Due to drought tolerance, selected varieties intended for upland ecosystem are tried in the irrigated lowland areas that are threatened of scarcity of water supply that can be evidently insufficient to complete the growth and development of normal irrigated rice varieties. In non-threatened areas, using the technology coupled with the intermittent irrigation scheme will reduce water use without necessarily reducing rice yield.

Crop establishment

Traditional methods. In the old times, rice is planted in four general ways: "*caiñgin*" or mountain planting; the dry planting called "upland", or "*secano*" or "*hasik*" or "*dalatan*"; the "*sabog*" (palay broadcasted on the rice paddies); and the "*tubigan*" (transplanted) [Camus, 1921].

Caiñgin, the oldest method of planting rice, was done on the slope of mountains after being cleared and burned of underbrush and trees. This is destructive and is actually prohibited. Planting this area to rice was done at the onset of rain. Holes are made in the ground with a sharpened stick and 3-10 grains are dropped in each hole and covered with soil by foot. Upland rice varieties were used in this method. The *caiñgin* method was done only in one particular area for three years or less, then left fallowed for another 3-4 years after reopening the same area for rice planting.

Secano is the non-transplanted method of planting rice in the upland areas or in a high rolling land. There were two methods of establishing rice: drilling in the seed and sowing or broadcast seeding. In the drill method, shallow furrows were made by means of a plow or *lithao* (a comb harrow-like animal drawn implement that has wide wooden teeth for making shallow furrows in cultivated dry fields). The seeds are sown by hand and then the seeded field or furrows were then harrowed with a native harrow to cover the seeds. This method made weeding easier because of the spaces made between rows. In the other method, the seeds were just broadcasted in a plowed and harrowed area without any furrows. The seeding rate use in this method was 40 gantas (70 kg) per hectare (Camus, 1929).

Sabog is a method for planting lowland rice paddies with existing dikes and was done in some areas where irrigation is not abundant. The seeds were broadcasted by hand after the area was plowed and harrowed until the soil was totally puddled. The land was prepared with as little water as possible and the seeds were sown at the rate of 35 gantas (61 kg) per hectare. Then, water is introduced in sufficient amount to allow germination of seeds and the field is maintained in submerged condition if rainfall was abundant or at just enough moisture for the entire rice growing period. The danger of this method was the insufficiency of water to maintain the crop. If rainfall occurs, that would save the plants, if not, an irrigation pump if available (this was only introduced in the early 1950's) is used to draw water from river or streams near the field. The crop is harvested before the close of the rainy season, and the fallowed area is used as pasture land for animals during the dry season until the time it is to be prepared for the next wet season.

Tubigan is the oldest planting method as this has been practiced in the rice terraces in olden times. This was also the most profitable planting method where irrigation was abundant because of the possibility of planting two rice crops per year (dry and wet cropping seasons). Paddy dikes were built and designed to hold water as the area is prepared in "muddy" or wet condition. In the wet season, once the rain started, the area was plowed once under water then harrowed thoroughly before leveling. Pre-germinated seeds at the rate of 20 to 25 gantas (35 to 44 kg) were first sown in 400 square meters of seedbed to plant a hectare and transplanted into the prepared fields when seedlings were already 30-40 days old after sowing. Transplanting was done by at least 12 hired transplanters at 40-60 centavos a day with one meal and one afternoon snack, normally speeding the movements of the transplanters by a music from a guitarist. Transplanting is usually done by women and children or solely by men depending on the region, by walking backwards in the soft mud while poking three to five seedlings at two and a half centimeters deep into the mud with their thumbs and the first two fingers, covering as much space as they can reach on either side. In Ilocos provinces, where the land is seldom thoroughly puddled, sharp-pointed wooden sticks were used to make holes into each 2 to 6 seedlings are set.

As early as 1919, transplanting rice in the lowlands during the dry season was practiced in places where there are irrigation systems. This was commonly called "*palagad*". Early maturing varieties were planted as the second crop so it can be harvested before the next or main crop. These varieties gave better yields on rainfed areas than the medium late or late maturing ones especially when there are short period of rainfalls (Bautista, 1949). In 1929, transplanted rice was found to be better than direct seeding of rice in the dry season (Camus, 1929). Farmers observed that seedlings grow faster than weeds unlike the direct-seeded rice, weeds are minimized in puddled fields (hence, weeding was lessened) and soil fertility is claimed to be better maintained.

Fig. __. Rice transplanting on bunded fields, with music from a guitar during the old days, is common in lowland areas.

With irrigation pumps, the method of planting rice rapidly changed from direct seeding to the more profitable transplanting (Sta Iglesia and Lawas, 1959), although in some areas where water is scarce, the *secano* or *sabog* method was still practiced.

Seedbed management. Earlier than 1921, there were three seedbed managements being practiced by the rice farmers. The first one was the "*punlaan*" where seeds were pre-germinated before sowing into slightly elevated beds in a well prepared plot and allowed to grow for at least 30 days before transplanting.

The second one was the "dry seedbed" method in which the area was prepared dry, not puddled nor flooded. A 1.5 meters x 10-20 meters-plot is constructed and the seeds are sown into it and harrowed lightly to cover the seeds, then watered subsequently; however the seedbed could get too dry and the soil too hard for the young seedlings to

grow and to be pulled later with minimum damage.

Fig. __. Seedling pulling at punlaan 30 days after sowing.

The third method was the "*dapog*" method in which a 1 x 15 meter-plot was constructed after the soil had been puddled, harrowed and leveled and banana leaves are laid, with the edges of the leaves towards the center of the bed, and allowed to sink about an inch deep to let mud run over the leaves. The banana leaves, aside from the thin layer of mud, are covered by thin layer of clean rice hull or finely chopped rice straw. Fifteen to 30 liters (8.8 to 17.6 kg) of pre-germinated seeds were spread into two (1x 15 sq m) seedbed plots enough to plant a hectare. Sowing was best done in the afternoon and the seedbeds are watered from time to time to avoid drying up of the seedbed. The banana leaf mate makes the roots run laterally thus intertwining with the other roots while keeping the seedlings in an erect position. The entire bed later form a carpet-like sheet of young plants that can be easily lifted and removed for transplanting from the banana leaves after 12-15 days and/or about 15 to 20 cm high. The seedling mat also promise an easier handling and transport of seedlings from the bed to the actual field.

The *dapog* method actually became a common practice in growing dry-season crop as it matures earlier than ordinary transplanted rice. This had been a good alternative to broadcast seeding. *Dapog*-raised seedlings offered the same short growth duration in the field as they mature earlier by 20 days than those grown in ordinary seedbed (Camus, 1921). The disadvantages of the broadcast seeding as compared to the *dapog* system were the impossibility of uniform and efficient seeding by hand or the impracticability or difficulty of weeding. Generally, however, the *dapog* system or the broadcast method is employed only where there is sufficient irrigation water during the growth of the crop.

Seeding rate. Ordinarily, one hectare required 32 kg of good bigger seeds and 22 kg of good finer seeds to plant a hectare (Bautista, 1949). The seeding rate, however, depended on the crop establishment method preferred by the rice farmers, the ecosystem, and the percentage of germination rate. Pre-germinated seeds were to be uniformly broadcasted into a 400 or 500 square meters on preferably lighter soils for easier pulling of seedlings. The seedbeds were irrigated from time to time and fertilizer (ammonium sulfate) was applied to hasten the growth of seedlings when they appeared spindly.

In the early 1990's, the 40 kg seeds/ha was demonstrated in the different provinces and municipalities through the Grain Productivity Enhancement Program (GPEP) of the Department of Agriculture. This has contributed to the adoption of lower seeding rates for transplanting from 105 in 1998 to 86 kg/ha in 2000 and from 150 kg to 129 kg/ha for direct seeding in irrigated lowland areas. However, there was no significant change in the seeding rates used in the rainfed direct seeded areas from 1998-2000.

Seedling age. As reported by Camus in 1921, the age of seedlings to be transplanted depends on the maturity of the varieties to be planted. For the short-season crop (< 120 days), seedling should be planted when they are 25 days old from sowing. Early maturing varieties (120-145 days) require seedlings that are 30 days old; for 145-170 days varieties, seedlings of about 30-35 days old; for 170-180 days varieties, 35 days old seedlings; those that matured over 180 days should be transplanted when seedlings are 40 days old after sowing.

However, this classification of varieties based on maturity seemed to have changed in 1949. Seedlings of the early maturing varieties are those mature at 140-160 days and should be transplanted at 20 to 35 days-old while the late maturing varieties are those that matured at 160-180 days and so should be transplanted at 35-42 days old. To date, late maturing varieties that mature in more than five months are now classified as traditional varieties and are usually planted in the upland ecosystems. The classified early maturing varieties now have less than 3 months maturity and can be planted from 18 to 21 days old after sowing. The medium maturing varieties matured in more than 3 months and can also be transplanted when the seedlings are 21 to 25 days old. Both classifications are adopted to lowland rice ecosystems.

In the earlier times, cutting of the tops of pulled seedling was practiced before transplanting to lessen transpiration while seedlings are recovering from transplanting shock and to prevent them from being blown down by high winds before plants fully developed their roots. To date, however, cutting of the seedling tops is seldom practiced as new varieties are already shorter than the traditional or older varieties.

Distance of planting. Transplanting distances and planting density varied on a case-to-case basis. For better results and economy, 3-4 seedlings were used per hill at a distance of 20 to 25 cm apart. In low fertile soils, 5-6 seedlings per hill were planted in 18 x 18 cm to 20 x 20 cm distances while seedlings were planted farther at 20 x 30 cm apart in high fertile soils. Within 5 days, dead or weak seedlings were removed and replanted with better ones (Bautista, 1949).

Although similar planting distances (20 x 20 cm) is being recommended at present, most farmers still prefer other planting distances to the "straight planting" method. Commonly practiced are the "*straight kulong*" and the "*waray*" method. In the "straight kulong" method, a baseline of 20 cm apart was first transplanted with rice seedlings and that become the guiding row of the transplanters, with seedlings planted backward with undefined planting distance per hill. In the "waray" method, planting distance between row and hills are not defined and no baseline is followed. With these methods, transplanters plant according to their pacing faster than straight planting while farmers prefer the two methods because the cost of transplanting is lower than with the "straight planting" method.

Pest and disease management

Rats and Rodents. A pair of adult rats can inflict more than 50% rice yield loss. As reported in 1921, the economical way to control them was to destroy their habitats by setting fire their hiding places and killing them. Field application of poisonous chemicals like white arsenic, barium carbonate, or strychnine sulfate is also recommended (Camus, 1921) with extra care due to possible effects to human and animals.

Aside from cleaning the surroundings of the rice farm, a sustainable rat management was developed based on the biology and behavior of rats. The community trap barrier system or CTBS is an environment-friendly, cost-effective and sustainable community-based approach where the farmers are to work in a group or team. The CTBS is put up 2-3 weeks before actual transplanting dates of the community, when rats are about to multiply in large number. Rice plants are planted near the habitats of rats and a plastic is constructed around the rice plants as barriers. The rats, having a strong sense of smell, would be able to find the crop in the CTBS. An opening is made on one side of the barrier leading to the cage or trap. The opening of the trap is designed like a cone to allow the rat to enter but will not be able to exit (Joshi, 2003).

Birds. The most destructive of the birds to the rice plant were the "*mayang pula*" and the "*mayang paking*". The control measures were to catch them for food and some just drive them away all day. However, mayas easily gets accustomed to this technique and are not easily shoved away from the palays. Some methods of catching them were devised like the use of Ficus gum placed in some sticks around the farms where the birds will gut stuck. The other methods are the use of a net trap in the field and by manually net sweeping the birds while they are resting at night time.

Insect pests. In the past, one of the most important insect pest is the migratory locust that are destroyed by driving them into pits. Another destructive pests reported by Camus (1921) are rice bugs, which are as destructive as the locusts but controlled by systematic crop rotation and clean culture. Another control measures done in those years were (1) using a putrifying meat in a bag as bait to attract adult bugs; this is afterwards burned and (2) early planting of rice as trap crop before the actual rice crop is to be established to allow the rice bugs to feed and live on the rice plants before the crop is burned together with the bugs, and (3) simultaneous and synchronous transplanting of varieties with the same maturity; however, this was not acceptable to other farmers because harvesting by hand was too slow and additional help is inevitable when all rice plants matures at the same time.

Rice stem-borer came next to rice bugs. Cleaning around the field before transplanting was done to destroy the eggs of the stemborer. Leaf folders and cutworms or army worms were also common especially in places where continuous planting of rice is practiced. Clean surroundings and crop rotation were suggested control measures at that time. On the other hand, as early as 1930, the case worms (*aksip na pula*) was already a common insect pests in rice aside from rice leaf roller (*Cnaphalocrosis medinalis)*, rice bug (*Leptocorisa acuta),* and stalk borer (*Schoenobius incertellus*) [Aragon, 1930]. To combat the case worms, complete drainage of the paddy field was done until the pest was eliminated (Bautista, 1949). Almost all of the above insects were observed in 1952 with the addition of the occurrence of leafhoppers. Some control measures were done like poster campaigns by, informative articles, bulletins, circulars about the insects; application of calcium arsenate and other arsenicals, dust preparation, and oil emulsions; encouraging rearing of predators and parasites that attack the various pests and cultural measures, e.g. timely application of derris and pyrethrum (Otanes, 1952).

Two years after, in 1954, the brown leafhopper (BPH), a new pest of rice was widely observed in the Philippines. It was first observed in Calamba, Laguna but has not become serious until 1973 when thousand of hectares were destroyed by the BPH. The infestation continued through 1974 in Laguna affecting over 10,000 hectares. In 1976 serious outbreaks were observed in Mindanao causing considerable losses. Along with BPH, the grassy stunt virus transmitted by the BPH soon made its appearance in Laguna rice fields, greatly compounding the losses in yield suffered by the rice farmers. During the infestation, technical personnel, chemicals and equipment were pooled to suppress the spread of the pest. The farmers were organized into pest control groups to cover wider area. Educational drive was also undertaken among farmers to introduce modern crop protection. Upon the initiation of the Bureau of Plant Industry, a rice planting ban during the 1974 dry season was instituted in Laguna in an attempt to break the BPH cycle with grassy stunt virus. Only rice variety IR-26 was used for planting (BPI, 1981).

Extensive use of chemicals or insecticides was commonly practiced and even calendar spraying was recommended through the Masagana 99 rice program of the 1970s. The farmers believed that all insects are harmful and were not aware that there are also friendly insects in the rice paddy areas. Continuous spray of the insecticides, however, caused the build-up of insect immunity of to insecticides and their increase in number while also killing the friendly insects. The harmful effects of chemicals on the environment and on human health prompted scientists to develop the Integrated Pest Management that seek to control only the harmful insects.

Fig. __. Calendar spraying of chemicals has more harmful effects to the rice environment and to humans than benefits to rice farming.

Diseases. One cause for the declining yield of modern rice varieties is the increased insect and disease pressure to which these varieties are not resistant. In 1939, Serrano reported a viral pathogen causing stunt or dwarf disease locally known in Bulacan as "aksip na pula" and by the Ilocanos as "tungro". Rice tungro is considered the most destructive disease in the Philippines. During the 1940's the annual production loss due to rice tungro was estimated at 30% (1.4 million tons). Hundreds of thousands of hectares of rice were devastated in Central Luzon, Bicol region and other areas in the Philippines in 1970-71. Localized outbreaks in 1975 occurred again in Central Luzon while in 1977 complete crop failure in 180 hectares in Cavite also took place. During these outbreaks, campaigns from BPI were waged aggressively to suppress the disease. Pesticides were distributed free to augment farmers' pesticide to contain the fast spread of the disease. Educational campaign was also undertaken through organized farmers' classes and meetings to introduce modern crop protection technology in which farmers were also taught the use of resistant high yielding varieties as a preventive measure against the recurrence of the disease. More intensive campaigns were made in rice farming areas like those of North and South Cotabato, Davao del Sur and Zamboanga del Sur in sporadic proportion and especially in places where farmers still insist to the planting of susceptible varieties and lack the facilities and equipment to control the disease.

In Mindanao, in late 1976, a new rice disease called infectious gall disease was discovered. The disease was serious, affecting over 1000 hectares of rice with an estimated loss of over 50 percent of the crop. With the vigorous campaign of BPI to plant high yielding resistant varieties like IR32, IR 36, IR42, the infestation of both the BPH and infectious gall were controlled (BPI, 1981).

Weeds. In the irrigated lowlands of Muñoz, five common weeds in rice fields were identified: *Monocharia hastate*, *Pistia strationles, Eichornia crassipes, Cyperus iria* and *Cyperus haspan*. Hand weeding is employed and the weeds are being fed to their pigs (Aragon,1930). Aside from hand weeding, weeds were controlled by periodical application of water to suppress their growth. Those that survived were pulled from time to time and trampled into the soils (Bautista, 1949). Since the introduction of HYVs in the 1970s, however, chemical herbicides sprayed using knapsack sprayers before or after weed emergence have become common particularly in direct seeded fields.

Golden snail. In the 1970's, there was a worldwide craze to grow the golden apple snail for food purposes with both the government and private groups endorsing massive production of this snail for food and profit. After few years of production, however, the golden snail turned out to be a rice pest in the paddy soils (Madamba and Camaya, 1987). Rice seedlings at 14 to 24 day after transplanting were found to be most susceptible to golden snail damage that could reached 20 percent and more if this cannot be controlled. Golden snails were also a potential pest of Azolla which were grown as a possible source of nitrogen for rice plants (Lara and Querubin, 1986).

Integrated pest management. Before the 1960s, farmers grew traditional varieties that are often heterogeneous mixtures and that are selected with resistance to insect pests and diseases. Indigenous practices such as application of concoctions of botanical and inorganic pesticides, removal of infected plants and practice of various rituals for repelling pests were practiced.

With the introduction of HYVs during the Green Revolution period, the new varieties together with modernized technology packages created favorable conditions for disease development and insect pest infestations. The short-statured IRRI varieties with higher number of tillers, the use of higher nitrogen rates, and the continuous planting all year round enhanced a favorable growth environment for pathogens that normally were not serious problems with the traditional varieties and practices (Teng, 1994).

As early as 1926, the use of toxic substances have been recommended for disease control, primarily against fungal pathogens. Fungicides like Benlate and Dithane M-45 for seed borne pathogens were recommended for seed treatment by Masagana 99. Chemical control offers immediate solution to ensure high yield even by resistant varieties. With the Masagana 99, calendar-based chemical application was recommended with 5-6 times/season regardless of levels of infestations. The heavy reliance on to chemical control, host plant resistance, and widespread cultivation of HYVs resulted to increased and unexpected emergence of problems caused by weeds, insects, and diseases. Approach to control was not systematic and any institutionalized standardized effort to pest control is highly unlikely to work over a large area so that the government declared IPM as the national crop protection policy in 1986.

IPM became the cost-reducing technology for pest control in rice, emphasizing ecology-based approaches using season long farmer training (known in 1993 as farmer field schools or FFS). Among the control tactics and measures of IPM include the use of resistant varieties such as the Matatag lines which were bred as stop-gap lines in tungro-infected areas, cultural methods such as sanitation, proper spacing, low use of nitrogen and proper water management but more importantly by practicing synchronous planting on a large contiguous area, biological control methods such as the use of Trichoderma and Pseudomonas against sheath blight, and, on need basis, chemical; control.

Biotechnology. Biotechnology is one of breakthrough technologies that offers a sustainable and practical solution to many problems in rice production particularly on pest protection. With plant breeding methods, this technique could speed up the development of improved cultivars with higher yields that offers resistance against major pests that continues to saddle rice production in the country.

Through biotechnology, one or more genes resistant to a particular disease can reduce disease infection of a host cultivar. Resistance to bacterial blight, sheath blight, and tungro, three of the major diseases in the country, is being addressed by biotechnology research at IRRI and PhilRice.

III. Labor saving technologies

A. Direct seeding

Rice transplanting dominated rice production during the Green Revolution and shortly after as one of the packaged recommendations of Masagana 99 program by the government. In Iloilo, however, broadcast seeding combined with the introduction of IR36 and the availability of commercial herbicides to control weeds took off as an impetus to a provincial rice program called Kabsaka (*Kaumahan sa Pagsasaka*). Rice seeds are broadcast manually into cultivated dry fields and germinate once rains come in. The program promoted this practice because of the absence of gravity irrigation water in the area and to reduce cost. Farmers are then encouraged to broadcast mungbean prior to or right after harvesting while the soil surface is still wet for germination. Many farmers also broadcast seeds on wet fields where water is plentiful and this started the practice called wet direct seeding.

Initially, wet direct seeding was saddled by problems of water management, poor land leveling, and weed growth which eventually led to poor yields. With time and as farmers become skilled in proper leveling and water management, yields of direct-seeded fields are no longer different to transplanted fields. Nowadays, however, wet direct seeding of rice is being posted as an alternative planting method to answer scarcity of labor during peak periods. It requires well-leveled puddle soil surfaces (to minimize water puddles that eventually reduces seedling recovery), good water management during the first week after seeding, and good weed control, the latter often through the use of pre- or post-emergence herbicides.

Direct seeding of rice is better established in the dry season to avoid damage from rainfall, pests, and diseases that are more prevalent during the wet season. At present, the combined method of transplanting (for wet season) and direct seeding (for dry season) is practiced in many irrigated areas. Some fields with good drainage, however, practice wet direct seeding of rice irrespective of season mainly as a method to save on time, labor, and costs. Consistently, high seeding rate, ranging from 150 to 250 kg/ha, is used in the direct seeding method of establishment regardless whether they are sown in the irrigated or in the rainfed ecosystem to give allowance to plant damage due to rats, birds and golden snails.

Machinery for direct seeding. Beginning late 1970s, IRRI had been spearheading in the development of simple hand operated row seeders for direct seeding of pre-germinated paddy grains into the soil surface. The most successful of these efforts is the IRRI drum seeder which a cylinder covered at both ends and having perforations at each end for seeds to come out once the cylinders are rotated by a groundwheel as an operator pulls the machine. To date, this seeder is still becoming popular since it allows farmers to seed in neat rows at lower seed rates of 40 to 80 kg/ha.

Fig. __. The IRRI drum seeder facilitates wet seeding in neat rows with less seeds than broadcast seeding.

B. Farm Mechanization

Mechanizing the rice production operations has often been a result of increased drudgery when the task is done manually, the intensive power required in some operations like land preparation , the increasing cost of manual labor and the significant amount of time devoted to it (Table __), and the resulting quality of output when using tools or machines.

Mechanization has always been associated with big or engine-powered machinery; however, it can also include the use of tools and devices to make field tasks easier and its completion faster. These tools could be in the form of hand hoes and carabao-drawn implements such as the moldboard plow and comb harrow that have proven very useful during the former years. Nowadays in the Philippines, mechanization is more associated with engine- or motor-operated equipment or field machinery, the most common of which is the hand tractor and the rice thresher.

Table __. Present labor utilization in rice production.

Operations	Transplanting (>4 t/ha yield)	Direct Seeding		Japan Transplanting
		Low yield (<4 t/ha)	High yield (>4 t/ha)	
Land preparation	104	112	80	53
Seedbed preparation, pulling/bundling/ transplanting/	8 112	-- --	-- --	-- 110
Broadcasting		16	24	
Crop care & maintenance	24	40	64	157
Harvesting & threshing	480	288	408	80
Drying/storage	56	24	48	30
Total	784	480	624	430
Labor productivity, paddy kg/man-day	83	64	88	104

Source: Serrano, 1994; Takahashi, 1995.

<u>Land preparation</u>

Traditional practices. Preparing rice fields for planting has been the start of mechanization for rice in the Philippines as it starts a series of field operations. It is one of the most labor and power intensive among activities in the field and farmers had to accomplished this at reduced drudgery. Rice in the old days was cultivated only once per year, during the rainy season, hence, time and efficiency were of less consideration to labor and costs.

If this was not done manually by hoe, farmers in the former times heavily relied on groups of carabaos, supervised by one or two farmers, to trample and puddle submerged fields until the soil is soft enough for planting rice seedlings. Even at the present times, this method is still practiced in the lower rice terraces of the Cordilleras and in Samar (where it is known as "*payatak").* Before trampling, the field is soaked with rainwater or water flowing from the watershed above the rice plot until it is soft enough for the animal trampling.

In elevated areas where carabaos could not access the rice terraces, Ifugao and Kalinga men and women often prepare rice fields by inverting the mud by hand or with a shovel and trampling the soil with their feet. This is a very laborious and tedious task, not including that the terrace' repair (and the construction of the rice terraces itself also done manually by previous generations).

<u>Moulboard plow</u>. The first moldboard plow was introduced in the Philippines by a Spanish priest in 19th century. In 1925, the moldboard of carabao-drawn moldboard plows were already locally made by Chinese artisans and skilled Filipino blacksmiths out

of scrap iron, white fine-grained iron or discarded railroad rails. Other parts, such as the beam, handle and landside, are usually fashioned by the farmer from buttresses, trunks, and branches of hard trees, although these may be occasionally purchased from plow dealers.

The use of carabao pulling a single moldboard plow to prepare flooded rice fields persisted for many years but is also a hard work and time consuming. It was estimated that a farmer had to walk an equivalent distance of around 60 km to plow a hectare, taking around 77 h, while requiring another 9-13 passes with a comb-toothed harrow to make the field ready for planting.

Tractors. Tractors, however, offer more power than animals in achieving timeliness without sacrificing the quality of work. The first attempt to introduce tractors for plowing in the Philippines was done also by the Spanish authorities in 1905. European-made cable plows pulled by two or three steam engines had been tried in Negros and Laguna but the plows' durability and performance were still unsatisfactory for the tough soils in the test sites at that time.

In 1928 until 1932, government engineers at the Bureau of Agriculture tested and demonstrated several American tractor models in sugarcane fields in Negros Occidental. Mechanization of land preparation was more vigorously pursued after World War II owing to the destruction of work animals during the war, with the government taking the lead. Between 1950-1970, a lot of researches at the BPI, UPLB, and Central Luzon State University were made on the introduction and testing of different tractors for wetland tillage. In 1953, a David Brown tractor equipped with a rotavator was tested first time for plowing flooded paddy fields. Although past studies have shown that big tractors were not economical yet to use for small rice plots, these tests have pointed out the potential problems of tractors in wet rice fields, such as wheel slippage and bogging down caused by the machine's excessive weight. It was these problems that BPI engineers, in cooperation with dealers of agricultural machinery, successfully tried and introduced extension steel wheels having angle lugs on the side of rubber-tired wheels to provide traction necessary in propelling the heavy tractor f

Fig. __. Big four-wheel tractors with rotavating attachment preparing flooded rice fields.

In the 1950s, duty-free importation of tractors and subsidized credits for tractor purchase complemented with carabao shortage after the war might be an underlying factor for adoption of tractors during this time (Barker et al, 1972).

In the late 1960s, double cropping became possible with the introduction of early maturing high yielding varieties and irrigation. The turn-around time between the first crop and the second crop had to be shortened to allow two crops per year. Faster methods of land preparation, together with postharvest activities, became critical. Big, four-wheeled tractors with extension steel lugwheels continued to dominate the irrigated rice areas in the Philippines, particularly in Central Luzon and near sugarcane plantations where tractors are already being used. In 1966, government loans were provided to buy big tractors and promote mechanization.

IRRI Power tillers. Farmers in 1965 also started to purchase and use imported tillers or hand tractors in rice paddies. Carabaos were difficult to maintain by poor peace and order situation and difficulties in caring and maintaining animals. In 1968, most Laguna farmers already considered the hand tractor as faster and easier and cheaper to use than carabao-drawn plow and harrow. The hand tractors were also noted to make deep paddies shallower, are safer to use and keep than carabaos, to have better stand for the rice crop and to bring no worry after use.

With the wide adoption of early-maturing high yielding varieties in the 1970s, machine use was further encouraged. There were now labor shortages during peak seasons and greater need to accomplish land preparation within a much shorter period. For instance, in a Laguna village by the mid-70s, hand tractors had almost completely displaced carabaos in land preparation. Tractors could operate more efficiently in deep water fields adjacent to the Laguna de Bay owing to their floating wheels. The increased speed of land preparation was also advantageous for the dry season crop (following the wet season crop) in avoiding water shortages during the late dry months. The growing scarcity of grazing land as a result of expansion of rice cultivation areas might have also contributed to the replacement of carabaos by machines.

In 1972, a small, 5-7 hp single-axle lightweight power tiller was developed and released locally by IRRI at 50% less price than imported tillers. The IRRI tiller is simpler than imported models as it employs motorcycle chains and sprockets in its transmission that local manufacturers could assemble and repair. Small backyard shops also found the design compatible with their skill and limited resources. In just a year after its introduction, more than 2500 hand tractors were sold in the Philippines. This number was 2.5 times greater in sales during the previous three years, which was dominated by imported tillers. Later, more than 10,000 IRRI-designed hand tractors were locally produced through 1976.

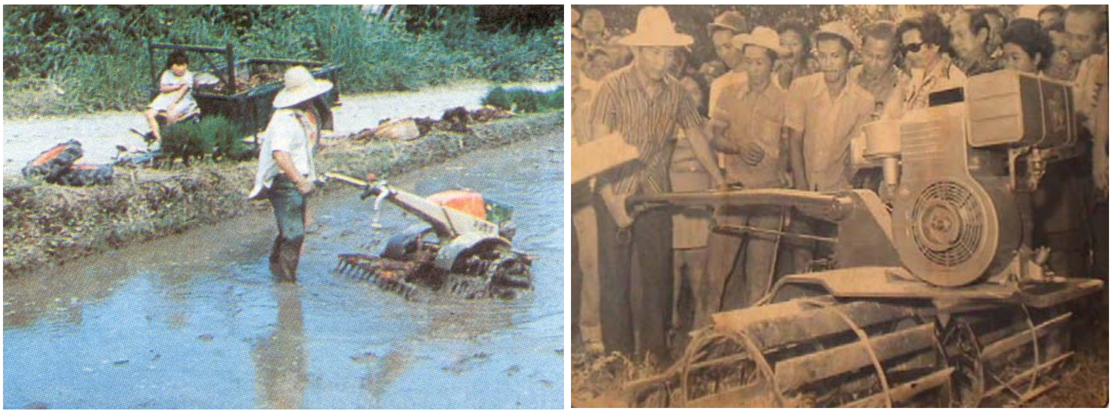


Fig. __. Imported hand tractors in late 1960s and a commercial version of IRRI power tiller with the then President Ferdinand Marcos in the 1970s.

Kuliglig-era. This was the start of widespread mechanization of paddy land preparation in irrigated areas using small hand tractors. The design of the IRRI power tiller has been modified by local manufacturers through time. The split-type transmission casing has been replaced with box-type casing, chains and sprockets have been enlarged, and the size has also been increased with wider cagewheels, bigger engines and longer handles to ease turning. The use of hand tractors (now locally known as "*kuliglig*" after the rice field cricket which was adopted by one manufacturer as brand) rose from 14 per thousand hectares in the Philippines to approximately 20 per thousand hectares in 1990 (Herdt, 1983). The irrigated areas tend to be more highly mechanized, with over one hand tractor per 10 hectares of paddy land, while the less favorable areas continued to rely on animal power.

In most rice villages nowadays, the kuliglig hand tractor is used not only for land preparation but also in transporting people and products in and out of village when not preparing the field. In many villages in Central Luzon, its use has evolved into a passenger vehicle because it is the only vehicle rugged enough to handle farm dirt roads that are often muddy or difficult for other vehicles to go through.

Fig. __. The hand tractor is useful in hauling products and people in farming villages.

In the 1970s, most kuligligs were manufactured in medium-sized Bulacan workshops; nowadays, a lot of these are now simply made and repaired in backyard shops found in most towns or villages. Because it is simple to make, repair and maintain, it is widely used in irrigated fields and its popularity is expanding in rainfed areas. The design has not changed much from the original IRRI design of the 1970s although bigger chains and sprockets coupled with more powerful gasoline (10-16 hp) or diesel engine (6-8 hp) is presently fitted.

Because of absence of complicated steering clutches normally found in imported models, kuliglig handles are made long for easier hand turning. Implements commonly hitched behind include the disc plow which cuts through the soil surface as it is dragged at an angle, the comb harrow which facilitates soil puddling in combination with wide steel cagewheels, and the trailer which is a box-shaped platform fitted with surplus car wheels for hauling or transport on roads.

Kuligligs are very popular due to the simple construction that enables small welding shops to easily assemble and unskilled farmers to repair and maintain it. Custom service units have replaced the carabao in most rice areas and generate additional income for its farmer owners from neighboring fields.

Fig. __. Kuliglig hand tractors, with trailing or riding attachments are becoming common sights in the villages.

<u>Palay Harvesting</u>

Manual reaping. In the 1900s, harvesting or cutting mature palay stalks in the field begins in December and lasts until March in Central Luzon. There were several practices of harvesting rice: one is by cutting off the rice heads, usually of upland or bearded palay, one by one or at most three at a time, with a hand-held tool called "*pang-ani*" or "*yatab*". The second most common method is to cut the straw midway above the ground with a sickle or serrated knife called "*lingcao,* fastened in the back of a crooked tree branch having a hook at the end for gathering the straw into a bunch. The hook is held in the right hand; with it the rice is pulled up and grasped by the left hand, the hook is then loosened and the straw cut with the knife and tied into bundles about 10-15 cm in diameter. The bundles are so uniform they are sometimes used as a unit of measure, each containing about 0.3 kg of threshed grain. These are left scattered in the ground to dry and then piled into stacks on the dikes until the harvest is over, when they are hauled to the stack.

The lingcao was later replaced with sickle called "*karet*" or "*kumpay*", which is a slightly-hooked knife, with serrations at the inside and fitted with a short straight handle. There had been attempts at UPCA, BPI and CLSU to introduce and demonstrate rice combines from the US and Japan before and after the war. Because of the size and weight of the American combines, these attempts were made in upland rice fields since big combines would sink in the small bunded wet fields. Japanese combines were very sophisticated and expensive for the rice farmers at this time so these were confined in experimental stations and demonstration fields.

Fig. __. Traditional harvesting using karet or kumpay

Mechanical reapers. Towards the 1970s, both UPLB and IRRI have been active in trying out different harvesting designs. At UPLB, different designs from Japan, India, and China were tested and tried in farmers' fields. Significant achievements in mechanizing rice harvesting, however, were achieved by the IRRI engineers who successfully developed local prototypes.

The most successful of the many prototypes attempted by IRRI during this period is the reaper-windrower designed with Chinese engineers and released in the Philippines and Southeast Asia in early 1980s. The reaper cut rice stalks through a reciprocating serrated blades atop a stationary ledger, convey the stalks to one side with two sets of vertical flat belts having steel lugs, and release the stalks in neat windrow at the side of the machine. A separate team of manual labor collects and bundles the stalks after a few days of field drying prior to threshing.

Many small manufacturers started the reaper mass production in 1985 with IRRI technical assistance. Central Luzon farmers immediately adopted the reaper, attesting to the need for such machines and the receptiveness of farmers and manufacturers at this time when industrialization is beginning to set in.

With the continuous use of the local reaper, however, several problems set in, such as poor durability and precision in manufacturing, poor servicing, and hired labor displacement. Meanwhile, a newly-introduced Japanese reaper of similar design started to become popular. Although imported and more expensive, this reaper model is more reliable and easier to handle especially in maneuvering headlands because it has a reverse motion. At present, this imported reaper is still slowly increasing although its high cost limits wider adoption.

Fig. __. The IRRI reaper can harvest 2.4 ha/d but its popularity was overtaken in the late 1980s with an imported harvester from Japan.

The imported rice reaper continues to become popular in Central Luzon although adoption is slow mainly due to its high price. Because of the expensive cost of imported reapers, a local reaper design utilizing rotary disc cutters was developed with Japanese engineers and recently introduced by PhilRice. With mechanisms similar to previous designs except for the cutting components, this version was simpler to manufacture and maintain and incorporates features for easier operation similar to imported models. This reaper utilizes high speed rotary cutting discs with few blades to cut rice stalks and open transmission with motorcycle chains and sprockets for ease of maintenance and repair.

Rice stripper. Rice stripping is a harvesting process of stripping grains from a standing plants without harvesting or cutting the whole plant. Based on a stripping concept from the United Kingdom for large harvesters, stripping is achieved by rubber teeth with key-shaped holes attached to a rotor rotating upward and enclosed in a hood that directs the rice panicles into the rotor for “combing” action. IRRI engineers adapted this concept for small fields of Asia by gathering stripped materials (grains and some straw) into a collection box behind the stripping rotor The striped materials are already

90-97% threshed but still needs separate rethreshing and cleaning. Although less laborious than the reaper, this stripping system has lesser loss than the manual or reaper systems since the grains are handled by them machine without leaving them in the field.

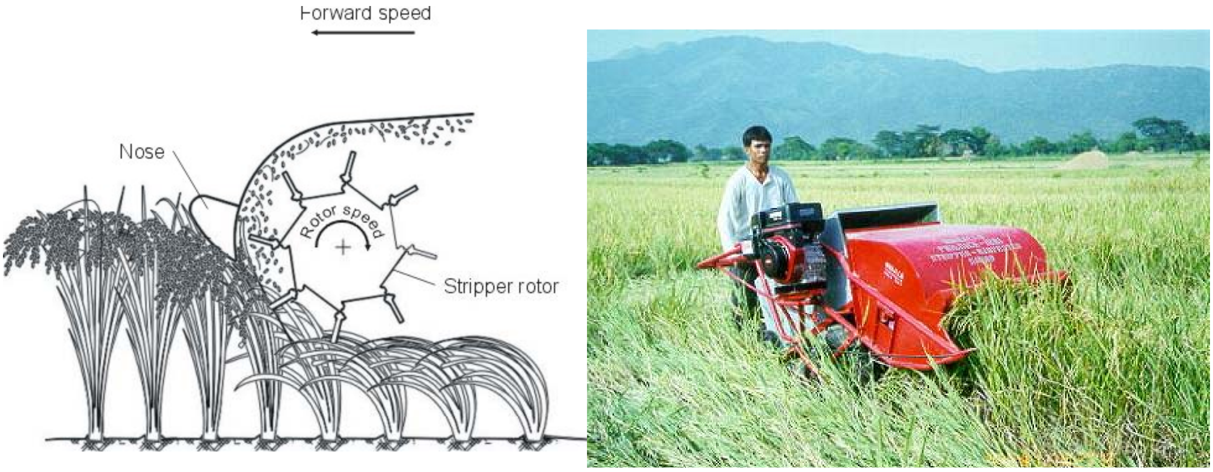


Fig. __. The IRRI Stripper Gatherer harvests grains and already threshes 90-97% of the grain during stripping.

Combine harvester. Prompted by the need for faster, cheaper and more efficient harvesting methods than reapers or strippers, many attempts have been made to introduce imported rice combines in the Philippines but these were unsuccessful because the imported models were expensive for rice farmers and big and heavy for small wet paddy plots characteristics of Philippine rice fields. In 2002, however, PhilRice adapted a Chinese combine design which harvests and threshes paddy grains in one pass. The machine, now fitted with cleaning and bagging components, is small and lightweight for small wet paddies and easy to operate with one person to maneuver and another person to attend bagging. It has a capacity of 1 ha/d and comes with rubber tires that can be changed into steel starwheels for wet muddy fields. The machine is powered by a small gasoline engine, which makes the design relatively cheaper than imported models for the Filipino farmer.

Fig _. This small and lightweight rice combine is more appropriate for small wet fields in the Philippines than the big and sophisticated imported combines.

Palay threshing

After harvesting, rice stalks were gathered and stacked high in dry ground for threshing. Threshing is done to separate the palay grains from stalks and leafy materials. Small farmers normally thresh their traditional rice immediately after harvest, mostly by treading out the grain on a hard earthen floor manually, by a team of carabaos or horses, or on slatted platforms and by beating with flails against stones, hard wooden boards, or a bamboo stand (*hampasan*).

With traditional treading, rice sheaves are spread on the threshing floor and the grain is trodden by animals driven in a circle until almost all grains are threshed; any remaining grains left in the panicles are cleaned by hand or by feet. Sometimes a wooden roller with short teeth or spikes is driven over the sheaves and as many as 20 carabaos or horses are used at one time. Fifteen animals when used at one time could easily thresh 200 cavans of palay in five hours. Threshing in this manner is generally done by moonlight and becomes an important family activity. However, although it was a social occasion in the neighborhood, many desired to complete the operation faster because of the drudgery, the high labor required, and the long time needed to complete threshing with these methods.

Photo from Huke & Huke, 1990.

Fig. __. The traditional hampasan for rice threshing made of stone and bamboo slats and traditional winnowing using bilao.

Later, the one-man, foot-operated pedal rice thresher was introduced by the Chinese and the Japanese to the country before the second World War. The machine is pedal operated by using a bicycle chain and sprocket to transmit power from the human leg to the threshing drum. It is easily transported from one farm to another. Formerly made of wood with some metal parts, it is now produced out of steel frame and canvass which reduces the weight and cost of the machine. Threshing efficiency is 98% and capacity of 120 kg/hr with two persons operating.

However, the pedal thresher, although widely used n East Asia, never became popular in South and Southeast Asia since it offered no significant time and energy savings over hand threshing. However, in the Ilocos region where the rice straw has to be preserved for use in vegetable farming after rice, this thresher is still popular. Some are now run by small gasoline engines and even locally manufactured in the area.

The McCormick Deering thresher. In the 1920s, there were several hundred imported threshing machines being used by big farmers mostly in Nueva Ecija, Bulacan and Pangasinan. These big threshers, locally known as *tilyadoras,* were the same McCormick threshers developed over 50 to 70 years earlier in Europe and America. These are pulled by a 60hp tractor or hauled by truck when moved from place to place and driven by the same tractor with long flat belts during threshing. Rice stalks are fed in sheaves on the elevator feeder of the machine and rice grains comes out in a separate outlet while stalks mixed with some grains are ejected out of a long spout at the back of the machine. McCormick threshers were sold in the Philippines at $5,000. Later in the 1960s, exact copies of these threshers are already manufactured locally.

Farmers would hire people to haul the harvest to the site of the machine, making big haystacks or *mandalas* of rice stalks. The purposes of the haystacks are to minimize the movement of big tilyadoras in the field, for less exposure to rain of rice stalks kept in big mandalas and to allow drying before threshing since grains shatter easily during threshing, paddy could be stored immediately, while there was efficient separation of the grains from the straw and better grain quality and price. Usually a crew of eight to 12 men operate these machines. About 20 to 30 tons of paddy can be threshed per day. Payment for work was made in cash or as palay.

In major rice areas in the 1960s, the tilyadora started to replace foot or animal treading and hampasan since its use was considered of less cost to farmers. The system using tilyadora entailed an equivalent cost of 13 cavans for harvesting, stacking cut rice stalks, actual threshing as well as hauling of threshed paddy to the farmer's house using the truck used to haul the same tilyadora. With hampasan, ten cavans is needed to pay for just harvesting and threshing while laborious pre-threshing tasks (stacking and hauling) still required additional cost.

Small axial-flow rice threshers. In the late 1960s to early 1970s, HYVs with shorter duration allowed two cropping season in a year. With the advent of double cropping of rice and the increased quantities produced, the period around harvesting and threshing for the first crop and land preparation for the second crop became extremely time bound, resulting in major labor peak. Farmers started to look for other threshing alternatives as the use of big tilyadoras became impractical.

With the limitations of the bulky and big tilyadoras, IRRI embarked in 1965 to develop a smaller thresher suited to modern varieties. This thresher had to be low-cost, light weight, could be fabricated locally and more suited to small farmers' needs. Out of different alternative thresher concepts, a thresher that allows operators to feed all of the stalks could provide higher output than the type that requires the operator to hold on the stalk during threshing. Thus, after trying a hold-on table-type design, the axial flow principle was finally adopted because it has simpler arrangement of threshing and separating sections.

In this design, rice stalks are fed into a rotating drum housed in a chamber and equipped with peg teeth. Upon entry into the chamber at the feed end, the stalks are hit by pegs against regularly-spaced lateral bars around the rotating drum to separate the grains from the straw. The straw moves from the inlet to the outlet in the process and ejected out and far from the machine. A fan underneath blows air to winnow the grain as it falls from the chamber. The grains are further cleaned by a rotary screen before it finally gets out of the machine. The thresher was mounted on small, narrow wheels for mobility and powered by small gasoline engine.

The axial flow thresher was released in 1973 and manufacturers came up with innovations found in commercial models. These modifications include the use of car tires, spring-supported chassis as well as oscillating screens beneath the threshing chamber prior to fan winnowing. Provisions were also made to allow the thresher to be pulled by a carabao, hand tractors or jeepneys. Later, smaller models that can be carried manually by a group of men were introduced in Bicol and the Visayas.

During the harvesting season, rice threshers are commonly seen along farm roads or at the rice fields with its crew of five to seven men in addition to a group of women winnowers. The thresher can thresh rice from a hectare of field in half to one day depending on thresher size. One or two of the crew haul paddy stalks from a small haystack or *talumpok* next to the thresher, another manually feeds the thresher, two attend to bagging while another recycles some grains coming out of the screen for re-cleaning. Another person attends to bag closing and haul the paddy bags into a hand tractor. Payment is paid in kind at 6-8% of the paddy output but the crew is often paid in kind or in cash, depending on need.

Fig. __. IRRI axial-flow thresher released by IRRI in early 1970s and commercial model at present.

By 1975, these mobile threshers have quickly spread in the irrigated areas and became popular for contract operations. By 1982, 73% of the Central Luzon rice farmers were using them and by 1990, all other forms of threshing disappeared from the area. In some areas, however, the use of axial flow threshers also changed the labor contract labor system, taking out the share of manual labor in favor of the machine. This has become a trend for hand tractors as well. Custom service operation has caused small farmers to benefit from the use of threshers and hand tractors.

The adoption of threshers also resulted in a decline of threshing labor requirements due to large gains in labor productivity, from eight labor days per ton of paddy for foot threshing to less than one day per ton. In Nueva Ecija, Laguna and Iloilo, postharvest labor in mechanized farms was around 25% lower than on farms in which rice is manually threshed, with roughly 31% coming from landless households.

Using thresher, however, has resulted in considerable reduction of the drudgery of postproduction tasks. The lighter nature of the work made it possible for women and children to substitute for men in the threshing operation. Where off-farm employment opportunities exist, thresher use could result in increased incomes of labor households since men maybe released for other income generation while women and children provide threshing labor.

It has been estimated that mechanical threshers reduce grain loss by 0.7 to 6% compared to manual threshing. However, women and children from landless family winnows the straw from the thresher to recover grains lost for table food or cash.

Palay drying

Prior to the Green Revolution period of 1960s, farmers only plant once during the wet season and the stalks are left in the field for drying before these are threshed or placed in big mandalas for the big threshers. In those days, there was no need for palay drying since the grains from mandalas are practically dried prior to threshing. Also, because there was plenty of time between harvesting and threshing, rice stalks in the mandalas are already dried by the time a tilyadora arrives for threshing.

This situation, however, changed radically with the introduction of early maturing varieties and the availability of irrigation that made possible double cropping seasons in a year. The turn-around time between harvesting the first crop and planting the second crop has now become limited. Harvesting the first season crop also coincides with the rainy months of October to December so that farmers could no longer dry harvested stalks in the field. Because of high yields and large volume of paddy to be handled, farmers are forced to drying freshly threshed grains on any available pavement, including roads and highways. During the 1970s to 1990s, the Philippines was considered to have the longest dryer in the world since the roads from Bulacan to Cagayan are used heavily as drying pavements during the wet season.

However, sun drying is not always possible during the rainy season and timely drying of wet harvest became of great importance. Farmers encounter a lot of losses including poor grain quality during the wet season although sundrying is still resorted to because it is cheapest. To discourage sundrying on roads, the government offered pavement dryers that are also used as basketball courts or dancing halls during festivals.

Fig. __. Drying of wet palay in the highways and pavements is common but also results to accidents and losses.

Mechanical dryers. The earliest mechanical dryer introduced in the Philippines was the box-type flatbed dryer developed by UPLB engineers in the 1970s. Air, heated by a kerosene burner at 40 to 60^{o}C, is blown by a truck radiator fan through the mass of wet grain placed above a perforated flooring. As heated air is pushed through this mass of wet paddy grains, it absorbs moisture from the wet grains before it goes out into the atmosphere. IRRI later scaled up the UPLB model into a 40-cav model which can be heated by a rice hull furnace. Although very simple, however, farmers did not adopt the dryers widely because of their small capacity, its high operational cost with kerosene fuel, its limited use only when climate is not favorable for sun drying, as well as other socioeconomic constraints.

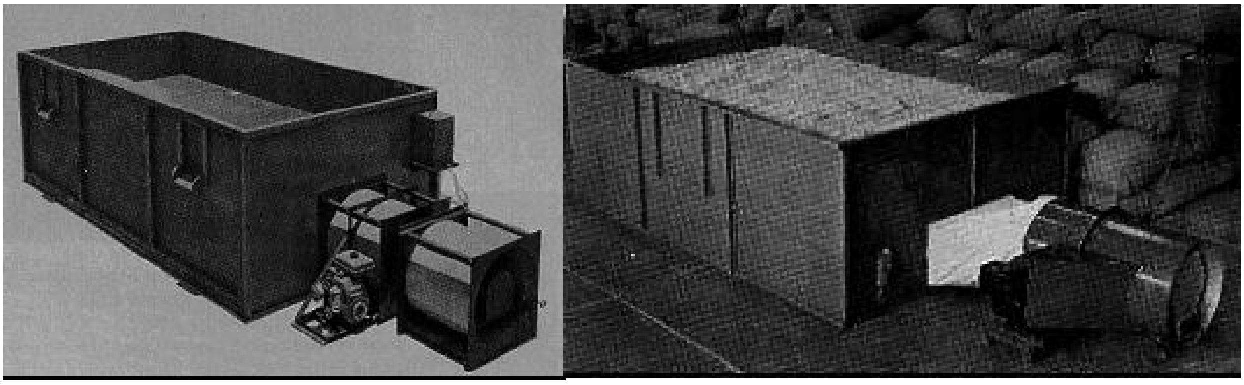


Fig. __. The box-type flatbed dryer innovations from UPLB and IRRI in the 1970s.

In the 1980s, Vietnamese engineers further scaled up the flatbed dryer heated by rice hull furnaces. PhilRice successfully adapted and introduced the 6-ton model for cooperative and village custom drying of palay, corn and other crops.

Fig. __. PhilRice adaptation of a high-capacity flatbed dryer from Vietnam models.

Modern dryers. Presently, more sophisticated, high capacity dryers were developed locally and introduced from other countries. The earliest design introduced into the country in the 1900s was a continuous-flow multipass system with tempering periods from the U.S. LSU dryers were produced locally for government warehouses and some big millers. A more popular design is the batch recirculating dryers imported from Taiwan, Japan and Korea although their construction is not rugged enough for the operating conditions of most millers and traders.

The Bureau of Postharvest Research and Extension also developed a small, mobile pre-dryer called flash dryer to pre-dry paddy to 18% MC and to go with in-store bins following the in-store principle of deep bin dryers from Australia. However, farmers quickly rejected the flash dryer because of incomplete drying and its high kerosene cost while millers prefer shorter drying periods as more practical.

Recently, government agencies collaborated through the Philippine Rice Postharvest Consortium (PRPC) to develop a batch recirculating dryer that can be locally manufactured for reduced cost compared to imported models. The resulting PRPC dryer is expected to be more suited to the operating and local paddy conditions in the Philippines.

Rice milling

Traditional milling is accomplished in the 1900s by hand pounding the palay in a concrete or wooden mortar with a wooden pestle called "*mazo*". The first pounding takes off the hull and further pounding removes the bran but also breaks the grain. Further winnowing with a bamboo tray called "*bilao*" separate the hull from rice grains. This traditional hand-pounding chore allowed two to three men and women moving in to graceful harmony and is a form of socializing for romance and marriages in villages.

Fig. __. Manual pounding using mortar and mazo with bilao for winnowing.

Kiskisans.. In the 1920s, rice mills along the railroad stations started to become common in rice provinces. Some were water-powered mills, normally found in Cavite, Laguna and Tayabas. They charge from 20 to 50 centavos for each cavan of rice while other mills receive only the by-products as payment. This rice mill is called "*kiskisan*" which is an adaptation of the European coffee grinder and is a one step process of rice milling. It has a robust cast iron construction where a screw action forces the grain into the milling chamber from one end. The husks and bran layers are removed by friction of the grain rubbing against each other inside the chamber. The bran, useful as animal feed, gets mixed with crushed hull and broken grains and comes out from a screen below the milling rotor while milled rice comes out at the other end for further sifting. Because of high breakage, the total milled rice recovery from kiskisans is low (from 50 to less than 60% out of the potential 70%) and the resulting whole rice grains are also very low. This poor performance has led the government in the early 1970s to discourage its use and further proliferation, to the advantage of more modern milling facilities that were introduced as replacement of kiskisans.

Fig. __. Village kiskisans provide milling services in the villages for a long time until its use was discouraged by the government due to its low recovery.

Modern rice mills. Japanese engineers developed a small two-stage rice mill called rubber roll rice mill (also known locally as *baby cono* or mini *cono*). This rice mill eventually replaced the kiskisan in providing milling services in rural areas. Milling and whole grain recoveries of this mill are better than kiskisans (above 60%). In addition to village mills permanently installed in village or town centers, these custom mills are also found mounted behind jeeps or small truck to service farmer-villagers.

Fig. __. Single-pass rubber roll rice mills as stationary units in village/town centers or mounted behind locally assembled jeep provide milling services in the villages.

Big rice millers now adopt multiple milling units to improve milling and whole grain recoveries. These units separate the processes of dehulling or dehusking (taking off the hulls from the paddy grains), whitening (removing the bran layer enclosing a dehusked grain), polishing (to give the grains a polish attractive to consumers) and separating broken grains from whole grains. In larger mills, the husked grain, called brown rice, are further stored temporarily in tempering bins to "rest" the grain before these are whitened and polished with spray mists of water to come up with glossy, whole grains. These technology improvements were developed abroad although local manufacturers have been fairly successful in producing local versions.

Fig. __. Modern rice mill systems employ multiple passes of grains through different mill components to maximize recovery and whole grains output.

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