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REVIEW ARTICLE

Exchange and Utilization of Global Genetic Resources in the National Coconut Breeding Programme in Sri Lanka: A Historic Overview

M.K. Meegahakumbura[1#*], H.D.M.A.C. Dissanayaka[1#], S.A.C.N. Perera[2], C.R.K. Samarasinghe[1], P.R. Weerasinghe[1], V. Vidanarachchi[3] and L. Perera[1]

[1] *Genetics and Plant Breeding Division, Coconut Research Institute, Lunuwila, 61150, Sri Lanka*

[2] *Department of Agricultural Biology, University of Peradeniya, Sri Lanka*

[3] *Tissue Culture Division, Coconut Research Institute, Lunuwila, 61150, Sri Lanka*

[#] *These Authors contributed equally to this paper*

**Corresponding Author:muditha77@hotmail.com*

ABSTRACT

Systematic coconut breeding has a long history in Sri Lanka. Diverse coconut germplasm becomes the basis for coconut breeding. Crop breeding needs to change its directions with the priority needs of the industry. This review paper sheds a glimpse into the historical, conventional and modern germplasm exchange over the last century from early 1900s to 2019 and their subsequent utilization in the National Coconut Breeding Programme in Sri Lanka. This is the first attempt of reviewing acquisition of exotic coconut germplasm , their conservations and prudent utilization in the national coconut breeding programme in Sri Lanka with challenges, opportunities and success stories.

Keywords: Coconut Germplasm, Breeding, Germplasm Importation, Molecular markers

1. INTRODUCTION

Germplasm, the total gene pool of a crop species, is considered the life–force of a breeding programme. It is available in several forms as varieties, land races, modern cultivars, breeding stocks or wild relatives and they provide the basic raw material for crop improvement. Accordingly, owning a rich collection of germplasm provides plant breeders the ability to develop new cultivars for the changing needs of the human society and its environment. Acquiring novel germplasm possessing desirable traits and alleles is a must to enrich the germplasm repositories. Germplasm exchange therefore is not novel concept but has been in practice from the ancient times dating back to the initiation of agricultural civilization.

Coconut has a long history in Sri Lanka and 'Mahawansha' provides written evidence for systematic coconut cultivation from the king Agbo's period in 8th Century. The island nation of Sri Lanka is blessed with a rich diversity of coconut germplasm to be used both by the growers and the breeders although Sri Lanka is not a centre of coconut origin. However, with the conversion of traditional coconut growing to plantation industry, a need was arisen for noval genetic diversity to sustain the coconut improvement. These noval genetic

resources to broaden the diversity can be achieved through importing or exchanging new germplasm from other countries. The establishment of Coconut Research Institute, Sri Lanka in 1929, provided the much-needed platform for systematic coconut germplasm exchanges.

2. COCONUT GERMPLASM IMPORTATION AND EXCHANGE IN SRI LANKA

When reviewing the history of coconut germplasm exchange in Sri Lanka, three main stages can be identified as;

1. Germplasm importation by the coconut growers in colonial era
2. Germplasm importation by the breeders of the Coconut Research Institute of Sri Lanka at the initial stages
3. Germplasm importation in the new era with the diversity information at the molecular level

2.1. Gremplasm importation by coconut growers and their subsequent utilization by coconut breeders

The Genetics Division of Coconut Research Institute was established in 1929 as a pioneering research division of the institute and one of the first tasks of it was to collect and conserve the existing local and previosuly imported exotic germplasm within the country. As a result of germplasm importation by planters/growers witout the involement of the insttiute by 1940, the division had already conserved 19 young San Ramon Tall plants at the field gene bank of Bandirippuwa Research Station (Annual Report, 1940). The same annual report records the commencement of a well-designed experiment at the Rathmalagara Research Station to evaluate the potential of toddy production among Sri Lankan Dwarfs and Malayan Dwarfs. For this experiment, Sri Lankan Dwarfs had been collected from Bandirippuwa Estate whereas Malayan Dwarfs had been obtained from Johanna Watta estate in Chilaw. Therefore, it is clear that these two varieties, San Ramon and Malayan Dwarfs had been imported without the involvement of Coconut Research Institute. San Ramon is believed to have been previously imported in ships as seednuts by an English planter in the Clovis estate in Kurunagalla. The original San Ramon trees are still available in the Clovis estate which is now blocked out and owned by villagers. Most probably, the Malayan Dwarfs may have been introduced to the country in the same manner.

The first attempt of incorporation of exotic varieties in the coconut breeding programme of Sri Lanka was recorded 70 years ago in year 1949. In this breeding programme, the conserved exotic variety San Ramon had been crossed in varying combinations with Sri Lankan Dwarfs, Talls and King coconuts to produce 6 inter varietal crosses namely San Ramon x Dwarfs, Dwarfs x San Ramon, King Coconut x San Ramon, San Ramon x King Coconut, Sri Lankan Tall x San Ramon and San Ramon x Sri Lankan Tall(Annual Report, 1955).

These six crosses together with a few other crosses of local varieties have been planted at Ratmalagara Estate as hedgerow planting. However, the data collection had not been continued at this experiment. The authors revisited the experimental site and observed that the plants bear considerable yields even after 60 years and therefore, a fruit component analysis was carried out and the results will be

reported in due course.

In early 60's San Ramon that has been located in Clovis estate, a private ownership in Kurunegala has been purified by self polination by the CRISL and planted as a block in Bandirippuwa estate. In late 1960's San Ramon has been crossed with Dwarf Green and Sri Lanka Tall and has been planted in Bandirippuwa estate as blocks and not in any experimental design. Later in 1986, San Ramon has been again utilized to produce two of the above crosses and a new multilocational experiment called progeny trial, has been initiated to evaluate the performances of Tall x San Ramon and Green Dwarf x San Ramon together with recommended cultivars CRIC60 and CRIC65 (Annual Report, 1986). Based on the results of this experiment two new inter varietal hybrids, namely CRISL98 and CRISL 2004 (Kapruwana), made with exotic variety San Ramon were released for commercial cultivation in the years 1998 and 2004 respectively. (The detailed evaluation of this experiment was published at the 3rd plantation crop research symposium; Perera *et al*., 2010).

The same exotic tall variety San Ramon was later used in a breeding programme with Sri Lanka Brown Dwarf and another new hybrid with San Ramon named CRISL 2013 (Kapsetha) was recommended for commercial cultivation in the year 2012. (Annual Report, 2003 and Dissanayake *et al*., 2012)

All these three hybrids are characterized by their high quality and quantity of kernel and copra that was inherited from parent San Ramon. Table 1 summarizes the main features of recommended cultivars produced with exotic variety San Ramon tall.

2.2. Early germplasm exchange programmes of Coconut Research Institute, Sri lanka

The first systematic exotic coconut germplasm importation by the Coconut Research Institute commenced 82 years ago in the year 1938 when 24 seed nuts were imported from Papua New Guinea. Of these 24 seed nuts, 16 seedlings had been field planted at the Rathmalagara Research Station in 1940 (Annual Report, 1940) and the yield recording has commenced in the year

Table 1: Main features of recommended hybrids produced with exotic variety San Ramon

Cultivar	Cross	Year of release	Potential yield (nuts/ha/year)	Copra yield (g/nut)
CRISL98	Sri Lanka Tall x San Ramon Tall	1998	15,000	280-300 g
CRISL2004 (Kapruwana)	Green Dwarf x San Ramon Tall	2004	22,000	250-260 g
CRISL2013 (Kapsetha)	Brown Dwarf x San Ramon Tall	2012	20,000	250-260 g

1952. However, after 1952, there were no clear records of utilizing this valuable genetic resource.

In the same year, Sri Lanka has exported coconut germplasm to Sudan, India and Venezuela (Annual Report, 1938). In 1939, 24 more seed nuts similar to Rath Gonthembili had been imported from Zanzibar (Semi-autonomous region of Tanzania) however, the raising of thses seedlings had failed (Annual Report, 1939).

The first exotic germplasm introduction in the form of pollen exclusively for hybridization purpose was commenced in 1972. Pollen of three promising dwarf varieties namely Cameroon Red Dwarf, Brazilian Green Dwarf and Ghana Yellow Dwarf has been imported to Sri Lanka with the intention of producing Tall x Dwarf hybrids. The pollen had been supplied to Sri Lanka form IRHO France through its station at Port Bouet, Ivory Coast (Annual Report, 1972). From the material available at the local coconut field gene banks it can be assumed that a limited number of seed nuts of Cameroon Red Dwarf and Brazilian Green Dwarf have also been imported during the same period of time and field planted in Bandirippuwa and Pasikudah. Remaining few Cameroon Red Dwarf and Brazilian Green Dwarf planted in Bandirippuwa Estate had been self pollinated in 1993 and resulting seedlings have been planted at PRS coconut genebank for conservation. A successful pollination programme had been carried out with these pollen during 1973-1975 and seedlings of Sri Lankan Tall x Brazilian Green Dwarf, Sri Lankan Tall x Ghana Yellow Dwarf together with San Ramon (selfed) and Intra-varietal Dwarf crosses have been planted for evaluation at the field number 16 of Bandirippuwa Estate (Coconut Quarterly, 1974 and 1975). The initial data on time taken for flowering has been recorded since 1980. However, this groundbreaking experiment had been terminated during the year 1985 (Annual report, 1985). Although the reason for termination of this research was not mentioned, the authors observed that the experiment has not been planted as blocks but, planted only as rows and not following a proper experimental design.

During 1980s, negotiations have been made with Indonesia to import exotic coconut seed materials (Annual report, 1984). However, this attempt have not been materialized due to lack of an International agreement on coconut germplasm exchange (Annual Report, 1985).

During early 1980s, King Coconut germplasm along with a few other Sri Lankan varieteis have been exported from Sri Lanka to Oman and they are used as a natural beverage there to date (Bourdeix and Perera, 2009).

In 1994 another breeding programme has been initiated between exotic variety Cameroon Dwarf x Ambakelle Tall with the objective of evaluating its potential for sap production. The seedlings of this cross have been planted at Halkandawila, Payagala in 1997 with Dwarf x Tall and Dwarf green x Debarayaya accession hybrids. However, this site has been maintained only as a observation block and no data collection apart from the scoring of initial growth measurements, has been carried out.

2.3. Coconut germplasm exchange and utilization in the molecular era

The early coconut germplasm evaluation programmes of Sri Lanka were carried out mostly based on the morphological and phenotypic characters. In 1990s, different populations (Namalwatta, Kasagala, Debarayaya and Amabakelle Tall) within the

Sri Lankan Tall variety had been identified and used in the breeding programme with the objective of producing improved intra varietal hybrids. However, at the field, no significant differences had been observed between these TallxTall hybrids and the original populations revealed lack of sufficient variations among populations to generate hybrid vigour for the economically important traits and emphasizing the need of more precise methods for germplasm evaluations (Annual Report, 1996).

Later part of 1990s marks the utilization of molecular markers in the evaluation of local and exotic coconut germplasm. A significant amount of information was generated on the diversity of the local and global coconut germplasm with molecular markers specially using the Microsatellite marker analysis (Perera *et al.* 2001). These experiments exposed the narrow genetic base within Sri Lankan Tall populations highlighting the need of germplasm enrichment through introductions. In the same study, it was revealed that the coconuts in South East Asian and the Pacific region are genetically distinct to coconuts grown in the South Asia and the African region. Moreover, Dwarf coconuts collected across the globe were clustered with the Talls coming from South East Asian and the Pacific region indicating a common origin. Higher genetic diversity has also been reported from the coconuts in South East Asian and the Pacific region (Perera *et.al.* 2003, Gunn et al., 2011). As a result, crossing Sri Lankan Tall coconuts with the Talls coming from South East Asian and the Pacific region or with the Dwarf coconut was identified as the way forward in developing desirable coconut hybrids in Sri Lanka. This was a breakthrough discovery that changed the direction of the coconut breeding programme in Sri Lanka and provided a solid platform for the germplasm importations.

3. SYSTEMATIC GERMPLASM IMPORTATION AND CONSERVATION IN RECENT YEARS

With the clear understanding of the need to diversify the genetic base of coconuts in Sri Lanka, Genetics and Plant Breeding Division of the Coconut Research Institute made several attempts to import exotic germplasm. Systematic Coconut germplasm exchange was finally materialized with the assistance of the international Coconut Genetic Resources Network (COGENT) in 2002. The first exchange was made with our closest neighbor India, from where Sri Lanka received 4 exotic varieties in exchange of 4 Sri Lankan varieties (Table 2 & Table 3). Similarly, germplasm exchange was carried out with Papua New Guinea in 2003 and with Ivory Coast in 2004 (Table 2 & Table 3). Collectively 23 exotic coconut varieties were brought to Sri Lanka as embryos and field planted at the Bandirippuwa exotic germplasm block. Due to the risk of introducing lethal diseases from foreign countries to Sri Lanka, it was decided to import the germplasm in the form of embryos as it is the safest way of coconut germplasm exchange. Many coconut growing countries in the world used this strategy in germplasm exchange programmes. Tissue Culture Division of the Coconut Research Institute assisted the germplasm exchange through *in vitro* embryo culture technology. Three of these varieties namely, Thalasia Tall, PNG Yellow Dwarf and Nias Yellow Dwarf embryos showed very poor recovery. Although, Malayan Red Dwarf variety was imported both from Papua New Guinea and Ivory Coast, the seedling survival rate was very poor under field conditions.

Table 2: Summary the exotic coconut varieties imported to Sri Lanka.

Year of Importation	Exotic Variety	Country of Importation
2002	West Coast Tall	India
2002	Laccadive Ordinary Tall	India
2002	Andaman Tall	India
2002	Banawali Round Dwarf	India
2003	Kar Kar Tall	Papua New Guinea
2003	Markem Valley Tall	Papua New Guinea
2003	Rennel Island Tall	Papua New Guinea
2003	Gezelle Peninsula Tall	Papua New Guinea
2003	Thalasia Tall	Papua New Guinea
2003	PNG Yellow Dwarf	Papua New Guinea
2003	Nias Yellow Dwarf	Papua New Guinea
2003	Malayan Red Dwarf	Papua New Guinea
2003	Malayan yellow Dwarf	Papua New Guinea
2003	PNG Brown Dwarf	Papua New Guinea
2004	Polynesia Tall	Ivory Coast
2004	Tagnanan Tall	Ivory Coast
2004	Vanuatu Tall	Ivory Coast
2004	Tacunan Green Dwarf	Ivory Coast
2004	Niu Leka Green Dwarf	Ivory Coast
2004	Tenga Tall	Ivory Coast
2004	Malayan Red Dwarf	Ivory Coast
2004	West African Tall	Ivory Coast
2004	Catigan Green Dwarf	Ivory Coast
2004	Tahitian Tall	Ivory Coast

Although 15 Sri Lankan coconut varieties were sent to India, Papua New Guinea and Ivory Coast in this programme, the survival rates of the varieties in destination countries were very poor. Apart from the four varieties exchanged to India, all the other embryos of 11 varieties has been contaminated and failed to survive.

Table 3: Summary of the Sri Lankan coconut germplasm exchanged.

Year of exchange	Sri Lankan coconut germplasm exchanged	Country
2002	Sri Lanka Green Dwarf	India
2002	Sri Lanka Yellow Dwarf	India
2002	Sri Lanka Red Dwarf	India
2002	Gon Thambili	India
2003	Sri Lanka Green Dwarf	Papua New Guinea
2003	Brazilian Green Dwarf	Papua New Guinea
2003	Cameroon Red Dwarf	Papua New Guinea
2003	King Coconut	Papua New Guinea
2003	Deekiri	Papua New Guinea
2003	Sri Lankan Tall	Papua New Guinea
2003	Gon Thambili	Papua New Guinea
2003	Clovis	Papua New Guinea
2004	King Coconut	Ivory Coast
2004	Rathran Thambili	Ivory Coast
2004	Navasi	Ivory Coast

As most of the COGENT mediated coconut germplasm exchange programmes in the form of embryos showed very poor survival rates, a series of International workshops were held and discussions were made to improve the embryo exchange protocols. As a result, Sri Lanka received 3 more exotic varieties namely Thailand Tall, Panama Tall and Malayan Red Dwarf from Ivory Coast in 2010 using the improved protocol. Malayan Red Dwarf germplasm was received again from the Phillipines in 2013 enabeling field planting of healthy seedlings at the exotic field gene bank. Recovery rate of the Malayan Red Dwarf embryos was extremely poor and it took four importations to transfer healthy seedlings to the field and now the palms of 4th importation are in bearing stage.

In the year 2019, Aromatic Green Dwarf variety, a much awaited variety with high beverage value was received as embryos from China (Annual Report, 2019). These embryos are still in the laboratory in different development stages of embryo culture and the recovered seedlings will be planted at the exotic field gene bank.

4. NEW HYBRIDIZATION PROGRAMMES WITH EXOTIC GERMPLASM (AFTER 2005)

After the importation and conservation of exotic germplasm, a decision was taken to speed up the breeding programme by importing pollen from three promising

exotic varieties already conserved at the field gene bank. These varieties were selected based on their genetic distance with Sri Lankan coconut germplasm and their proven combining ability shown in coconut hybrids developed in the other countries. Three coconut varieties namely Rennel Island Tall, Tagnanan Tall and Malayan Red Dwarf were imported from CNRA, Ivory Coast. A new breeding programme was initiated in 2005 by crossing these exotic varieties with Sri Lanka Tall, Sri Lanka Green Dwarf and exotic variety San Ramon Tall. Six new crosses were developed in this programme namely Sri Lanka Tall x Rennel Island Tall (T x RIT), Sri Lanka Tall x Tagnanan Tall (T x TAGT), Sri Lanka Tall x Malayan Red Dwarf (T x MRD), Sri Lanka Green Dwarf x Rennel Island Tall (GD x RIT), Sri Lanka Green Dwarf x Tagnanan Tall (GD x TAGT) and San Ramon x Malayan Red Dwarf (SR x MRD). Tall x Brazilian Green Dwarf cross developed for the tolerance breeding programme for Aceria mite was also included in this experiment.

These seven new hybrids were field planted multi-locationally in 2008 with the recommended cultivars for field evaluation (Annual Report, 2008). These seven hybrids are currently under evaluation and after 11 years from field planting the new hybrid Sri Lankan Tall x Malayan Red Dwarf shows superior performances with respect to reproductive and yield traits (Meegahakumbura et al., 2019). It recorded an average of 153 nuts/palm/year yield in the Wet zone 10 years after planting. Moreover, this hybrid showed similar performances to the best hybrid cultivar, Kapruwana in the Dry Intermediate zone (Annual Report 2019). This new hybrid will be recommended and mass produced for the comercial cultivation in near future.

As mentioned earlier the exotic germplasm Brazilian Green Dwarf imported in 1972 was utilized again with Sri Lanka Tall, Gon Thembili and San Ramon Tall to produce 4 new hybrids with the objective of producing hybrids tolerant to *Aceria* mite infestation, (Annual Report, 2005) and are currently under field evaluation with promising results.

In addition, the hybrid, Tall x Brazilian Green Dwarf is being evaluated in the field for tolerance to Weligama Leaf Wilt Disease and it shows very promosing results after 10 years from planting.

The other variety imported to Sri lanka in 1972, Cameroon Red Dwarf was again utilized to produce the intra varietal hybrid Cameroon Red Dwarf x Sri Lanka Brown Dwarf (CRD x BD) with the objective of producing novel hybrids for beverage purpose and this hybrid too is being evaluated in the field with other local dwarf x dwarf hybrids.

Therefore, in summary, during the five year period from 2005 to 2010 exotic germplasm was extensively incorporated into the coconut breeding programme of Sri Lanka developing 11 new hybrids.

5. CONCLUSION

Exotic coconut germplasm importation and exchange has a very long history in Sri Lanka. First exotic coconut variety was imported in the year 1938 and the latest importation was in 2019. Coconut germplasm importation has broadened the genetic base of the coconut germplasm in Sri Lanka. Incorporation of the exotic germplasm into Sri Lankan coconut breeding programme was initiated in 1949. To date, more than 14 coconut hybrids have been developed using exotic varieties as parents. Three hybrids

namely, CRISL98, Kapruwana and Kapsetha have been already released to the National Replanting Programme. Inclusion of the Philippine variety San Ramon has especially increased the Kernel/Copra content of these three hybrids. This is a remarkable achievement in the coconut breeding programme in Sri Lanka. Utilization of the global genetic resources provided a new direction to the coconut breeding programme of Sri Lanka to meet the changing needs of coconut stakeholders.

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