

## **FOOT PRINTS IN RICE VARIETY IMPROVEMENT AND ITS IMPACT ON RICE PRODUCTION IN SRI LANKA**

R.M.T. RAJAPAKSE

*Plant Genetic Resources Center, Gannoruwa, Peradeniya*

C.A. SANDANAYAKE

*Regional Agricultural Research and Development Center, Bombuwela*

and

B.D. PATHINAYAKE

*Rice research Station, Ambalantota*

### **INTRODUCTION**

Pre-historic existence of rice is evident in Sri Lanka by the presence of wild species and land races. The prominence given to rice culture in the past (Pre-colonial era) is reflected by the magnificent irrigation systems constructed around the 5<sup>th</sup> century in the dry and intermediate zones. A wide range of cultivars had been grown for centuries under diverse agro-ecological conditions. However, very little information is available on rice cultivars and the technology adopted during this era. The collapse of ancient civilization in Rajarata and subsequent foreign invasions led to depopulation of the dry zone and the downfall of rice culture. The abolishing of the use of forced labor (*rajakariya*) in 1832 led to general neglect of the irrigation work and was accompanied by desuetude of the old customs of communal cooperation (*atham*) in paddy cultivation. Consequently the annual rice production fell to 0.114 million tons in 1856 with the cultivated extent being 0.159 million ha (table 1). With the enactment of the first paddy cultivation ordinance of 1857, which provision for voluntary restoration of the old systems, efforts have been made in the later half of the 19<sup>th</sup> century to increase rice production by expansion of land extent and provisions of irrigation facilities. As a result in 1903 the paddy extent increased to 0.285 million ha and the production to 0.27 million tons with an average yield of 0.96 t/ha (18.9 bu/ac) (Elliott, 1913).

During the early periods the cultivars used were exclusively traditional types. Liffe (1922) reported that a very cursory botanical study of such a type showed that it actually consisted of a number of types (varieties) and be considered as land races (Iliffe, 1922).

**Table 1. Progress of rice production in the later half of the 19<sup>th</sup> century.**

<i>Period</i>	<i>Land Extent million ha</i>	<i>Production million tons</i>	<i>Average yield t/ha</i>	<i>Average yield Bu/ac</i>
1856	0.159	0.144	0.72	14.2
1892	0.245	0.200	0.82	16.3
1893	0.235	0.214	0.91	18.2
1902	0.265	0.235	0.88	17.7
1903	0.285	0.270	0.95	18.9

### PAST EFFORTS TO IMPROVE RICE CULTURE

At the beginning of the 20<sup>th</sup> century attempts have been made to improve yield per unit area. Seed rates, method of crop stand establishment were experimented and introduced. Land preparation, weed control, inorganic and organic manure and crop rotation were among many factors investigated to improve productivity /unit area. Most of the experiments were conducted by the Ceylon Agricultural Society (Harbord, 1913; Lord 1927). The estimated area under paddy in 1913 was 0.266 million ha and the production was 0.192 million tons with the average yield of 0.72 t/ha (14.4 bu/ac). Prior to 1930s research on variety improvement has not been conducted. In 1902 a collection of around 300 cultivated rice varieties collected throughout the island had been exhibited by Nugawela Disawa at the Kandy, Agricultural – Horticultural exhibition (Molagoda, 1924). Although there was little interest in improving rice varieties, pure line selection (purification of land races) had been stressed as a possible mean of rice variety improvement. As mentioned before land race is a mixture of rice cultivars varying in their plant height, maturity duration, grain type etc. Pure-line had been developed by purification and selection of land races. The pure lines are genetically uniform. Such selections that had been carried out at Anuradhapura and at Peradeniya paddy stations demonstrated 15% yield increase over the unselected types or land races under experimental conditions. However, those selections had no impact on the production despite many farmer competitions and demonstrations organized and carried out throughout the country to popularize those (Wickramasinghe, 1926; Lord, 1927; Haigh 1932). In 1940s the Sri Lankan population size was around 6 million and about 75% of the rice requirement was imported. In 1940s the annual cultivated area to rice was around 0.379 million ha and the annual rice production was around 0.262 million tons with a national average yield of 0.65 t/ha (13 bu/ac). The varieties cultivated were all traditional type cultivars with low grain yield potential.

During the second world war the country under went a severe shortage of foreign exchange and as a result food importation was drastically reduced and a severe shortage of food specially rice was felt. The colonial rulers then recognized the importance of agricultural development, particularly rice, the

staple food. Moreover there had been a public up rising against the long decades of neglect of rice improvement.

To increase rice production in the country two basic requirements were considered i.e. expanding the cultivated extent and intensifying the production per unit area of land. But expanding the extent under cultivation was very expensive leaving the other alternative as the only approach. The basic requirement for increasing crop production per unit area of land is improved seeds. Since there was little or no research carried out in the country at that time, this basic requirement was lacking for increasing production. Then the Department of Agriculture took over the responsibilities in rice variety improvement. Investigations carried out have revealed that there were around 150 varieties and those belonged to 4 different age classes *i.e.* 5-6 months, 4- 4.5 months, 3.5 months and 3 months. Each age class was dominated by one or a few varieties. Most commonly grown varieties were Podi wee, Muthusamba, Panduruwi (5-6 month age) Vellai illankalayan, Murungakayan (4-4.5 month), Vellai perumal, Heenati (3 month) and Pachchaiperumal (3 month). Of the cultivated varieties 50% belonged to photoperiod sensitive, 5-6 month age class, 31% to medium age class (4-4.5 month) and 10% belonged to short duration (3-3.5 month or less) cultivars. Most of the rice cultivation was done during *maha* season using long age varieties.

In 1940s the Department of Agriculture considered pure-line selection as the most appropriate method of improvement. The failure of the earlier attempt to develop pure lines was due to attempts not been made to isolate the most desirable pure lines. It was mostly purification of local varieties. A large number of selections may have been too large and therefore seed production and distribution may have failed. Therefore pure-line selection in 1940s followed a different trend. The best from earlier selections and several other pure-lines from popular indigenous varieties were isolated and released for cultivation. The best of these were Podiwi A 8 (5-6 month), Vellai illankalayan 28061 (4-4 .5 month), Vellaiperumal 28724 (3 .5 month) and Pachchaiperumal (3 month). The list of recommended pure lines is shown in table 2.

**Table 2. List of pure line varieties of rice**

<i>Cultivar</i>	<i>Pure line variety selected</i>	<i>Age in month</i>
Podiwi	a-8	6
Molagusamba	g-18	6
Kohumawi	B-11	6
Kuruluthuduwi	B-13	6
Dewaredderi	26081	5-5.5
Vellai illnkalayan	28061	4
Perillanel	26014	4
Oddavalan	2449/20	4
Madael	39MY 137	3.5-4
Suduheenati	ICPY 19	3.5-4
Suduheenati	ICPY 15	3.5
Kaluheenati	39 YM 3254	3.5
Sulai	27614	4
Pachchaiperumal	2462/11	4
Dhanala	37 YM 2014	4
Murunga	38 YM 137	4
Vellaiperunel	28724	4
Pokkali		4

Since the use of fertilizer was considered as the quickest way of increasing yield, it was applied to pure line varieties. Application of fertilizer (N) in pure line varieties succumbed to rice blast disease. The most popular pure line variety Vellai illankalayan 28061 and another variety Murungakayan 302 were found to be resistant to blast disease. All other pure lines were found to be susceptible to blast. Pure line varieties with the application of fertilizer had excessive vegetative growth and resulted lodging limiting increased rice production. Therefore high fertilizer response and blast resistance surfaced as major objectives in rice variety improvement.

#### INTRODUCTIONS FROM OTHER COUNTRIES

As an alternative, rice varieties from other tropical countries were introduced. Some of these were Ptb 16 from India, Mas and Sigadis from Indonesia. The introductions were also not successful because those were also susceptible to the blast disease, except Sigadis. Therefore the second phase of the variety improvement work ended without success, leaving the sole option of converging beneficial traits scattered in many different rice varieties into one variety by hybridization followed by selection and screening for pests and diseases and to other stress conditions in the segregating populations. The hybridization program was initiated at Agricultural Research Station Mahailuppallama and later shifted to Batalagoda in 1952, which became the Central Rice Breeding Station and subsequently Rice Research and Development Institute of Sri Lanka.

As a result of variety development through hybridization and selection a series of varieties referred as H varieties emerged and released for cultivation (table 3). Today we call these as Old Improved Cultivars (OIC). These were resistant to the blast disease and moderately responsive to added fertilizer and thus fulfilled the basic requirement for increasing production. However, these varieties also possessed some undesirable traits such as lodging and heavy canopy structure, which prevented obtaining higher grain yields. Therefore then rice breeders changed their strategies to develop New Improved Varieties (NIV).

**Table 3. Old improved cultivars recommended for cultivation in the 1960s.**

<i>Cultivar</i>	<i>Year of release</i>	<i>Age</i>	<i>Attributes</i>
H 9	1963	5	Photoperiod sensitive
H 4	1958	4.5	Red, Blast resistant
H 8	1966	4.5	Samba grain
H 105	1964	4.5	Blast resistant
H 501	1964	4.5	Red grain
H 7	1964	3.5	Red, Blast resistant
H 10	1968	3	Red, Blast resistant
62-355	1969	3	Rainfed, Red

### NEW IMPROVED VARIETIES

Development of Taichung Native 1 (TN1) in Taiwan, IR8 and IR262 at the International Rice Research Institute, Philippines paved the way to introducing the improved plant types to modern varieties. The major attributes of NIVs were improved photosynthetic efficiency, enhanced fertilizer response and resistance to lodging. Short duration cultivars (3-3.5 month) being more economical gained prominence over the medium age varieties. At present more than 78% of the paddy extent in the country is grown with short duration varieties and little over 20% grown with medium age varieties. The area cultivated to long age varieties is less than 1% of total cultivated extent with rice. With the NIVs the cropping intensity increased to present level of 119%. At present almost 100% of the rice area is under NIVs.

### EMERGENCE OF NEW PESTS AND DISEASES

The microclimatic changes brought in by improved plant type in the immediate surrounding of the paddy plant led to economically unimportant pests to become economically important. The other factor that aggravated this situation was continuous cultivation of rice crop in the field in both *yala* and *maha* seasons. These conditions provide good breeding ground for insect pests and also to disease causing agents. As a consequence the stability of cultivars was endangered. Therefore need to incorporate resistance to pests and diseases became a necessity to stabilize the yield.

## INCORPORATION OF PESTS AND DISEASES RESISTANCE TO NIVS TO STABILIZE YIELD.

Stabilizing rice yield was attempted through breeding for resistance /tolerance to stress factors which are either biotic or abiotic and was successful. Among the biotic factors diseases, Rice Blast (BL), Bacterial blight (BB) and Sheath blight (SB) are major diseases. Among the insects, Brown Plant Hopper (BPH), Rice Gall Midge (RGM), Rice Thrips (TH) are considered the major ones. Rice varieties resistant to BL, BB, Bph, and RGM were developed and released for cultivation (table 4).

**Table 4. Improved rice varieties recommended by the department of agriculture and their attributes.**

<i>Variety/ Age class</i>	<i>Year of released</i>	<i>Recommended for</i>	<i>Yield potential t/ha</i>	<i>Attributes</i>
<b>5-6 months</b>				
Bg 3-5	1973	ML	5.5	PS
Bg 407	1981	ML	7.5	PS Resistant to BB
Bg 745	1981	ML	6.0	PS, samba grain
Bg 38	1981	ML	6.0	PS, samba grain
<b>4-4.5 month</b>				
Bg 400-1	1980	GC	8.5	Wide adaptable, resistant to GM-1
Bg 379-2	1980	GC	8.5	Resistant Bph and BB
Bg 380	1982	DZ	10.0	Resistant to GM-1
Bg 450	1985	GC	8.8	Samba grain, resistant to GM-1
Bg 403	1993	GC	8.0	Resistant to BB, BL and Bph
Bw 78	1977	LCWZ iron toxic soil	5.0	Samba grain, ill drain soils, resistant to BL and Bronzing
Bw 100	1979	LCWZ	6.0	Samba grain, resistant to BL and Bronzing
Bw 451 (Bw 297-2)	1987	LCWZ Saline soil	6.0	Replacement for Pokkali Tolerant to salinity
Bw 400 (Bw 272-8)	1987	Saline soils		Red pericarp, tolerant to salinity, resistant BL
Bw 452 (Bw 85)	1992	GC	5.0	Red pericarp, little tall, tolerant to Bronzing and submergence in LCWZ,
Bw 435 Bw 293-2)	1992	LCWZ	7.0	Moderately resistant to BL, Resistant to GM-1 and tolerant to Bronzing
Ld 66	1971	Bronzing and acidic soils		Red pericarp, resistant to BL, like H4 dwarf,
At 401 At 69-5)	1992	Coastal saline areas	5.0	Red pericarp, good for Matara, Hambantota and replacement for H4
At 402 (At 84-3)	1992	Southern province	7.5	
At 5 (Samurdhi)	1998	Dry and Intermediate Zones	4.5	Basmathie rice
<b>3 5 month</b>				
Bg 94-1	1975	GC	8.5	
Bg 350	1986	GC	6.0	Red pericarp, resistant to GM-1

Table 4  
continued

Bg 352	1992	GC except iron toxic and cooler areas	8.5	Resistant to BL, BB moderately resistant to Bph, resistant to GM-1
Bg 357	1997	Island wide cultivation	10.5	Resistant to GM-1 and 2, BL, BB, Moderately resistant to Bph, moderately tolerant to bronzing,
Bg 359	1999	GC specially adaptable to LCWZ and MCWZ	7.0	Resistant to GM-1, GM-2, BL, BB, Moderately resistant to Bph, tolerant to bronzing, higher bushel weight
Bg 360	1999	GC	7.0	Very small grains fancy rice, resistant to GM-1, GM-2, BL, Moderately resistant to Bph, excellent eating quality.
Bw 267-3	1981	LCWZ bronzing areas	4.5	White grains, resistant to BL, iron toxicity and seed spotting
Bw 351 (Bw 288-1-3)	1986	Mineral soils of LCWZ	5.0	Red pericarp, Moderately resistant to sheath blight and iron toxicity
At 353 (At 76-1)	1992	Saline areas good for Nilwala scheme.	6.5	Red pericarp, Moderately resistant to BL, BB
At 354 (At 69-2)	1992	Saline areas	5.0	White pericarp,
Ld 355	1994	Southern province	4.5	Samba grains, moderately resistant to BL and BB
Ld 356	1994	Kalutara & Gall districts	4.5	Short round grains, Moderately resistant to iron toxicity, and seed spotting
<b>3 month</b>				
Bg 300	1987	GC	8.0	Resistant to GM-1, BL, BB, and moderately resistant to Bph.
Bg 301	1987	Manawari areas	6.0	Red pericarp, tolerant to drought, resistant to BL, BB
Bg 304	1993	GC specially suitable for drought prone areas	7.5	Resistant to GM-1, GM-2, BL, BB and moderately resistant to Bph
Bw 272-6B	1981	LCWZ	4.0	Red pericarp
Bw 302 (Bw 272-3)	1987	Saline & acid soils		
Bg 358	1999	GC	8.5	Samba grains
Bg 305	1999	GC	7.5	Resistant to GM-1 & GM-2, BL, Bph, BB.
At 303 (At 77-1)	1990	GC	5.0	Red pericarp, Resistant to BL

PS = Photoperiod sensitive; BB = Bacterial leaf blight; BL = Rice blast disease; GM-1 = Biotype one of rice gall midge; GM-2 = Biotype two of rice gall midge; Bph = Brown plant hopper; LCWZ = Low Country Wet Zone; MCWZ = Mid Country Wet Zone

The major abiotic stress factors were edaphic and region specific. Breeding for tolerance was successful for iron toxicity and salinity and varieties with resistance to them were developed and released for cultivation. Varieties adaptable for specific regions were also developed and released for cultivation. One such variety is Bg 359 which had been released in 1999. It is

suitable for cultivation in the low country wet zone and in the mid country wet zone.

Resistance to biotic stresses governed by major genes is short lived. The resistance to RGM in rice varieties Bg 300 and Bg 400-1 was immune and it was broken down within eight years of their release making them susceptible to RGM due to the emergence of a new biotype. However rice scientists at Batalagoda were able to develop rice varieties with resistance to the new biotype of RGM. Some of them are Bg 304, Bg 357 and Bg 359. Such breakdown may also occur to other insect pests and to diseases. Therefore enhancing stability of varieties would be a constant struggle, which keep the rice breeder vigilant so long as the process evolution continues in nature. Control of pests and diseases through chemicals is not encouraged due to high cost and also due to adverse impacts on the environment. Therefore the only option is the use of resistant varieties. Diverse genetic resources (resistance sources) of diverse origin are needed in developing durable resistant varieties to cope with the evolutionary changes of the pests and diseases causing agents. These evolutionary processes cannot be eliminated. Therefore to develop varieties with durable resistance (for long lasting resistance) diverse resistant genes scattered in different germplasm (same species or from different species) has to be pyramid into one variety. Therefore preservation of biodiversity of rice genepool and its wild species is very essential. Most of our traditional as well as rice varieties received from other rice growing countries are conserved by the Department of Agriculture at Plant Genetic Resources Center, Gannoruwa, Peradeniya to be used by rice scientists.

At present nearly forty high yielding rice varieties have been developed and released by the Department of Agriculture. However, only about ten of them are popular among farmers. Today the most popular variety is Bg 300 followed by Bg 352. These two varieties alone occupy 35% of the total cultivated extent of rice in the country. The popularity of these varieties could be attributed to short age coupled with high grain yield potential.

#### PROGRESS OF RICE PRODUCTION IN SRI LANKA

The progress of annual rice production is shown in table 5. When Sri Lanka gained independence in 1947 the annual cultivated extent to rice was 0.393 million ha. Rice varieties cultivated were all traditional type with poor yielding ability. During that time country's rice production was around 0.262 million metric tons and the national average yield was 0.65 t/ha (13 bu/ac). Pure line varieties dominated the decade 1950s. These varieties together with other agronomic practices were able to increase annual rice production to 0.687 million metric tons with an average yield of 1.73 t/ha (34 bu/ac). In the decade 1960 OIVs were the popular varieties grown and the production increased as shown in the table 5. In 1999 the annual cultivated extent to

paddy was 0.730 ha and the production was 2.8 million metric tons with an average yield of 3.72 t/ha (74 bu/ac). During this 50 years, the production has increased eleven fold and the area cultivated to rice has increased little less than two fold. The yield per unit area has increased five and a half fold. At present the country produces its own rice requirement. The major contributing factor to increased production today is the adoption of high yielding rice varieties. Today all rice land is cultivated to NIVs and occasionally some traditional and OIVs are cultivated in small extents. The other contributory factors are use of fertilizer and adoption of better management practices such as proper land preparation, weed control and adoption of new pest control techniques. Today most of the cultivated rice varieties are resistant or tolerant to many biotic or abiotic stresses. The Department of Agriculture has formulated a package of practices for adoption to further enhance the production based on technological innovations achieved during the recent past. The practices emphasized in this package are as follows:

1. Cultivation of appropriate rice varieties,
2. Cultivation of good quality seed,
3. Timely and collective cultivation,
4. Use of organic manure with inorganic fertilizer and their timely application,
5. Efficient weed control through land preparation and other methods,
6. Adoption of improved integrated pest management practices,
7. Proper harvest and post harvest operations,
8. Increased value addition to products.

This package has proved its potential by obtaining yields above 6 t/ha in most the locations carried out and in some locations up to 10.5 t/ha. The government is making an effort to promote this package (*yaya* programme) throughout the country. As a result of this *yaya* program an increasing trend in rice production is observed.

**Table 5. Impact of rice variety improvement on production and yield during the last six decades**

<i>Decade</i>	<i>Variety type</i>	<i>Annual cultivated extent mil ha</i>	<i>Annual production mill Mt tons</i>	<i>Average yield t/ha</i>
1940	Traditional	0.392	0.249	0.63
1950	Pure lines	0.388	0.654	1.68
1960	OIVs	0.496	1.011	2.04
1970	OIV&NIV	0.616	1.489	2.41
1980	NIVs	0.700	2.254	3.22
1990	NIVs	0.730	2.664	3.65
1999	NIVs	0.730	2.715	3.72

Source: RRDI, Batalagoda.

## PRESENT STATUS AND FUTURE REQUIREMENT OF RICE IN SRI LANKA

Rice is the staple food of Sri Lankans. The cultivation of rice is the livelihood of more than 800,000 families. More than 30% of the total labor force is directly or indirectly involved in the rice sector. Sri Lanka has 730,000 ha of aswaddumized land, out of which nearly 560,000 and 310,000 ha are cultivated in *maha* and *yala* seasons, respectively. During a normal year 255,800 ha are sown under major irrigation in *maha* and 176,600 ha in *yala*. Extent under minor irrigation declines from 135,800 ha in *maha* to meager 56,000 ha in *yala*. A similar decline is also seen in rainfed-sown extent from 168,700 ha in *maha* to 77,300 ha in *yala*.

Rice accounts for about 45% of the per capita calories and 40% of the per capita protein consumption in the average Sri Lankan diet and its per capita consumption is estimated around 106 kg per head per year. Assuming a population growth of 1.0% and per capita rice consumption of 106 kg the projected annual rice consumption at present is 2.035 million metric tons. In the year 2010 it will be 2.23 million metric tons. In 2010 the paddy requirement is 3.53 million metric tons. To produce enough rice in 2010 the national average yield will have to be increased from the present level of 3.7 t/ha to 4.6 t/ha.

To meet the rice demand in the country with the increasing population the option is to increase the productivity per unit area of land. In 1871 the land-man ratio was 2.7 ha/person and at present it is 0.34 ha/person. Today the land-man ratio for paddy is 0.098 ha/person, little less than 1/10<sup>th</sup> of an acre. Therefore, future rice research are directed to enhance productivity /unit area.

### FUTURE VARIETY IMPROVEMENT STRATEGIES

The yield potential of present day NIVs is around 10 t/ha and national average is 3.72 t/ha. From the past experience rice breeders know that if the yield potential of rice varieties is further increased from the present level to a higher level it will also increase the rice yield at farmers level. For this purpose two avenues have been identified. These are (1) exploitation of heterosis vigor (Hybrid rice) and (2) development of inbred rice varieties with the new plant architecture, the “new plant type” for broadcast conditions. From the hybrid rice at least a 30% increase of yield potential is expected and from new plant type varieties another 2-3 t of grains /ha is expected. At present the RRDI has directed its rice variety improvement program to achieve these goals. The other goals are improvement of grain quality, to upgrade eating/milling quality and for rice based food products and brewereges.

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