RICE RESEARCH INVESTMENTS, VARIETAL RELEASE AND ADOPTION IN SRI LANKA

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Abstract

Sri Lanka has shown a significant achievement in rice production leading to the realization of self-sufficiency. The outstanding performance of the rice sector is mainly attributed to technological advancement and implementation of favorable policies by the government. Development of improved rice varieties is the major component of this technological change. These improved varieties are now widely adopted by farmers throughout the country. To sustain the productivity growth, it is important that the rice breeding program of Sri Lanka continues to improve rice varieties that are best adapt to field conditions. Analyses of the varietal release patterns and cultivar-specific estimates of area under improved varieties are needed to help design future breeding priorities. The study provides such an analysis using data generated from different approaches including a survey of rice scientists and the expert panel elicitation of cultivar-specific adoption rates. The brief review of trend, government policies and research direction illustrates the growing interest on rice cultivation in varying agro-climatic zones. At present, rice breeders mainly concentrate on varietal development for problem areas which have potential improvement. The results of expert panel estimation of varietal spread in Sri Lanka were comparable with available secondary information. The expert panel exercise is a cost-effective and a rapid approach in

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estimating varietal spread which can avoid problems with present lag in data collection process. With a system of collecting varietal adoption data already in place, expert panel elicitation method is useful in verifying accuracy of estimates derived from national surveys. Moreover, timely availability of varietal adoption information is useful in reviewing investment on research and development and setting rice breeding priorities.

Keywords: *Expert panel elicitation, rice research investment, varietal adoption patterns*

Introduction

Rice is the staple crop in Sri Lanka occupying 47% of the agricultural area and contributing 11% to agricultural gross domestic product (Central Bank, 2012). Rice occupies nearly 12% of arable land in Sri Lanka and around 1.5 million farm families are involved in rice production. The country achieved self-sufficiency in rice in 2010 owing to the adoption of improved technologies and strong government support.

Rice production increased from 1.92 million tons in 1979 to 4.28 million tons in 2010. The increase in production is partly due to the expansion in rice area from 0.78 million hectares in 1979 to 1.05 million hectares in 2010. This expansion in area was achieved through the cultivation of paddy lands in conflict-affected areas after the cessation of the civil war. The re-cultivation of abandoned paddy lands during the civil war was the result of government encouragement and escalation of rice prices. Increase in rice yield was the main contributory factor in increased production as the yield almost doubled from 2.75t/ha in 1979 to 4.54t/ha in 2010. This improvement in productivity is a result of the remarkable contribution of rice research and improvements in irrigation infrastructure.

The Rice Research and Development Institute (RRDI) in Sri Lanka is the sole agency responsible for the generation of rice production and protection technologies. These technologies helped improve productivity and profitability of rice production in the country. Since its inception in 1952, RRDI continues to develop high-yielding rice varieties (HYV) with multiple resistance to major biotic stresses and tolerance to abiotic stresses. By 2010, RRDI has released 69 rice varieties adaptable to diverse agro-ecological conditions (see Appendix for a complete list of varietal releases). Although there has been almost full adoption of HYVs, 58% of the total rice area is grown with only 4 dominant varieties (Jayawardena *et al*, 2010). Three of these varieties were released before 1993. Hence, there is a need to know what is happening to varietal change as a result of rice genetic improvement. Information on cultivar-specific adoption helps in deciding on relative resource allocation and specific lines of research. However, a large amount of resources and time is required to conduct surveys to collect such information.

This study aims to develop alternative methods of obtaining "quick and clean" estimates of varietal adoption levels that can be used to regularly monitor varietal adoption. The study also aims to assess rice varietal release pattern and extent of investment in rice genetic improvement. The general approach adopted follows the research design developed in the project "Tracking of Improved Varieties in South Asia (TRIVSA)" which is a collaborative study between the International Rice Research Institute and the Department of Agriculture of Sri Lanka. The expert panel elicitation method was tested in the study as an alternative to the conventional method of using household survey to obtain estimates of varietal adoption. Results of the expert panel elicitation method was compared with estimates derived from varietal adoption data collected by the Department of Agriculture and the Department of Census and Statistics in order to identify strengths and weaknesses of the method.

The report is organized as follows. The first section briefly discusses the rice production systems and trends in Sri Lanka from 1979 to 2010. The second section discusses the organization of and investments in rice research. Results of the expert panel elicitation method are discussed in the succeeding section and finally, conclusions are presented in the final section.

Rice Production Systems

In Sri Lanka, rice is grown in two seasons; *Maha*, the wet season crop, and *Yala*, the dry season crop. *Yala* is grown in April to September while *Maha* is grown in October to February. *Maha* is the main rice-growing season as nearly 61% of the annual production and annual rice area is from *Maha* season as recorded in 2010.

Agricultural land in Sri Lanka is divided into three climatic zones based on rainfall; dry, wet and intermediate. Most of the southeast, east and northern parts of the country comprise the dry zone and receive rainfall of 1200-1900 mm/year. Much of the rain falls in October to January and little precipitation is received for the rest of the year. Also falling under the dry zone is the arid northwest and southeast coasts which receive the least amount of rain (600-1200 mm/year) normally, concentrated within the short period of the monsoon. The central hilly areas and southwestern part of Sri Lanka known as the wet zone receives ample rainfall of over 2500 mm/year without pronounced dry periods. The intermediate zone is the area between the wet and dry zones receiving an average rainfall of 1750-2500 mm/year. Rice is cultivated in all 3 zones with the dry zone covering 60% of total rice area, the intermediate zone and the wet zone cover 22%, and 18%, respectively, (Table 1).

There are two types of irrigation schemes in Sri Lanka, major and minor. Major irrigation system is defined as one that has a command area of more than 80 ha. Small tanks or minor irrigation systems are those having an irrigated command area of 80 ha or less (Sivayoganathan and Mowjood, 2003). Major and minor irrigation schemes provide assured irrigation to 53% and 23% of total rice area, respectively, while rice production in the remaining 24% of the area relies on rainfall.

Table 1: Rice Area by Agro-ecology and Source of Water in Sri Lanka, 2010

	Sown Area ('000 ha)	% Share in Area
Agro-ecology		
Dry Zone	639	60
Intermediate Zone	237	22
Wet Zone	189	18
All	1065	100
Source of irrigation		
Major	562	53
Minor	247	23
Rainfed	257	24
All	1065	100

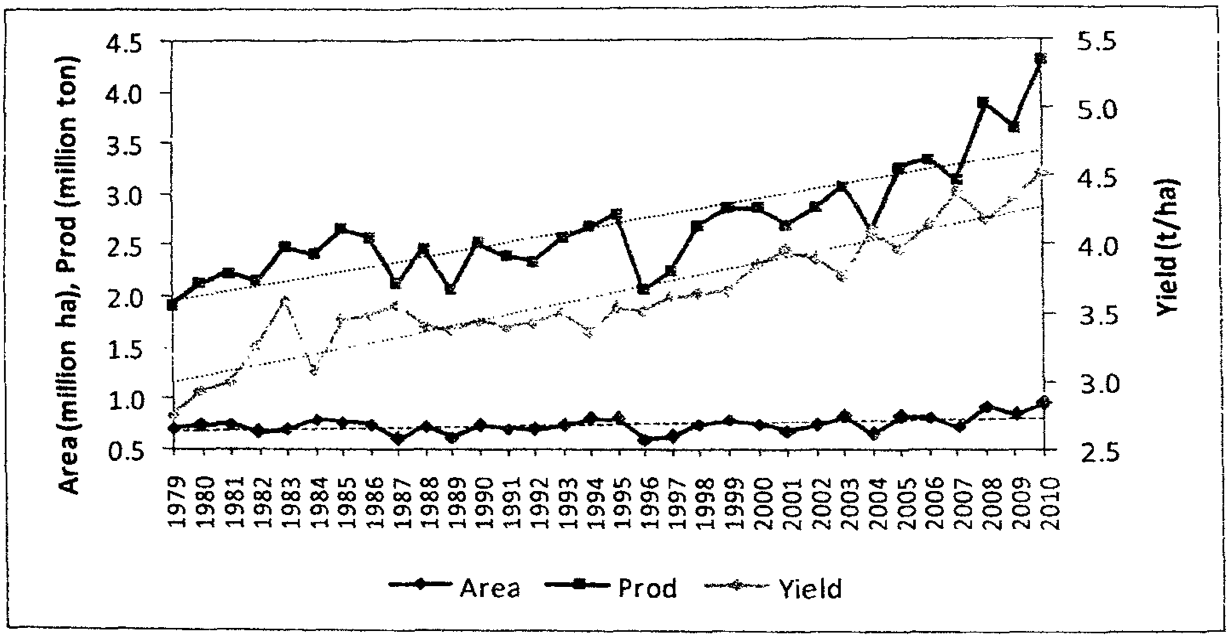
Source: Department of Census and Statistics, Sri Lanka.

Rice-growing areas in Sri Lanka can be categorized as favourable and unfavourable based on water availability. Irrigated areas (major and minor) can be considered as favourable environments since it has assured water supply throughout the growing period. These favourable areas determine the national rice production and research and investment on rice were generally concentrated in these areas. These favourable areas are also the major rice-growing areas contributing 76% to national rice production in 2010 (Department of Census and Statistics). Unfavourable areas, on the other hand, are areas with poor drainage and areas exposed to salinity and iron toxicity. Karunagoda *et al* (2010) reported that in their study which was conducted in favorable areas in districts of Polonnaruwa, Ampara, Anuradhapura, Hambantota and Kurunagala, rice is cultivated for commercial purposes as marketable surplus was about 65-75% of the rice harvest. On the other hand, areas cultivated under rainfed conditions were generally considered unfavourable areas. These unfavourable areas are important in terms of household food security as farmers in these areas produce rice for their own consumption. In addition, the wet zone serves as a buffer zone whenever calamities cause crop damage in major growing areas.

Trends in Rice Production, Area and Yield

Rice production as presented in Figure 1 shows an upward trend in the period 1979-2010 despite fluctuations. Fluctuations in production are due to changes in government policies and climatic conditions. The abolishment of the Paddy Marketing Board and reduction of the government support through liberalization of rice market under private sector led to a decline in production while policies such as technological advancement and escalation of world market price of cereals led to the increase in production. The annual growth rate of production 1.66% is mainly due to growth in rice yield (Table 2). Growth in production was the highest in the *yala* season. As the yield has almost the same growth rate in each season, expansion in area during the *yala* season made a significant contribution to the growth in production during that season. A closer look at the growth in area by source of irrigation in the *yala* season shows that expansion in rice area during the season is due to expansion in area irrigated through the major irrigation scheme (Table 3). Irrigation by the major irrigation scheme was also implemented in re-cultivated areas following the civil war and in rainfed rice cultivating areas, as a decline in rainfed rice cultivating area during the *yala* season is observed (Figure 2). This is further supported by the high negative annual growth rate of -1.98% in the rainfed area during the period (Table 3).

Figure 1: Trends in Rice Area, Production and Yield in Sri Lanka, 1979-2010



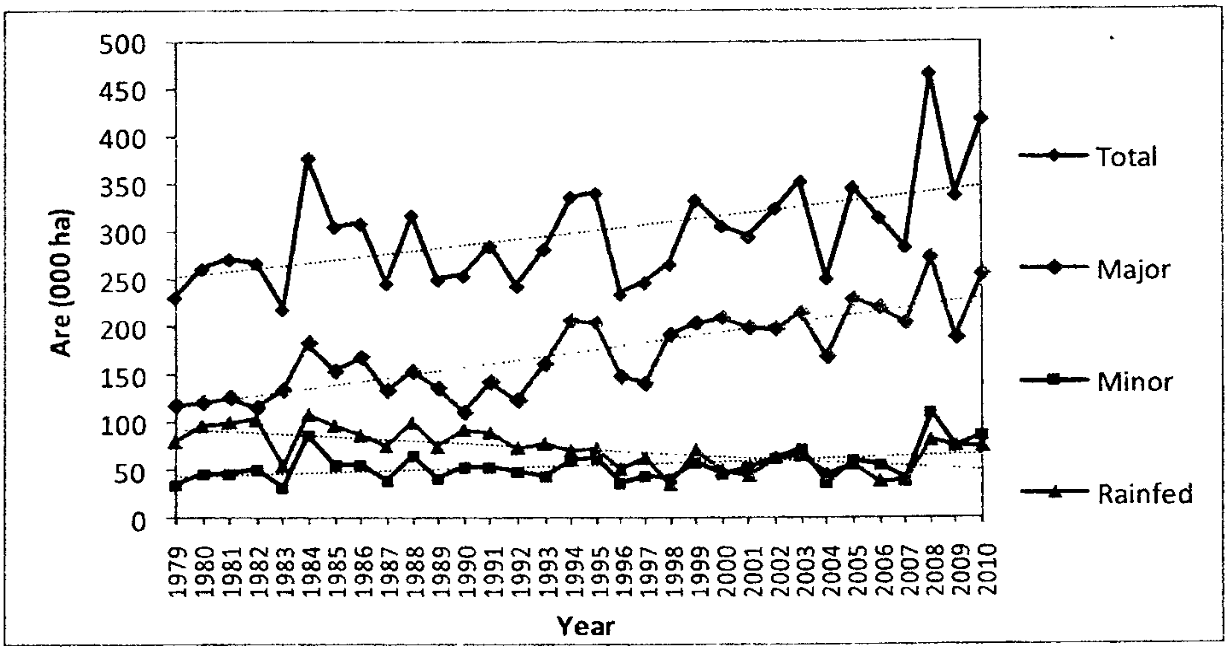
Source: Department of Census and Statistics, Sri Lanka

Table 2: Annual Growth Rates (%/year) of Rice Area, Production and Yield, 1979-2010

Season	Area	Prod	Yield
Maha	0.26	1.35	1.09
Yala	1.01	2.27	1.26
Annual	0.52	1.66	1.14

Source: Authors' estimation

Figure 2: Trends in Rice Area by Source of Water During *Yala* Season, 1979-2010



Source: Department of Census and Statistics, Sri Lanka

Table 3: Annual Growth Rates (%/year) of Rice Area by Season and Source of Water, 1979-2010

	Major	Minor	Rainfed
Maha	1.11	0.32	-0.93
Yala	2.14	1.25	-1.98
Annual	1.53	0.58	-1.25

Source: Authors' estimation

Factors Affecting Rice Production

Government policies played an important role in achieving self sufficiency not only in rice but also in other food crops. Policies in support of rice production mainly include provision of subsidies for producers, trade protection, guaranteed price scheme, development of irrigation infrastructure, credit and insurance programs. The impact of these policies on rice production has been investigated by many researchers. The most prominent policy is the input subsidy program which had a significant impact on rice production in the country (Ekanayake, 2006; Rajapaksa and Karunagoda, 2009; Weerasooriya and Gunarathne, 2009).

Furthermore, Rajapaksa and Karunagoda (2009) and Ekanayake (2006) confirmed that paddy production is more responsive to farm gate paddy price than input price hence, output price policies were important in the increase of paddy production. Rice marketing has undergone a series of changes in the last decade and government intervention was carried out through the expansion of market facilities. As a result, substantial improvement in rice marketing was observed, however, Karunagoda *et al* (2010) recommended further institutional development to obtain maximum benefits. In addition, Walisinghe *et al* (2008) reported that rice markets are well integrated indicating that efficiency in rice pricing was achieved through the development of market infrastructure.

On the other hand, technology improvement also had a positive impact on rice production as the institution on rice research introduced several HYVs. Widespread adoption of these varieties led to a positive effect on paddy production. Observing the importance of this activity, the government prioritized investments on rice research. Present investment on rice research needs to continue to cater to the future demand for rice to ensure national food security. With the present population growth rate, rice demand is expected to increase to 2.7 million tons in 2020 (Herath *et al*, 2010). Apart from population growth, rice demand depends on other factors such as price of rice and substitutes for rice, per capita income, food consumption diversification, and urbanization. Empirical studies that have estimated own price and cross price elasticities of rice and rice substitutes showed that urbanization may reduce the demand for rice. Despite an expansion of urban areas, rice consumption has shown an increasing trend (115 Kg/head/yr) over the years (Food Balance Sheet, 2010). In addition, recent climatic changes pose a severe threat to rice production from time to time.

Organization of Rice Research

The urgency and importance of increasing domestic rice production was recognized with the dawn of independence in 1948 and development of improved varieties through hybridization was considered the key approach to raising production. Accordingly, an extensive hybridization program was initiated in 1952 to meet the demand for four different maturity durations ranging from 5-6 months to 3 months. The initial success of the above hybridization program was a medium-maturity variety (125 days), H-4, which was released to farmers in 1958. Due to its wide adaptability to a range of soil and environmental conditions, H-4 rapidly gained farmers' acceptance. H-4 was soon followed by H-

7 (100 days), H-9 (150days), and H-10 (90 days). These varieties commonly identified as old improved varieties (OIV) combined blast resistance with moderate response to chemical fertilizers (Weerarathne and Senadhira, 1981).

With the release of OIVs in late 1950s and early 1960s, major changes occurred in the rice production system as the traditional system of single cropping was replaced by double cropping. H-4 was popularly grown in the *yala* season while H-7 and H-10 were widely grown in the *maha* season. The stagnant national average of 1.5t/ha in the 1950s was elevated to 2.0t/ha in the late 1960s. The plant type of the OIV was similar to the traditional cultivars but entailed reduced plant height. However, at high fertilizer levels, the OIVs were susceptible to lodging. Varieties with lodging resistance, a much needed characteristic that will complement the use of high levels of nitrogen, became available with the incorporation of the dwarf gene from IR 8. IR 8 is a semi-dwarf variety developed by the International Rice Research Institute (IRRI) that produced high yield when grown with fertilizers in irrigated fields.

The second stage of the hybridization program in the late 1960s and early 1970s used dwarf germplasm from IRRI. This hybridization program produced a series of new varieties called new improved varieties (NIV). NIVs such as Bg 3-5 (5-6 months photo-period sensitive), Bg 34-6 (3 1/2 months), and Bg 34-8 (3 months) have a combination of traits such as dwarf plant type, good level of tolerance to lodging, moderate resistance to prevalent diseases, and higher responsiveness to chemical fertilizer. When grown under proper management, NIVs have potential yields of 7 t/ha which was a significant improvement over the OIVs. This development increased national average yield to 2.8 t/ha in early 1970s. As farmers adopted dwarf plant types and adjusted management practices, further increases in yield were achieved in mid-1970s. Three new varieties, Bg 90-2 (4-4 1/2 months), and Bg 94-1 and Bg 94-2 (both 3 1/2 months), were released in mid-1970s. Yield potential of new varieties under favorable management approached a record yield of 10t/ha. Adoption of NIVs not only signified a change in the plant types grown by farmers but also a change in rice management practices particularly on the use of inputs such as fertilizer and pesticides. The NIVs, though characterized by high yield potential, lacked resistance to common insect-pests prompting farmers to use high levels of pesticides which then led to environmental problems. Therefore, incorporation of resistance to brown plant hopper (BPH) and gall midge (GM) in the breeding programs became essential. This resulted in the development of GM-resistant varieties such as Bg 400-1 (4 months) and Bg 276-5 (3 months), and the BPH-resistant variety Bg 379-2 which were released in early 1980s.

Since 1980s, the varietal development program focused in developing varieties with adaptability to specific climate and soil conditions. Accordingly, regional development of varieties became a major aim of the breeding program. Regional stations in Ambalantota (At), Labuduwa (Ld), and Bombuwela (Bw) worked on developing varieties suitable to local conditions. Special emphasis was given to attributes such as better grain quality and tolerance to abiotic stresses such as iron toxicity and salinity. Adoption of NIVs and other associated production and protection technologies, on plant protection, use of fertilizer, and other crop management helped increase national average yield up to 4.5t/ha in 2010. In spite of desirable attributes of NIVs, a limited number of varieties were more popularly accepted by farmers. Identifying factors affecting varietal adoption is important in directing rice genetic improvement programs for developing varieties that cater to the needs of the farmers.

Investments in Rice Research

According to Niranjan (2004), in general, the nominal terms of expenditure in rice research has been increasing at a rate of Rs 922,636 per year in the period from 1959-1999. Abeysiriwardena (2004) reported that funding of rice research in Sri Lanka has been fluctuating at around Rs. 13 million in the period 1995 to 2004. Regardless of the amount of research funding, about 70% was utilized for rice breeding. This is a good indication of the relative importance of breeding as varietal improvement is paramount to increase the production in any crop. Abeysiriwardena (2004) also highlighted the importance of biotechnology in varietal development as plant biotechnologists incorporated the rice breeders in their genetic improvement work.

Out of the total resources available for rice breeding, RRDI utilized 95% for line development and evaluation and only 5% for germplasm enhancement from 1985 to 2000. However, by 2004, 5% of the allocation was diverted to plant biotechnology from the conventional breeding budget. The use of biotechnology in rice breeding is mainly on wide hybridization and haploid breeding.

Full Time Equivalent Analysis (FTE)

A survey of rice researchers' time allocation on rice varietal improvement was conducted using a structured questionnaire in 2010. Data was collected on rice research involvement by scientists from the Department of Agriculture, Agricultural universities and other related research institutes.

Following Pandey and Pal (2007), rice scientists' time allocation in rice breeding-related work was estimated using full-time equivalent (FTE). FTE is defined as the sum of percentages of time spent on a specific research over all researchers, divided by 100. An FTE value of one is equivalent to one person working full-time. FTE was also used as a proxy to investigate the resource allocation for different agro-ecological zones of rice.

Of the 41 researchers included in the survey, only 24 were working on rice breeding-related research of which 16 were plant breeders. The lone scientist in the field of bio-statistics was working on screening for drought-tolerant varieties and screening of aerobic rice varieties. Full-time equivalent of the 24 scientists was 18.5 in 2010. With a rice area of 1.05 million ha, FTE per million hectares was 17.5.

Increase in rice production that led to the country becoming self-sufficient in rice also led to farmers having marketable surplus. As a market for premium quality rice is emerging, breeding programs must be geared towards development of varieties with good grain qualities as desired by consumers. An assessment of time allocation by theme showed that varietal development is now addressing issues related to abiotic stresses and grain quality while they continue to develop varieties with high yield and pest and disease resistance (Table 4). The themes were identified by the researcher survey.

Table 4: Time Allocation of Rice Scientists Involved in Breeding-related Research by Theme, 2010

Theme	FTE	% Share in FTE
Abiotic stresses (drought, salinity, iron toxicity, heat)	3.7	20
Higher yield	2.6	14
Pest and disease resistance	2.4	13
Grain quality	2.3	13
Crop management (pest, disease, weed, nutrient)	2.0	11
Varietal selection	1.1	6
Molecular breeding	1.0	5
Grain quality and abiotic stress)	0.9	5
Aerobic rice	0.9	5
Conservation of germplasm	0.9	5
Pest and disease resistance and iron toxicity	0.8	4
Total FTE	18.5	

Source: Authors' estimation

The dry and intermediate zones were the main focus of rice resource investment in terms of scientists' time allocation as its share in FTE was 75% in 2010 (Table 5). This share in FTE was to a certain degree proportional to the area coverage of this agro-ecology which was 82% of rice area in 2010. Share in FTE of wet zone which covers 18% of rice area was 25%. With this share in FTE, more varieties are expected to be developed for the dry and intermediate zones.

Table 5: Time Allocation of Rice Scientists by Agro-ecology, 2010

Agro-ecology	FTE	% Share in FTE
Dry	2.90	16
Dry and Intermediate	10.40	56
Intermediate	0.50	3
Wet	4.7	25
Total	18.50	100

Source: Authors' estimation

Varietal Release Pattern and Farmer Adoption

Selecting a variety for cultivation requires careful consideration of climatic factors, soil type, irrigation facilities, farmer practices as well as consumer preferences (Weerakoon *et al*, 2005). Farmers consider the varietal traits when deciding on which variety to grow. Farmers prefer varieties which are high-yielding, with good eating and grain quality, semi-dwarf type, with good tillering and tolerant to abiotic stresses. On the other hand, farmers dislike varieties that are susceptible to pest and diseases.

Farmers also consider maturity in their varietal choices as short duration varieties will allow the cultivation of a second crop. As rice scientists incorporated maturity into their breeding work, varieties of different maturity were released over time (Table 6). Forty varieties released have 2 ½ - 3 ½ months' maturity. As shown in the table, breeders ceased to develop varieties with 5-6 months' maturity since the 1990s.

Table 6: Varietal Release Pattern by Maturity (number of varieties)

Maturity period	1958-1969	1970-1979	1980-1989	1990-1999	2000-2010	1958-2010
2 1/2 month	0	0	1	0	1	2
3 month	2	2	4	3	3	14
3 1/2 month	1	4	4	9	6	24
4-4 1/2 month	2	6	6	6	4	24
5-6 month	1	1	3	0	0	5
Total	6	13	18	18	14	69

Source: Rice Research and Development Institute

Table 7 presents varietal release by decade in different agro-ecologies. Of the 69 varieties released in Sri Lanka, majority are recommended for general cultivation and only a limited number is targeted towards specific agro-ecologies. Seventeen varieties are recommended specifically for the wet zone which covers only 18% of total rice area while 9% are recommended for unfavorable land which are areas with saline soils, acidic soils, iron toxicity, drought-prone and flood-prone. The trend has almost always been the same over time except in the 80s. Except for Bg 407 H, which is the first hybrid variety released 2005 in Sri Lanka, all others are inbred varieties.

Photoperiod sensitive rice varieties with long maturity (5-6 months) such as Bg 38 and Bg 745 are cultivated in lowland areas identified as *mawee* lands. These varieties can withstand extreme flood conditions in the early stage of crop growth. Rice cultivation in *mawee* land does not require weeding nor pesticides and is grown only in *Maha* season. Development of varieties for *mawee* cultivation was stopped in 1990s as the focus shifted towards development of short duration varieties.

Table 7: Varietal Release Pattern by Agro-ecology (Number of Varieties)

	1958-1969	1970-1979	1980-1989	1990-1999	2000-2010	1958-2010
Dry zone	1	0	0	0	1	2
Dry and Intermediate zone	0	0	2	1	0	3
Intermediate zone	0	0	1	0	0	1
Wet zone	0	3	6	5	3	17
General cultivation	4	8	5	9	9	35
Mawee land	1	1	3	0	0	5
Unfavorable land *	0	1	1	3	1	6
Total	6	13	18	18	14	69

* Unfavourable land areas with saline soils, acidic soils, iron toxicity, drought-prone and flood-prone.

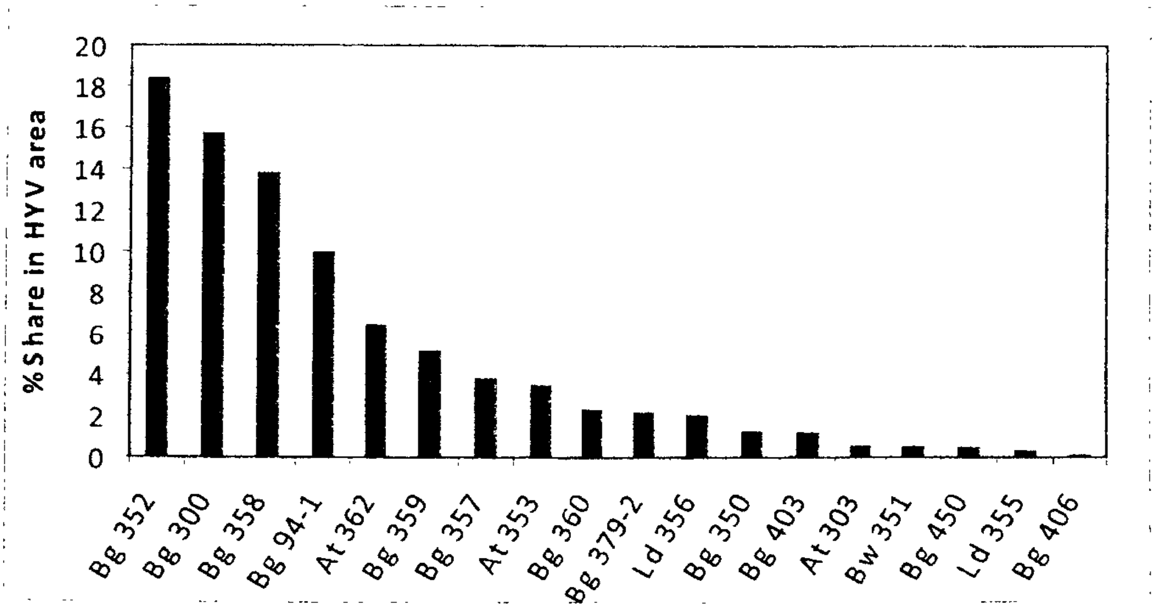
Source: Rice Research and Development Institute

Varietal Adoption Patterns

Despite the government's active role in improving rice production and promoting new releases, HYVs cover almost 98% of total rice area. Despite the numerous traditional varieties (TV) existing in Sri Lanka, TVs are grown only in 0.15% of the total rice area and the remaining 1.4% is unknown varieties. Traditional rice varieties are grown mainly in areas with specific environmental constraints or for specific markets as they are perceived to be more nutritious than HYVs.

The top 4 HYVs in 2010 which cover 58% of HYV area, are Bg 352, Bg 300, Bg 358 and Bg 94-1 (Figure 3). Except for Bg 358 which was released in 1999, the popular HYVs were released before 1993. These varieties have maturity of 3-3 ½ months and are recommended for general cultivation with potential yield ranging from 6.0-9.5 t/ha. Bg 300 was reported by Wang, et al (2012) to be dominant even in environments prone to abiotic stresses. Bg 300 is preferred by farmers for traits such as high-yielding, short maturity, and resistance to major rice pest and diseases. OIVs which are long duration varieties (H-series HYVs) are no longer grown as NIVs have completely replaced OIVs. Average varietal age of HYVs was estimated to be 18 years which indicates that varieties commonly grown by farmers in 2010 were those released in the early 1990s.

Figure 3: Major Rice Varieties Cultivated in 2010



Source: Rice Research and Development Institute, Sri Lanka

The study by Jayawardena et al (2010) showed that, out of the 68 rice varieties released by the Department of Agriculture up to 2009, farmers adopted 53 varieties. Among them, 15 varieties accounted for 68% of the total extent cultivated in Sri Lanka and four varieties (Bg 300, Bg 352, Bg 358 and Bg 94-1) dominate. Among the 15 popular varieties, 11 varieties belong to 3-3 ½ age class. The main reason for the adoption is high yielding ability in this group over other age classes. Alternatively, water shortage has influenced farmers to shift from long duration varieties to 3-3 ½ months age class. Rice varieties of 4-4 ½ months were highly adopted by farmers in 1980s. Adaptability of rice varieties varies across geographical locations in the country. Further, soil fertility, water availability, consumer preference, reaction to pest and diseases and other environmental factors affect the varietal spread.

Table 8 presents the percentage area grown to HYVs with different maturity. A large proportion of HYV area was grown to 3 ½ months in 2010 and these varieties cover 72% of the HYV area. Although not popular, 3 month-maturing HYVs were also grown but in 20% of HYV area only. An even shorter duration HYV (Bg 250), which is a 2 ½-month variety, is grown in a small proportion as farmers have just started adopting the variety since its release in 2005. This ultra short variety is recommended for drought-prone areas as it can be harvested early allowing the crop to withstand drought. HYVs with 4-4 ½ months maturity were also being grown but to a limited extent.

Table 8: Varietal Adoption by Maturity, 2010

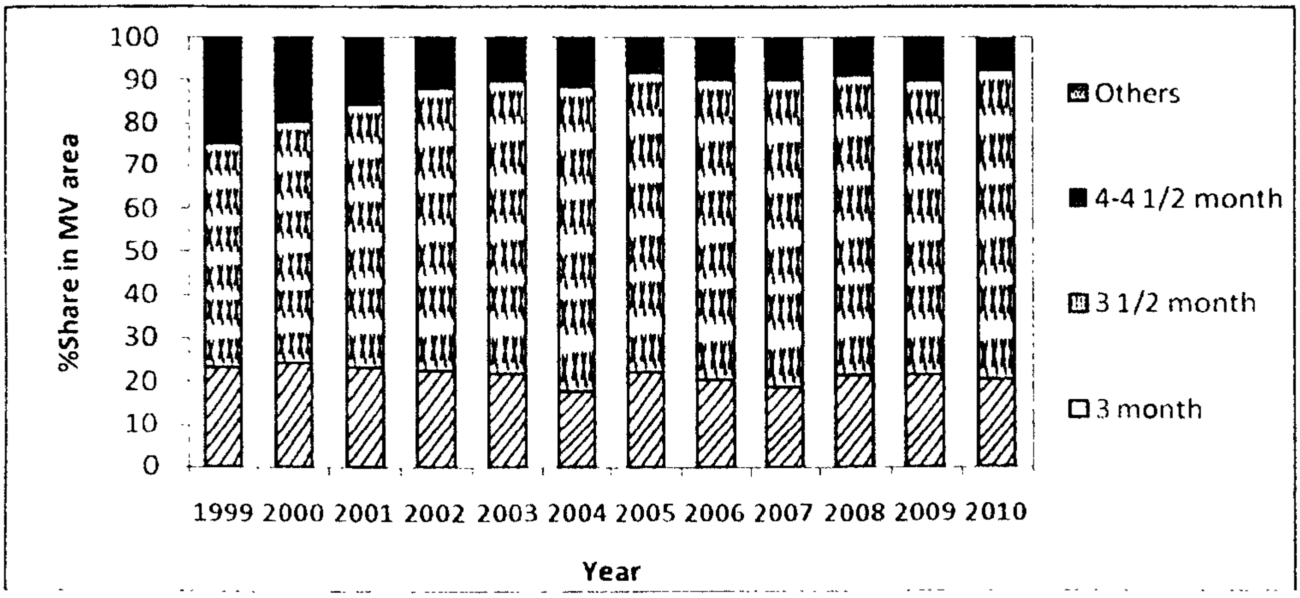
Maturity period	% Share in HYV area
2 1/2 months	0.3
3 months	20
3 1/2 months	72
4-4 1/2 months	7
5-6 months	0.1
Other HYVs	1.4

Source: Rice Research and Development Institute, Sri Lanka

Varietal Replacement Patterns

Results of the national surveys conducted yearly from 1999 to 2010 which contains varietal adoption data collected by the Rice Research and Development Institute of Department of Agriculture, Sri Lanka, and Department of Census and Statistics were used to show varietal adoption/dis-adoption pattern. Although 3 ½ month-maturing HYVs were already widely grown at 52% in 1999, adoption has further expanded to 72% in 2010 (Figure 4). A replacement of medium-duration HYVs (4-4 ½ months) with short-duration HYVs (3 ½ months) was observed. This replacement occurred mostly in the *yala* season in areas where irrigation was made available. Cultivation of early maturing HYVs during the *yala* season permitted the cultivation of a second crop. During the same period, area grown to 3-month maturing HYVs was observed to have stabilized at 22%.

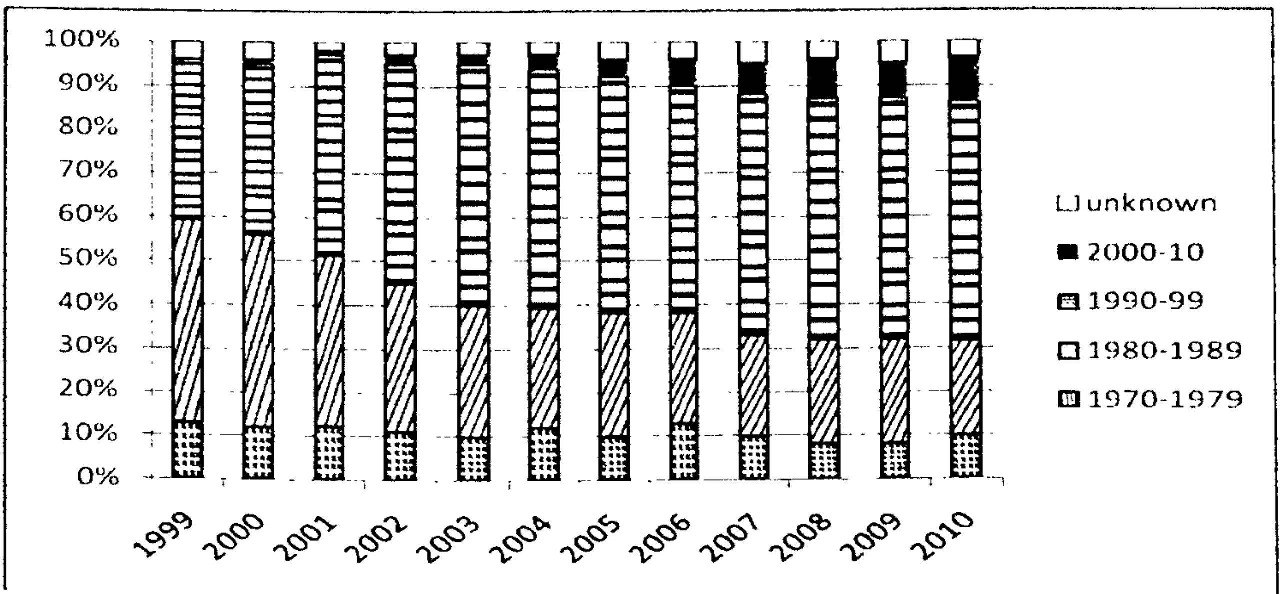
Figure 4: Trends in Varietal Adoption by Maturity, 1999-2010



Source: Rice Research and Development Institute

As expected, the trend analysis from 1999-2010 of varietal adoption by period of release shows a replacement of old varietal releases with new varietal releases resulting in a reduction of varietal age from 22 years to 18 years (Figure 5). Varieties released in the 1970s continued to be cultivated in about 11% of the HYV area within the period 1999-2010. Whereas, HYVs released in the 1980s were replaced with HYVs which are 10 years younger. HYVs developed in the last decade is slowly expanding and have reached 10% in 2010.

Figure 5: Trends in Varietal Adoption by Period of Release



Source: Rice Research and Development Institute

A comparison of varietal adoption between 2 periods, 1999 and 2010, is presented in Table 9. HYVs which were previously not grown as they were released only in 1999 and 2002 such as Bg 358, Bg 359, Bg 360 and At 362 collectively cover 27% of the HYV area in 2010. Old HYVs with 3 ½ maturity such as Bg 350,Bw 351, and Ld 355 and with 4-4 ½ maturity such as Bg 379-2, Bg 450 and Bg 403, showed a substantial decline from 32% to 6%. Most of these varieties were released before 1990. In significant proportion of HYV area 3 ½ month maturing HYVs are grown, which are more or less stabilized at 54% of HYV area and most of these HYVs were released in the early 1990s.

Table 9: Varietal Changes in the Period 1999-2010

Variety	Maturity	Year of Release	% Share in MV Area		Growth Rate (%/year)
			1999	2010	
Bg 358	3 1/2 month	1999	1	14	19
Bg 359	3 1/2 month	1999		5	35
Bg 360	3 1/2 month	1999		2	32
At 362	3 1/2 month	2002	0	6	48
Bg 350	3 1/2 month	1986	5	1	-12
Bw 351	3 1/2 month	1986	3	1	-15
Ld 355	3 1/2 month	1994	5	0	-26
Bg 379-2	4-4 1/2 month	1980	6	2	-7
Bg 450	4-4 1/2 month	1985	8	1	-20
Bg 403	4-4 1/2 month	1993	5	1	-10
Bg 94-1	3 1/2 month	1975	11	10	0
At 353	3 1/2 month	1992	5	4	-3
Bg 352	3 1/2 month	1992	13	18	3
Ld 356	3 1/2 month	1994	2	2	1
Bg 357	3 1/2 month	1997	2	4	6
Bg 300	3 month	1987	19	16	-1
At 303	3 month	1990	1	1	-3
Bg 406	4-4 1/2 month	2005		0	-6
Other HYVs			13	11	

Source: Authors Estimation

353 which was grown in 4% of HYV area is the only HYV that experts failed to identify as belonging to the top 10 popularly grown HYV.

Table 10: Estimates of Varietal Adoption from Expert Panel Elicitation and National Survey

	Expert Elicitation			National Survey
	Maha	*Yala*	Both Seasons	
%HYV area	100	100	100	98
Cultivar-specific adoption (%Share in MV area)				
Bg 352	20	16	18	19
Bg 300	15	20	17	16
Bg 358	14	14	14	14
Bg 94-1	9	8	8	10
At 362	7	6	6	7
Bg 359	6	5	5	5
Bg 379-2	4	1	3	2
Bg 360	3	2	2	2
Bg 357	2	2	2	4
At 307	2	3	2	1
Bg 250		0.15	0.06	
Other HYVs	22	26	23	19

Source: Authors Estimation

Lessons Learned

Expert panel elicitation method expedites the long process of data collection and tabulation mechanism which is characteristic of survey methods. For a rapid appraisal of the varietal spread, expert panel elicitation method is advantageous because of its cost-efficient and time-saving attribute compared to the conventional survey method. However, the method is highly dependent on proper identification of resource persons who are knowledgeable about varietal adoption in the specific area of interest. Expert elicitations conducted at sub-national levels such as regional or district level may be useful in planning, breeding and extension programs adaptable to the region or district. Expert elicitations may also be conducted for representative areas of different agro-ecological zones to improve the precision of the estimates.

Results of Expert Panel Elicitation

Although Sri Lanka has a system already in place for the collection of general statistics relevant to the agriculture sector, timely availability of reliable data is a constraint. As tracking varietal change is useful in assessing the impact of crop genetic improvement, particularly for a crop that is as important as rice, a method of obtaining quick and clean estimates of varietal adoption is necessary. In order to address problems related to the present data collection system, expert panel elicitation method was tested.

A panel of experts consisting of research administrators, breeders, extension agents, economists, seed and planting material experts, and resource persons representing the Department of Agriculture, state universities and private institutions was convened. Two farmer leaders were also invited to the elicitation meeting. These experts have served in different rice-growing areas and therefore have a fair understanding of varietal adoption in different agro-ecological zones. Farmer leaders provided knowledge based on their experience and experiences of their constituents.

The expert panel elicitation method used in Sri Lanka under the TRIVSA project is a modified Delphi method which involved 2 rounds of elicitation of varietal adoption in each season. Estimates of area coverage of different varieties were based on the perception of resource persons considered to be knowledgeable on varietal adoption. The first round involved elicitation of estimates for each season from individual experts. Experts were then grouped into 2 heterogeneous teams and a second round of elicitation was done for each season from each team. Annual estimates were obtained by aggregating estimates for each season. Aggregating season-wise estimates was done using rice area in each season as weights.

Results of the final round of estimation are depicted in Table 10. Expert estimates were validated using national survey results which contain varietal adoption data collected by the Department of Agriculture in collaboration with the Department of Agrarian Services and published by the Department of Census and Statistics. Area grown to all HYVs in both seasons was over-estimated by experts by only 2%-pts when compared with the national survey estimate. The top 9 HYVs based on area coverage as reported in the national survey were well identified by experts with a mean absolute error of 1%-pt. The top 6 HYVs ranked by experts were consistent with the rankings in the national survey. At

However, expert panel elicitation method may not be useful in Sri Lanka for the time being since there is already a system in place for collecting information on area coverage of different varieties. This method may be useful in cross-checking results of the national survey for accuracy. The high correspondence between the expert estimates and the survey estimates is because experts invited to the elicitation had access to reports on varietal adoption collected in the national survey. Hence it is important to invite experts with ground-level knowledge of varietal adoption if it is to be used to cross-check the survey results. Expert panel elicitation method will also be useful in the event that the activity on data collection of varietal adoption is terminated.

Conclusions

At the onset of the Green Revolution, increase in production through improvements in productivity was the motive of rice breeding programs. RRDI and its satellite stations continuously make efforts to elevate the genetic potential of rice varieties through conventional and heterosis breeding. Development of early-maturing high-yielding rice varieties complemented with improvements in irrigation infrastructure led to the increase in rice production and expansion in rice area which was more prominent during yala season. These changes contributed to the country becoming self-sufficient in rice and farmers having marketable surplus. As a market for premium quality rice is emerging, breeding programs must be geared towards development of varieties with good grain qualities as desired by consumers.

As allocation of rice research funds are not normally segregated by agro-ecology, comparison of rice investment by agro-ecology was made possible with the estimation of FTEs. By and large, investment on rice research is concentrated in high potential areas such as the dry and intermediate zones while unfavorable areas such as the wet zone receive low research investment. Such allocation of investment was found to be satisfactory as the resource investment for each agro-ecology was proportional to the share in area of the agro-ecology to a certain extent.

Government efforts in disseminating HYVs paid-off as 98% of rice area is grown with HYVs. However, despite the availability of 69 HYVs developed by RRDI, only a limited number of varieties are popularly cultivated in 2010. Four HYVs which have maturity of 3- 3 ½ months cover a total of 58% of the HYV area. NIVs have completely replaced OIVs. Varieties commonly grown by farmers in 2010 were those that were released in the early 1990s.

Expert panel elicitation method piloted in this project showed results which highly corresponded with estimates from the national survey. The top 6 HYVs ranked by experts were consistent with the rankings in the national survey. However, this high correspondence is due to experts having access to reports of varietal adoption from the national survey. As there is a system already in place to collect data on varietal adoption, the new method may be useful in validating results of the national survey. Proper identification of resource persons knowledgeable in varietal adoption at the farm level in different rice-growing areas is important if the method is to be used to validate results of the national survey.

The study proves that the expert panel elicitation method is a cost-effective and rapid approach to estimate varietal adoption and may be used as an alternative to the conventional method of using farm household surveys. This method will provide timely available data on varietal adoption, which are useful to policy makers in allocating research investments and to breeders in assessing breeding programs.

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Appendix: Rice Varieties Released in Sri Lanka, 1958-2010

Year of Release	Release Name	Duration (months)	Recommendation
1958	H-4	4 - 4 1/2	General cultivation
1964	H-7	3 1/2	General cultivation
1966	H-8	4 - 4 1/2	General cultivation
1968	H-10	3	General cultivation
1968	H-9	5 - 6	*Mawee* land
1969	62-355	3	Rainfed/Manawari
1970	Bg 11-11	4 - 4 1/2	General cultivation
1971	Bg 34-6	3 1/2	General cultivation
1971	Bg 34-8	3	General cultivation
1971	Ld 66	4 - 4 1/2	Iron toxic soil and acidic soil
1971	Ml 273	4 - 4 1/2	General cultivation
1973	Bg 3-5	5 - 6	*Mawee* land
1975	Bg 94-1	3 1/2	General cultivation
1975	Bg 90-2	4 - 4 1/2	General cultivation
1977	At 16	3 1/2	Southern province
1977	Bw 78	4 - 4 1/2	Low country wet zone, Iron toxic soil
1978	Bg 94-2	3 1/2	General cultivation
1979	Bg 276-5	3	General cultivation
1979	Bw 100	4 - 4 1/2	Low country wet zone, Iron toxic soil
1980	Bg 379-2	4 - 4 1/2	General cultivation
1980	Bg 400-1	4 - 4 1/2	General cultivation
1981	Bg 750	2 1/2	Low country intermediate zone
1981	Bw 266-7	3 1/2	Low country wet zone
1981	Bw 267-3	3 1/2	Low country wet zone, Iron toxic soil
1981	Bw 272-6B	3	Low country wet zone (suitable for mineral, half bog and bog soils)
1981	Bg 38	5 - 6	*Mawee* land
1981	Bg 407	5 - 6	*Mawee* land
1981	Bg 745	5 - 6	*Mawee* land
1982	Bg 380	4 - 4 1/2	Major irrigation in Dry and Intermediate zone
1985	Bg 450	4 - 4 1/2	General cultivation
1986	Bg 350	3 1/2	General cultivation
1986	Bw 351	3 1/2	High potential area (mineral soil) of Low country wet zone
1987	Bg 300	3	General cultivation
1987	Bg 301	3	Rainfed Dry & Intermediate zone
1987	Bw 302	3	Saline and acid
1987	Bw 400	4 - 4 1/2	
1987	Bw 451	4 - 4 1/2	Low country wet zone, saline soil

Year of Release	Release Name	Duration (months)	Recommendation
1990	At 303	3	General cultivation
1992	At 353	3 1/2	Saline area
1992	At 354	3 1/2	Saline area
1992	Bg 352	3 1/2	General cultivation
1992	At 401	4 - 4 1/2	Costal Saline area
1992	At 402	4 - 4 1/2	Southern province
1992	Bw 452	4 - 4 1/2	General cultivation
1992	Bw 453	4 - 4 1/2	Low country wet zone
1993	Bg 304	3	General cultivation
1993	Bg 403	4 - 4 1/2	General cultivation
1994	Ld 355	3 1/2	Southern Province
1994	Ld 356	3 1/2	Kalutara and Gall districts
1997	Bg 357	3 1/2	Island wide cultivation
1997	At 405	4 - 4 1/2	Dry and Intermediate zone with assured supply of water
1999	Bg 358	3 1/2	General cultivation
1999	Bg 359	3 1/2	Wet zone
1999	Bg 360	3 1/2	General cultivation
1999	Bg 305	3	General cultivation
2002	At 362	3 1/2	General cultivation
2002	Bw 361	3 1/2	General cultivation
2003	Bw 363	3 1/2	General cultivation
2004	At 306	3	General cultivation
2005	Bg 250	2 1/2	Drought and Flooded area
2005	At 307	3	General cultivation
2005	Bg 406	4 - 4 1/2	Northern region
2005	Bg 407H	4 - 4 1/2	High potential area
2005	Bg 454	4 - 4 1/2	General cultivation with assured supply of water
2006	Bw 364	3 1/2	Wet zone
2008	Ld 365	3 1/2	Wet zone
2008	At 308	3	General cultivation
2009	Bg 366	3 1/2	General cultivation
2010	Ld 408	4 - 4 1/2	General cultivation

Source: Rice Research and Development Institute