Development of High Yielding and Early Flowering New Coconut Cultivars with Exotic Pollen

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Development of High Yielding and Early Flowering New Coconut Cultivars with Exotic Pollen

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Abstract

Coconut is a socio economically vital crop in Sri Lanka. Due to its recently discovered health benefits, coconut industry is flourishing across the globe. As coconut hybrids (or crosses between varieties) produce 40% more yield than conventionally grown Sri Lankan Tall variety, introduction of new hybrids is the way forward for supplying nuts for increasing demand. Over the past 80 years, Sri Lankan coconut breeders have utilized all the locally available genetically diverse Dwarfs (Green, Yellow and Brown) and exotic accessions available locally such as San Ramon in breeding programme. As a result, by the start of new millennium, coconut breeding was almost at a dead end due to lack of genetically diverse material. Based on the results of previous molecular studies, 23 exotic coconut accessions were imported from 2002 to 2004 predominantly with South East Asian and Pacific origins *via* embryo culture. Seedlings were then generated and planted at the field gene bank to broaden the genetic base. In the current study, to speed up the coconut breeding programme, pollen from selected exotic germplasm *viz*. Rennel Island Tall (RIT), Tagnanan Tall (TAGT), Malayan Red Dwarf (MRD) were imported and successfully crossed with Sri Lankan Tall and Sri Lankan Green Dwarf to develop six new coconut crosses. In addition, the pollen from a previously acquired exotic accession Brazilian Green Dwarf (BGD) was also used in this crossing programme. According to the results of the multi-locational analysis for mean flowering time, early nut yields and kernel productivity, two promising new crosses *viz*. T x MRD, T x RIT were identified. These crosses have a great potential to be released in near future as commercial cultivars for the National Coconut Replanting Programme in Sri Lanka.

Key words: *coconut breeding, Cocos nucifera, exotic varieties, new coconut crosses*

Introduction

Coconut (*Cocos nucifera*) is a versatile crop and one of the main energy sources in Sri Lankan diet. Frequent climate changes with long and unpredictable droughts, land fragmentation and new outbreaks of pests and diseases have challenged the coconut industry in the recent past. Increasing the productivity of coconut lands by introducing new high yielding and early bearing crosses developed using diverse genetic backgrounds is the way forward to mitigate these challenges. Coconut has been systematically planted in Sri Lanka since the eighth Century AD and the identification, classification, conservation, and utilization of coconut germplasm were initiated in 1940s. Coconut breeders in the past had to depend on the available local coconut germplasm for the development of new coconut cultivars. Sri Lanka Tall (SLT), Sri Lanka Dwarf forms (SLD) and the solitary introduction from the Philippines namely, San Ramon (SR) were extensively used for the development of coconut crosses to date. Interestingly, all these varieties and forms have been successfully used by breeders in the past for developing improved cultivars, for instance CRIC60 is a selection of SLT, CRIC65 is a cross between SL (Green/Yellow form) Dwarfs and SLT. CRISL98 was developed by crossing SLT and Philippine SR while Kapruwana is a cross between Sri Lankan Green Dwarf and SR (Perera *et al*., 2010). Sri Lankan Brown Dwarf was also crossed with SLT and SR (Dissanayake *et al*., 2012) to produce the recently released coconut cultivars Kapsuwaya (SLBD x SLT) and Kapsetha (SLBD x SR) respectively. With these six recommended coconut cultivars, Sri Lankan coconut breeders had used all the diverse germplasm available in the country and coconut breeding came to a stagnant point. The prospects of developing more coconut cultivars with significant yield enhancement therefore, were meager by further exploiting the local germplasm. Thus, novel approaches were needed for the continuation of the coconut breeding programme in Sri Lanka.

Understanding the genetic diversity and relationships among coconut varieties are vital to plan the future coconut breeding programmes. Sri Lankan Tall and Dwarf coconut samples were used in the molecular analysis and successfully found out their relationships by Perera *et al*. (1998 & 2000). South East Asian (SEA) and Pacific Tall coconuts were found to be genetically different from Sri Lankan Talls (Perera *et al*., 2001; Meegahakumbura *et al*., unpublished data). Dwarf coconut forms across the globe were clustered with the SEA and Pacific Talls indicating a common origin (Perera *et al*., 2003, Gunn *et al*., 2011). Furthermore, Sri Lankan Tall coconuts exhibited a narrow genetic base emphasizing the need of importing exotic germplasm to broaden the genetic base (Perera *et al*., 2001). Therefore, 23 exotic coconut accessions mostly with South East Asian and Pacific origin were imported from 2002 to 2004 from India, Papua New Guinea and Ivory Coast as embryos. Seedlings were generated via embryo culture and planted at the exotic field gene bank located at Bandirippuwa Estate, coconut Research Institute (Annual Report 2006). In order to accelerate the breeding programme a decision was taken in 2005 to import pollen from three promising accessions that were planted at the exotic field gene bank of Bandirippuwa Estate.

The objectives of the current study were; 1) to develop new coconut progenies by crossing with exotic pollen and 2) to carryout multi-locational evaluation of newly developed progenies for early flowering, nut yield, kernel production and productivity.

MATERIALS AND METHODS

Development of new crosses

A decision was taken to import pollens from three accessions out of the 23 exotic coconut accessions imported to Sri Lanka to speed up the coconut breeding programme (Anon., 2006). Based on the genetic diversity (Perera *et al*., 2002) and proven combining ability in the globally released coconut hybrids, two exotic tall coconut accessions (Rennel Island Tall and Tagnanan Tall) and a Dwarf accession Malayan Red Dwarf (MRD) were selected for importation of pollen. Pollen was also harvested from the previously introduced exotic dwarf accession *viz*. Brazilian Green Dwarf (BGD). These four pollen types were used as male parents in combinations shown below with Sri Lanka Tall and Sri Lanka Green Dwarf to produce following six new progenies.

New coconut crosses:

1. Sri Lanka Tall x Malayan Red Dwarf (T x MRD)
2. Sri Lanka Tall x Rennel Island Tall (T x RIT)
3. Sri Lanka Tall x Tagnanan Tall (T x TAGT)
4. Sri Lankan Green Dwarf x Rennel Island Tall (DG x RIT)
5. Sri Lankan Green Dwarf x Tagnanan Tall (DG x TAGT)
6. Sri Lanka Tall x Brazilian Green Dwarf (T x BGD)

Multi locational evaluation

Four multi-locational experiments were planted (Table 1) each in a Randomized Complete Block Design (RCBD). Each experimental site consists of three to four blocks and six to nine palms per plot. The standard cultivars *viz*. CRIC65, CRISL98 (T x SR) and Kapruwana (DG x SR) were used for comparisons. All four sites were planted in year 2008.

Table 1. Summary of the Multi-locational trials planted with newly developed coconut crosses

Location	Year of Planting	Soil type	New crosses and standard cultivars planted	Agro Ecological Zone	Total number of seedlings planted
Marandawila NLDB Farm	2008	Loamy sand, sandy loam to sandy clay loam	T x RIT, T x TAGT, T x MRD T x BGD, DG x RIT, DG x TAGT, CRIC65, CRISL98, Kapruwana	Intermediate Zone (IL1)	460
Beligama NLDB Farm	2008	Sandy clay loam to clay loam	T x RIT, T x TAGT, T x MRD T x BGD, CRIC65, CRISL98, Kapruwana	Intermediate Zone (IM3)	422
Middeniya Research Station (CRI)	2008	Sandy clay loam to clay loam	T x RIT, T x TAGT, T x MRD T x BGD, CRIC65, CRISL98, Kapruwana	Dry Zone (DL1)	401
Siringapatha NLDB Farm	2008	Loamy sand, sandy loam	T x RIT, T x TAGT, T x MRDT x BGD, DG x RIT, DG x TAGT, CRIC65, CRISL98, Kapruwana	Wet Zone (WL3)	430

Data collection

Precocity in flowering and initial yield data from two sites one representing the Wet Zone of Sri Lanka; WL3 (Siringapatha) and the other representing the Dry Zone of Sri Lanka; DL1 (Middeniya) were considered for the current study. Time taken to produce first inflorescence from time of planting (flowering) was recorded in months and number of nuts produced was recorded in all bunches harvested during year 2016. Fruit component data were collected by randomly collecting two nuts per palm from all the palms in experimental plots. Nuts were collected from four picks year around and fresh nut weight, husk weight, water weight and Kernel weight of each nut were recorded. Data were analyzed in General Linear Model procedure and mean separation was done by Tukey pair wise comparisons using MINITAB ver. 18.

RESULTS AND DISCUSSIONS

Analysis of Variance (ANOVA) procedure on flowering revealed significantly different cultivar effects at both sites. Flowering data at Siringapatha revealed that, Kapruwana and the new cross DG x RIT flowered significantly earlier than that of the Tall x Tall cross (T x TAGT) and recommended Tall x Tall cultivar (CRISL98). Interestingly, T x RIT did not show any significant difference in the flowering time compared to Dwarf x Tall crosses/cultivars despite of being a Tall x Tall cross. This is the first incidence where a Tall x Tall cross showed earliness in flowering comparable to Dwarf x Tall crosses/cultivars. Present result was unique as Rennel Island Tall contributed to earliness in flowering in crosses made with both Sri Lankan Green Dwarf and Sri Lankan Tall. RIT is one of the largest fruit bearing variety in the world and renowned for its earliness in flowering and higher combining ability. Similar results of precocity has been reported when RIT was used as a parent in the popular coconut crosses “Maren” (Malayen Red Dwarf x Rennel Island Tall) and “Camren” (Cameroon Red Dwarf x Rennel Island Tall) created at Ivory Coast and Solomon Islands respectively. Moreover, the Tall x Tall cross Vanuatu Tall x Rennel Island Tall has showna mean of 46 months to initiate flowering after planting in Vanuatu. In contrast, new Tall x Tall cross T x TAGT reported the longest time taken to initiate flowering among all crosses/cultivars planted at Siringapatha.

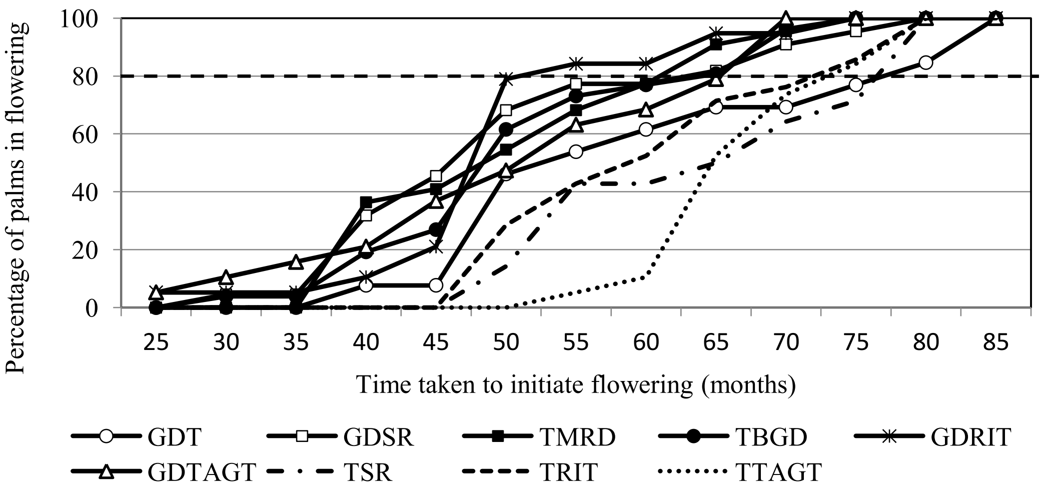

Fig. 1. Trends in time taken for flowering in new crosses and standard cultivars of coconut at Siringaptha

The palms of all new crosses and cultivars produced by crossing Sri Lankan Green Dwarf with Pacific Talls (RIT, TAGT and SR), initiated flowering just after two years from planting (Fig. 1). Although CRIC65, the standard coconut hybrid in Sri Lanka reported its first palm flowering at 35 months after planting, it took 77 months to achieve 80% of palms in flowering where as 80% of the palms of the new cross DG x RIT attained flowering in 50 months after planting. However, the mean flowering time reported by standard cultivars at Siringapatha is remarkably longer than what was reported for standard cultivars in previous experiments (Dissanayaka *et al.*, 2012). The poor soil condition at Siringapatha might have hindered the nutrient retention capacity resulting in late flowering.

The Dry Zone site, Middeniya repeated a similar trend to Siringapatha with respect to time taken for first flower initiation. Kapruwana and TMRD reported similar mean flowering time at Middeniya (45 months). Dwarf x Tall cultivars again exhibited significant early flowering compared with Tall x Tall cultivars.

Middeniya being a marginal site in the dry zone, T x RIT did not exhibit its precocity as in the Wet Zone site providing evidence for Genotype x Environment interaction. Yet, the first T x RIT palm flowered at 26 months after planting, at Middeniya which is the lowest reported time taken for first flower initiation by a palm of Tall x Tall crossing in Sri Lanka (Fig. 2). Lower variation was observed among palms of T x MRD with respect to time taken for flower initiation and it achieved 80% flowering within four years after planting followed by Kapruwana. Poor performance for time taken for mean flowering of T x TAGT was also obvious at this site.

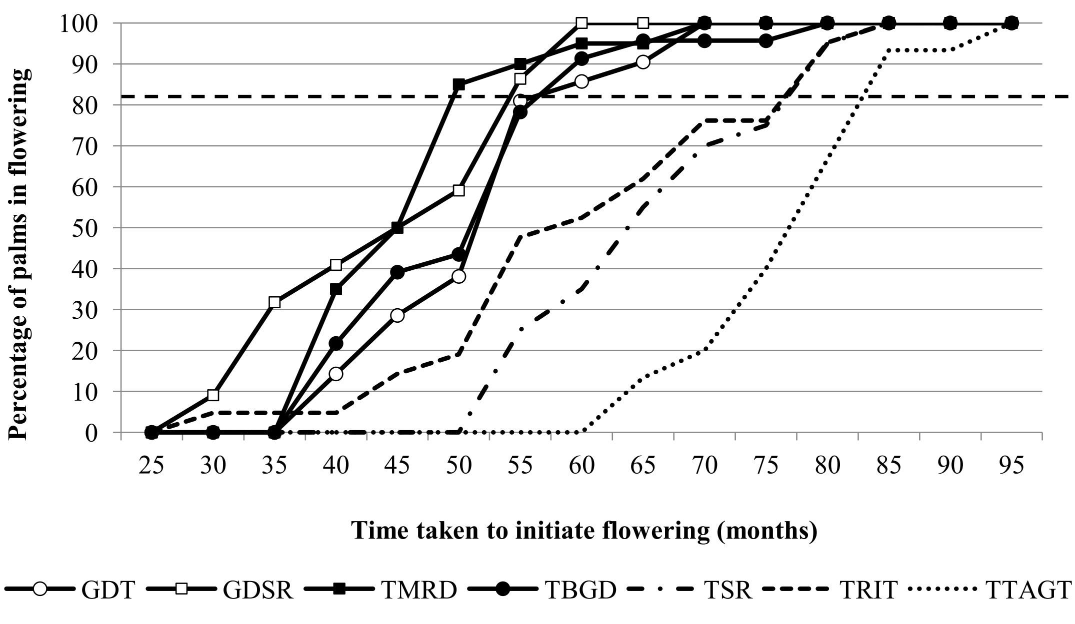

Fig. 2. Trends in time taken for flowering in new crosses and standard cultivars of coconut at Middeniya

Due to the limitation in the size of the blocks at Middeniya, two Dwarf x Tall crosses DG x RIT and DG x TAGT were not planted in this experimental site. Yet, two separate blocks of these two crosses were planted at the same estate and the crosses were showing exceptionally early flowering similar with the trend reported at Siringapatha (Data not presented).

Collection of nut yield data was initiated at Siringapatha and Middeniya in 2016 and the annual yield data were used for the present nut yield analysis. Results are presented in graphical form for easy understanding. At Siringapatha, Tall x Dwarf cultivar Kapruwana and the new cross T x MRD reported significantly higher nut yields compared to the Tall x Tall cultivar CRISL98 and cross T x TAGT (Fig. 3). Similar to the trend reported with respect to flowering, new Tall x Tall coconut cross T x RIT did not report significant differences in nut yield in comparison to Dwarf x Tall cultivars. Lowest nut yield data were reported for T x TAGT which was late flowering too. This is the first set of nut yield data reported from this exotic crosses trial blocks at Siringapatha and yields are expected to increase when the yields become stabilized.

Fig. 3. Annual nut yields of new crosses and standard cultivars of coconut at eight years after planting in Siringapatha

At Middeniya, Kapruwana reported the highest nut yield followed by CRIC65 (Fig. 4). No significant difference in terms of nut yield among new Dwarf x Tall crosses and recommended Dwarf x Tall cultivars were observed. Tall x Tall cultivars reported significantly lower yield compared to Dwarf x Talls. Nut yield data reported for T x RIT at Middeniya was much lower than that of Siringapatha. Favorable weather conditions at Siringapatha in the Wet Zone of Sri Lanka possibly helped in expressing the true potential of the new cross T x RIT. However, one year data is not at all sufficient for firm conclusions in a perennial plant such as coconut.

It is a common observation in coconut that 20% of the coconut palms produce 80% of the annual nut yield. This conventional phenomenon was challenged with the results of the novel crosses developed using exotic pollen and some of the released cultivars. For instance, 55% of the Kapruwana palms at Siringaphatha and 65% of the palms at Middeniya were giving higher yields than the field average. This was followed by T x MRD which again reported a similar trend. In addition, at the favorable site Siringapatha, 50% of the T x RIT palms were showing higher yields than the field average. Surprisingly, maximum yields over 100 nuts were also reported for recommended cultivars Kapruwana, CRIC65 and new crosses T x MRD, T x RIT and T x BGD (Table 2). These results are truly promising as traditional Sri Lankan Tall palm takes 6 to 8 years for flowering and 15 years for yield stabilizing. In contrast, the new Tall x Tall cross T x RIT has the potential of producing 152 nuts per palm at the favorable site in the Wet Zone (Siringapatha) and 144 nuts per palm at the Dry Zone (Middeniya) at eight years after planting (Table 2).

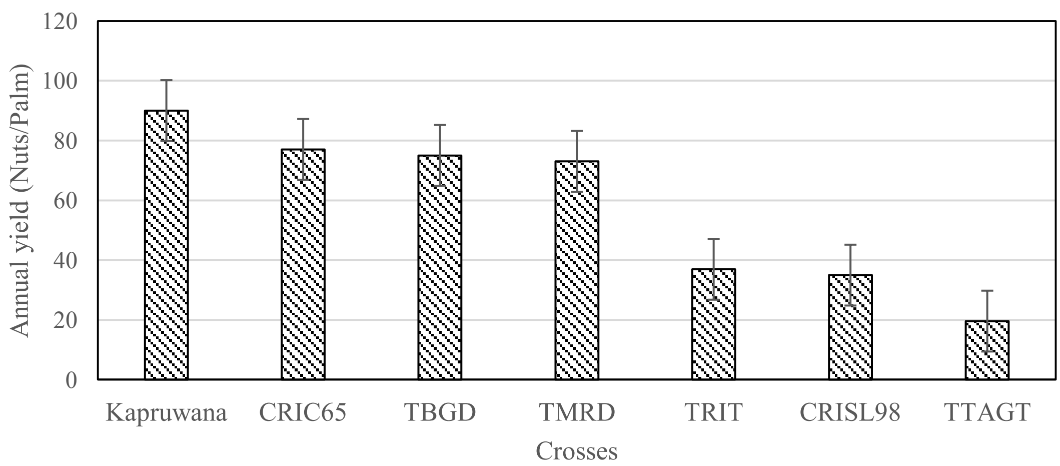

Fig. 4. Annual nut yields of new crosses and standard cultivars of coconut at eight years after planting in Middeniya

Table 2. Maximum nut yield and percentage of palms with greater yield than field average at Siringapatha and Middeniya

New cross/ cultivar	Siringapatha		Middeniya	
	Maximum yield	**Palms with greater yield than field average (%)**	**Maximum yield**	**Palms with greater yield than field average (%)**
CRIC65	90	42	193	50
Kapruwana	178	55	178	65
TMRD	167	52	130	60
TRIT	152	50	144	16
TBGD	121	37	142	55
DGRIT	119	50	-	-
DGTAGT	133	27	-	-
TTAGT	100	13	72	13
CRISL98	97	23	85	16

Fruit component analysis reconfirmed the superiority of new Tall x Tall cross T x RIT at the favorable site Siringapatha (Table 3). Among the fruit components, T x RIT reported the highest Fresh nut weight (1,878.5 g), Husked weight (946.9 g) and Kernel weight (421.5 g) together with other two Tall x Tall crosses/cultivar T x TAGT and CRISL98. There were no significant differences among Dwarf x Tall new crosses and recommended cultivars for Kernel weight.

Table 3. Fruit component analysis for new coconut crosses and standard coconut cultivars at Siringapatha

New crosses/ Recommended cultivars	FNW	HW	WW	KW
T x RIT	**1878.53[a]**	**946.934[a]**	**289.147[a]**	**421.533[a]**
T x TAGT	1883.69[a]	932.410[ab]	302.211[a]	410.589[a]
CRISL98	1849.58[a]	963.378[a]	255.628[a]	393.181[a]
DG x TAGT	1500.74[b]	750.966[abcd]	255.446[ab]	313.496[bc]
CRIC65	1485.77[b]	804.276[d]	202.164[bc]	305.622[b]
T x MRD	**1475.74[b]**	**810.199[cd]**	**186.871[bc]**	**300.105[bc]**
T x BGD	1533.93[b]	905.294[abc]	145.369[d]	294.704[bc]
Kapruwana	1393.53[b]	732.026[d]	194.626[c]	294.482[bc]
DG x RIT	1448.19[b]	862.974[d]	174.580[cd]	267.138[c]

FNW: Fresh nut weight; HNW: Husked nut weight; HW: Husk weight; WW: Nut water weight; KW: Kernel weight (Means with the same letter across each column are not significantly different at p=0.05)

The early nut production and kernel productivity per unit land area in the year at the favorable site Siringapatha is summarized in Table 4. The results revealed that despite T x RIT producing comparatively less nuts than its counterparts Kapruwana and T x MRD, it is the best cultivar in terms of kernel productivity (4547 kg/ha/year).

Table 4. Annual nut production and kernel productivity of newly developed crosses and standard coconut cultivars at Siringapatha, eight years after field planting

New crosses/ recommended cultivar	Annual nut yield (nuts/ha/year)	Annual kernel productivity (kg/ha/year)
TRIT	10,791	4,547.24
TMRD	12,545	3,763.56
Kapruwana	12,656	3,701.94
TBGD	9,799	2,888.24
DGRIT	9,232	2,466.38
CRIC65	7,947	2,428.46
DGTAGT	7,334	2,298.90
TTAGT	5,972	2,452.16
CRISL98	4,871	1,914.96

The present study is an early investigation conducted to demonstrate the potentials of the newly developed exotic crosses in terms of earliness in flowering and first recorded set of yield data at eight years after planting in 2016. The nut yields are not stabilized yet. However, the new Tall x Tall cross T x RIT showed very high potential in terms of precocity and kernel productivity despite of being a Tall x Tall cultivar and shows high potential to be a new choice of planting material of the coconut growers in Sri Lanka. The Tall x Dwarf hybrid T x MRD was also comparable with the recommended highest yielding cultivar Kapruwana and showed a potential to be another addition to the limited selection that the coconut growers have in terms of different types of planting material. Recording nut yield, fruit component and weather data are being continued at both Siringapatha and Middeniya for a future comprehensive analysis and for making recommendations of new coconut cultivars for the national coconut replanting programme in Sri Lanka.

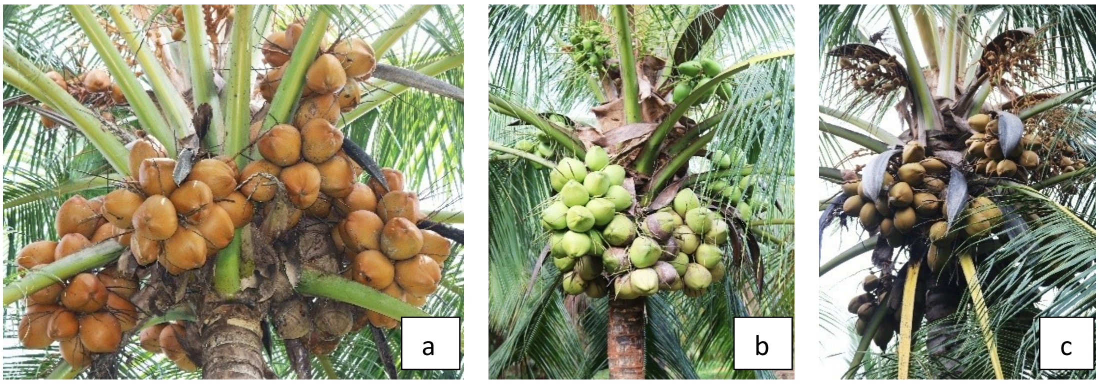

Fig. 5. The promising exotic crosses T x MRD (a), T x RIT (b) and DG x RIT (c)

The novel approach of parent population selection using molecular data has increased the efficiency and effectiveness of the breeding programme of Coconut Research Institute tremendously. The decision of importation of coconut pollen of selected varieties has reduced the duration of breeding cycle by 10 years allowing more new planting materials to be recommended in the near future. Currently the palms of imported exotic germplasm at gene bank of Coconut Research Institute are at bearing stage and being multiplied to produce these potential crosses in large scale.

Conclusions

Six new coconut crosses developed using four exotic pollen types for the first time in Sri Lanka; five crosses have shown similar performances in terms of yield with the recommended high yielding coconut cultivars such as Kapruwana. However, T x TAGT exhibited significantly poor performances in terms of nut yield at eight years after planting.

The present study for the first time developed an early flowering, high yielding and excellent kernel producing Tall x Tall coconut cross T x RIT to be recommended for the coconut industry in Sri Lanka.

T x RIT and T x MRD displayed promising performances at eight years after planting. Once the yields are stabilized, with further analysis, these new crosses could be released to the National Coconut Replanting Programme.

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