

Development of Promising Coconut Hybrids Utilizing Novel Brown Dwarf Coconut Variety

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ABSTRACT

Three new coconut hybrids; Sri Lanka brown dwarf x Sri Lanka tall (BD x T), Sri Lanka tall x Sri Lanka brown dwarf (T x BD), and Sri Lanka brown dwarf x San Ramon tall (BD x SR) were developed using a recently discovered local dwarf coconut variety; Sri Lanka brown dwarf. Their performances were evaluated at three locations (Raddegoda, Ratmalagara and Wanathawilluwa) with recommended coconut cultivars CRIC60, CRIC65, CRISL98 and Kapruwana for vegetative growth, time taken for first flowering, early nut yield, fruit components and kernel productivity. Brown dwarf crosses were comparable or better to other improved coconut hybrids for all the characters evaluated. BD x T was equally superior as Kapruwana, which is so far the best coconut hybrid for kernel productivity. High female flower production trait of brown dwarf has adequately inherited into BD x T and T x BD indicating their high yield potential at highly conducive environments for coconut. Hence, recommending brown dwarf crosses as new improved coconut cultivars will not only enhance the productivity of coconut lands but also will provide more options for growers and enhance the diversity of planting materials available for a sustainable coconut production even in the face of perceived climate change scenarios.

Key words: *Coconut, cultivar evaluation, Sri Lanka brown dwarf, vegetative growth, precocity, yield*

INTRODUCTION

Coconut, *Cocos nucifera* is renowned as the tree of life in the tropics due to its versatile uses. Coconut has a long history in Sri Lanka and it is the most widely grown plantation crop in the country occupying around 19% of total arable land. Because of the importance of coconut in the daily diet of the Sri Lankans, nearly 80% of the total production is being consumed domestically with a per capita consumption of 109 nuts (Coconut Research Institute of Sri Lanka, 2011). Furthermore, coconut significantly contributes to the foreign exchange earnings of the country (32.43 billion rupees in 2010) (Coconut Development Authority, 2010). However, there is a considerable gap between the national coconut production and the demand for fresh nuts and nuts required by the industry (Ministry of Coconut Development and Janatha Estate Development, 2011). Coconut varietal improvement programme plays a vital role in reducing this gap between demand and supply. Furthermore, varietal improvement programmes are needed to provide diverse planting materials to the national planting programme to ensure the sustainability of coconut cultivation in the face of changing biotic and abiotic environments.

The diverse genetic resources are the raw materials in crop varietal improvement programmes. Hence, germplasm collection, conservation and utilization are essential components in any crop breeding programme including coconuts. In Sri Lanka the first collection of coconut germplasm was done in 1940's - 1950's and that collection was categorized into three distinct varieties as

typica, nana and aurantiaca (Liyanage, 1958). This collection was comprised of eight forms of typica, three forms of nana and two forms of aurantiaca. The typica forms are generally allogamous and tall in habit with considerable tolerance to variations of soil and climate. Coconuts coming under this variety are grown commercially since; they produce large nuts with good copra quality. The three forms identified under variety Nana were named based on the colour of the pericarp; Sri Lanka green dwarf (*pumila*), Sri Lanka yellow dwarf (*eburnea*) and Sri Lanka red dwarf (*regia*). These forms are autogamous, precocious and high yielding but, produce smaller nuts with poor kernel content. The dwarf varieties are less common worldwide and represent only 5% of global coconut cultivation (Bourdeix *et al.*, 1990).

Coconut breeding is restricted to mass selection and hybridization (Liyanage *et al.*, 1988 and Bourdeix *et al.*, 2005) due to number of inherent breeding constraints in coconut palm itself (Liyanage *et al.*, 1988). The hybridization between typica (tall) and nana (dwarf) were highly successful in terms of precocity and yield (Liyanage *et al.*, 1988) and hybrids are much preferred by coconut growers. Hence, different forms of variety nana have been exploited as breeding materials for coconut hybrid production.

A systematic germplasm collection programme was initiated in Sri Lanka in 1984 to arrest genetic erosion and to conserve valuable genes which have so far not been exploited for utilization (Wickramaratne, 1984). A systematic and accelerated collection and conservation programme for coconut

germplasm was felt necessary as there had been a high rate of land fragmentation due to the rapid industrialization and urbanization in the traditional coconut growing areas, replanting of local materials with improved cultivars and furthermore due to natural disasters such as long droughts and cyclones.

Under this systematic germplasm collection and conservation programme, a few dwarf like palms with brown colour nuts, petioles and inflorescence were identified in 1992 from a few home gardens in Kurunegala and Puttalam districts. The morphological, morphometrical and molecular studies on these few palms confirmed that this brown colour, dwarf-like coconut palms as a novel coconut form within the variety nana (Perera *et al.*, 2002). Accordingly this coconut form was named as Sri Lanka brown dwarf (*braune*) and the list of varieties and forms of coconuts in Sri Lanka was updated (Peries, 1996). The initial palms were used for purification and multiplication and conserved in *ex-situ* field gene banks (Perera *et al.*, 2002).

The Sri Lanka brown dwarf is characterized by excessive number of female flowers per inflorescence (more than 80 per inflorescence) (Perera *et al.*, 2002) and in comparison to other dwarfs, brown dwarf variety appeared more tolerance to moisture stress (Ranasinghe, 2005) suggesting the potential use of Sri Lanka brown dwarf in exploiting hybrid vigour for nut yield and moisture stress tolerance. This paper discusses the preliminary results of the potential use of Sri Lanka brown dwarf for coconut hybrid production for improved productivity.

MATERIALS AND METHODS

Development of coconut hybrids utilizing Sri Lanka brown dwarf

A controlled pollination programme was initiated in 2003 using Sri Lanka brown dwarfs conserved *ex-situ* at Poththukulama Research station, Pallama (PRS). The new crosses produced were Sri Lanka brown dwarf x Sri Lanka tall (BD x T), Sri Lanka tall x Sri Lanka brown dwarf (T x BD, the reciprocal of the former), Sri Lanka brown dwarf x San Ramon tall (BD x SR). San Ramon tall is an exotic coconut variety now naturalized in Sri Lanka, from the Philippines (Fernando, 1999), which consisted of the genome of Pacific and Southeast Asian origin (Perera *et al.*, 2000). BD x T and BD x SR were produced at the PRS using 14 brown dwarf palms as female parents. Pollen of Sri Lanka tall and San Ramon tall for the pollination programme were collected from Isolated Seed Garden, Ambakelle and from Bandirippuwa Estate, Lunuwila respectively. T x BD pollination programme was carried out at Isolated Seed Garden, Ambakelle using 20 Sri Lanka tall palms. Seed nuts produced from each cross were collected separately and were nursery laid at the Bandirippuwa Research Nursery, Lunuwila. Seedlings of control crosses CRIC60, CRIC65, CRISL98 and Kapruwana were produced at Isolated Seed Garden, Ambakelle.

Evaluation of hybrid vigour of brown dwarf crosses in different agro-ecological zones

The three brown dwarf crosses; BD x T, T x BD and BD x SR were field evaluated with four recommended coconut cultivars as

controls viz; Sri Lanka tall x Sri Lanka tall (CRIC60), Sri Lanka green dwarf x Sri Lanka tall (CRIC65), Sri Lanka tall x San Ramon tall (CRISL98) and Sri Lanka green dwarf x San Ramon tall (Kapruwana).

The experiment was planted at three sites representing different agro-ecological zones and different soil series. Table 1 shows the details of the experimental sites.

in DL₃ and experiences long dry spells from February to September each year. The 75% expected annual rainfall in this site is around 800 mm which is lower than the optimum annual rainfall requirement of coconut. This site receives most of the rainfall during *Maha* season (October to January) resulting a temporary water logging during the period. The maximum temperature ranges from 29 °C - 38 °C (Department of Agriculture, Sri

Table 1 - Details of experimental sites

Experiment site	Year of establishment	Agro-ecological zone	Soil type & series
Raddegoda Estate, Rideegama	2004	IL _{1a}	RBE Melsiripura series
Ratmalagara Research Station, Madampe	2005	IL _{1a}	RYP Andigama & Wilaththawa series
Panadura Estate, Wanathawilluwa	2005	DL ₃	Latozols Mawillu series

Raddegoda site is located in IL_{1a} and receives a well distributed annual rainfall of over 1400 mm. The maximum temperature ranges between 29 °C - 35 °C (Department of Agriculture, Sri Lanka, 2006). This site belongs to Melsiripura soil series, which is characterized as deep, well-drained loamy soils. Therefore, this site is considered as a favourable site for coconut cultivation. Although the site at Ratmalagara is located in the same agro-ecological region and receives adequate rainfall, the soil in this site is imperfectly drained and loamy to clayey with considerable amount of gravels. Hence, this site is characterized as a moisture and nutrient limited site. Wanathawilluwa site is located

Lanka, 2006) in this region and it is supra-optimal for coconut cultivation. The soil is characterized by imperfectly drained deep sandy soils. Coconut palms in this site suffers heat and moisture stress for a considerable period within a year.

Experimental design

The experimental design used was Randomized Complete Block Design (RCBD) with four replicates at Raddegoda and Ratmalagara sites and three replicates at Wanathawilluwa site. The plot size varied from 6-9 seedlings. The planting design was 8 m square and the plant

density was 165 palms per hectare. The seed hole size was 1 x 1 x 1 m at all three sites.

The sites were managed only with standard basic management practices such as application of recommended dosage of Young Palm Mixture (YPM) or Adult Palm Mixture (APM) fertilizer depending on the age, moisture conservation by maintaining mulch around manure circle, two to three cycles of weeding and irrigation only during long dry spells.

Data collection and analysis

Early growth of seedlings as measured by the rate of leaf production, girth at the base of seedlings and height of the seedlings up to 3 years in six months intervals and time taken for first flowering in number of months were recorded in all three sites. Female flower production, nut yield and fruit component data i.e; fresh weight, husk weight, husked nut weight, split nut weight, shell weight, volume of water and kernel weight, were collected only at Raddegoda site since 2011. Nut yield data were recorded monthly and fruit component data were recorded bimonthly. In each fruit component analysis, two nuts were randomly collected from each experimental palm. Data recording on female flower production, nut yield and fruit components were not yet initiated at Ratmalagara and Wanathawilluwa sites.

Data were analysed by General Linear Model (GLM) procedure and mean separation was done by Least Square Mean Difference and orthogonal contrasts in SAS 9.1.3 portable version.

RESULTS AND DISCUSSION

Early growth of seedlings

Different leaf production rates among varieties at different sites were observed. High rate of leaf production during early growth of seedling is correlated with precocity, nut yield and yield of copra and it is an indicative of the future yield potential (Liyanage *et al.*, 1988). At Raddegoda site the overall leaf production rate varied from 8-10 leaves per year and at Ratmalagara site it was 7-9 leaves per year. In contrast, at Wanathawilluwa site the overall leaf production rate was greater than other two sites (10-13 leaves per year), probably indicating the high rate of growth and development at supra-optimal temperature (Craufurd *et al.*, 2009).

Fig. 1 shows the total number of leaves produced by each cultivar at three sites during first 3 years from planting. At the favourable site Raddegoda, T x BD, Kapruwana and CRIC65 recorded the highest leaf production without showing any statistical difference among them followed by BD x T, BD x SR. At Ratmalagara site the highest leaf production was observed for BD x T, BD x SR and Kapruwana followed by CRIC65 and CRISL98. However, at both these sites the lowest leaf producer was CRIC60 and the values were statistically significant. At Wanathawilluwa site the two hybrids, CRIC65 and Kapruwana produced a noticeably higher number of leaves in three year period and it was significantly different from that of other cultivars during the period. This phenomenon is a suggestive of higher rate of growth response of crosses made with green dwarf for higher temperature, which seems to be a physiological adaptation for attaining the early reproduction (Craufurd *et al.*, 2009).

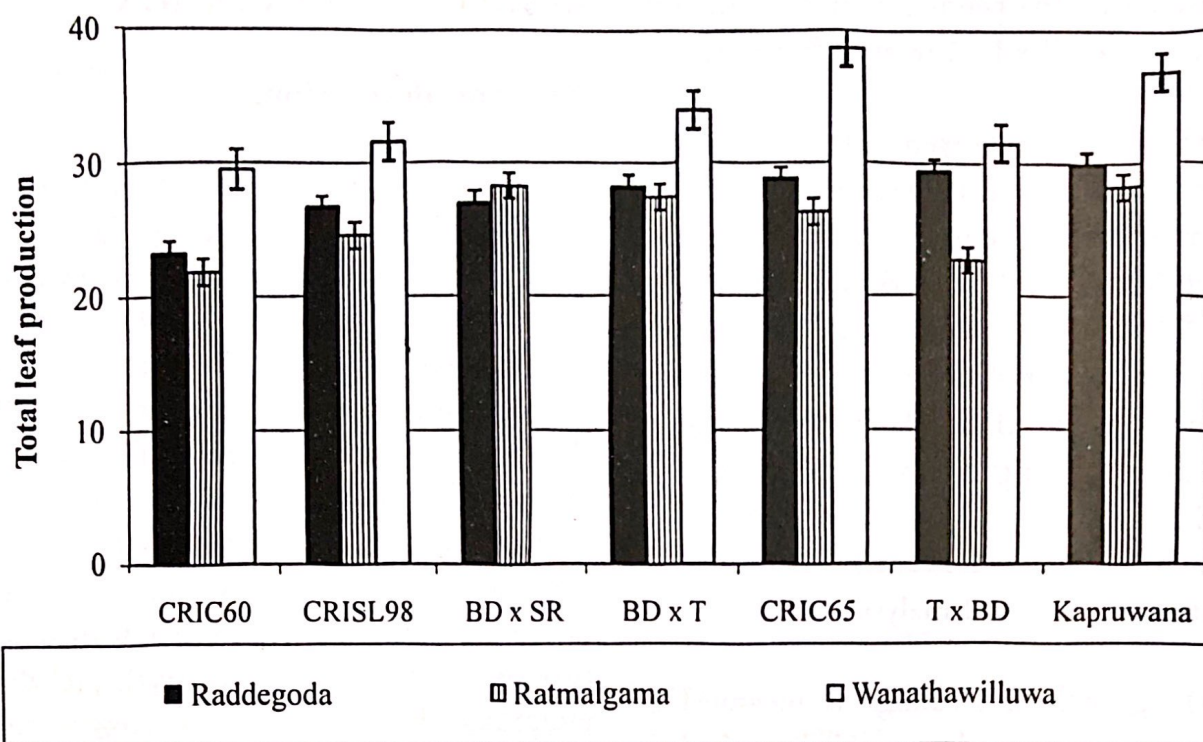


Fig. 1 - Total leaves produced by different cultivars at three sites from planting to 3 years after planting

The Table 2 shows the height and girth attained in 2 years after planting at three sites.

At Raddegoda site T x BD, Kapruwana and CRISL 98 were the tallest at 2 years after planting and followed by BD x T, CRIC65 and BD x SR. Similarly, the highest girth at the base was achieved in T x BD and Kapruwana seedlings. The girth of BD x T, BD x SR Kapruwana, CRIC65 and CRISL98 are not significantly different. The lowest values for both girth and height were observed in CRIC60. At Ratmalagara site the highest values for girth at the base were recorded for BD x T, T x BD and Kapruwana and those values were significantly different from the values recorded for CRISL98 and BD x SR. All the other pair wise comparisons were statistically insignificant. BD x T was the tallest at Ratmalagara and the only

significant difference with respect to height was recorded between BD x T and BD x SR. At Wanathawilluwa site, the highest values for both girth and height were recorded in T x BD, Kapruwana and CRIC65. Furthermore, for both girth and height no significant differences were observed between CRIC65 and BD x T. This observation at Wanatahwilluwa is in contrast with the observations made on leaf production at the same site. This indicates that the net assimilates resulting from the higher leaf production has not been utilized for increasing the girth and height of green dwarf crosses, but for attaining early reproduction due to unfavourable climatic condition.

Table 2 - Girth and height attained in 2 years after planting

Cultivar/ cross	Girth (cm)			Height (cm)		
	Raddegoda	Ratmalagara	Wanathavilluwa	Raddegoda	Ratmalagara	Wanathavilluwa
BD x T	45.9 c, d	65.0 a	61.8 b	311.7 b, c	394.9 a	333.7 b
T x BD	58.6 a	63.2 a,	70.2 a, b	338.4 a	379.1 a, b	385.9 a
BD x SR	49.0 b, c	53.1 b	Not planted	288.7 c, d	342.6 b	Not planted
CRIC65	47.6 c	57.4 a, b	67.7 a, b	296.1 c	364.7 a, b	348.6 a, b
Kapruwana	55.0 a, b	62.0 a	76.8 a	325.6 a, b	374.4 a, b	382.2 a
CRISL98	51.1 b, c	50.5 b	60.1 b	324.8 a, b	375.2 a, b	321.1 b
CRIC60	41.7 d	57.8 a, b	58.8 b	260.5 d	376.2 a, b	335.0 b

(Means with the same letter across each column are not significantly different at $p \leq 0.05$)

Time taken for first flowering

Time taken by different crosses for first flowering was different at different sites. Fig. 2, 3 and 4 show the percentage of palms in flower over the years at Raddegoda, Ratmalagara and Wanathawilluwa sites respectively.

As illustrated in Fig. 2, 3 and 4, crosses at Raddegoda showed the least staggered distribution in time taken for first flowering compared to that of other two sites. Furthermore, the lowest Inter Quartile Range (IQR) for hybrids between dwarf and tall was recorded at Raddegoda and it was 8 months. The IQR recorded at Ratmalagara and Wanathawilluwa were 13 and 19 months respectively, suggesting variable response of individual palms for less favourable conditions. At Raddegoda and Wanathawilluwa sites,

the crosses between dwarf and tall achieved 75% flowering before 4 years after planting. However, at Ratmalagara it took 5-5 ½ years to achieve 75% flowering. The two tall crosses; CRISL98 and CRIC60 have reached 97% flowering at Raddegoda site seven years after planting and it was 70% and 60% respectively at Ratmalagara site, six years after planting. At Wanathawilluwa site percentage of CRISL98 palms in flower was 41% and CRIC60 was 45%. Therefore, in these two sites the mean separation was done only for the crosses between dwarf and tall. The Table 3 compares mean time taken for first flowering by different crosses at three sites.

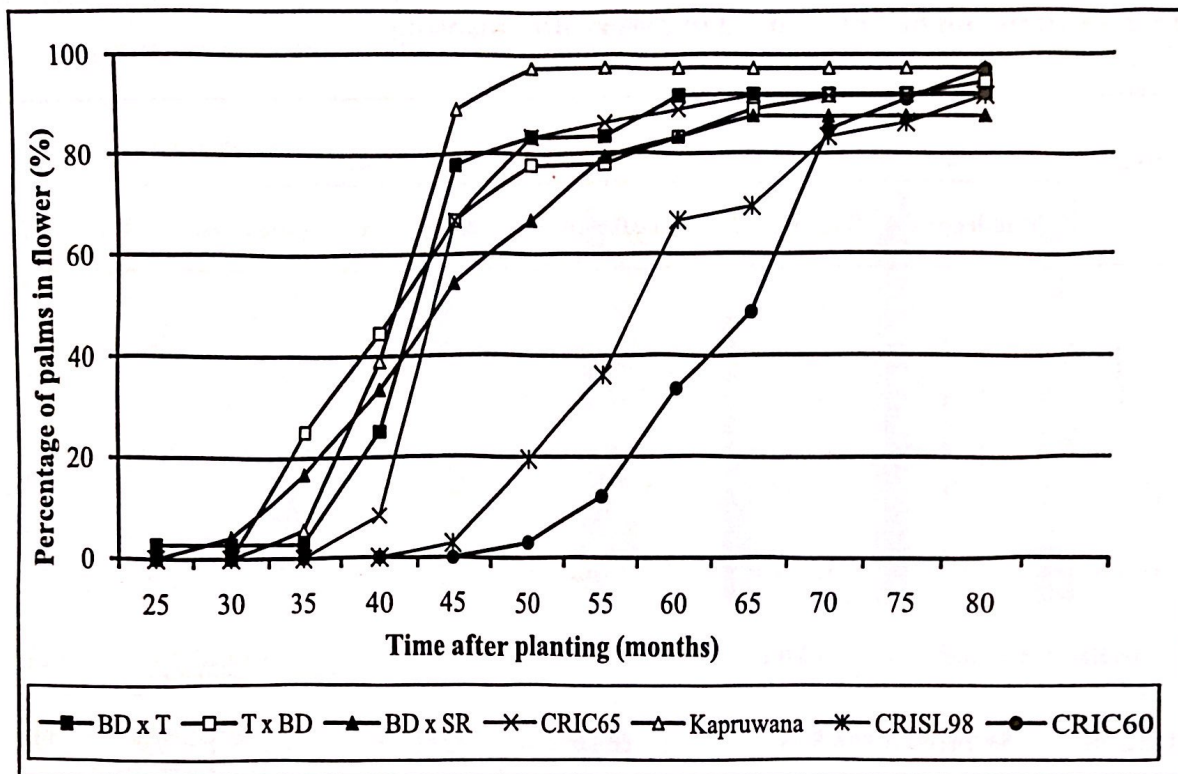


Fig. 2 - Cumulative percentages of palms in flower over the time at Raddegada site

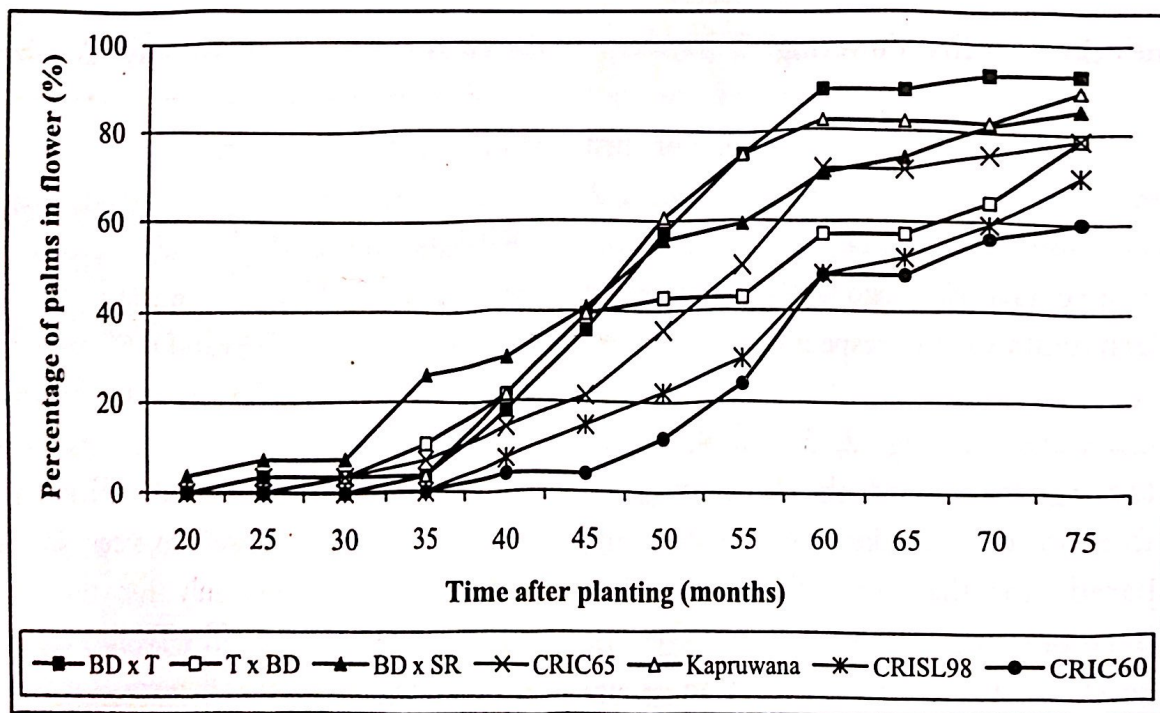


Fig. 3 - Cumulative percentages of palms in flower over the time at Ratmalagara site

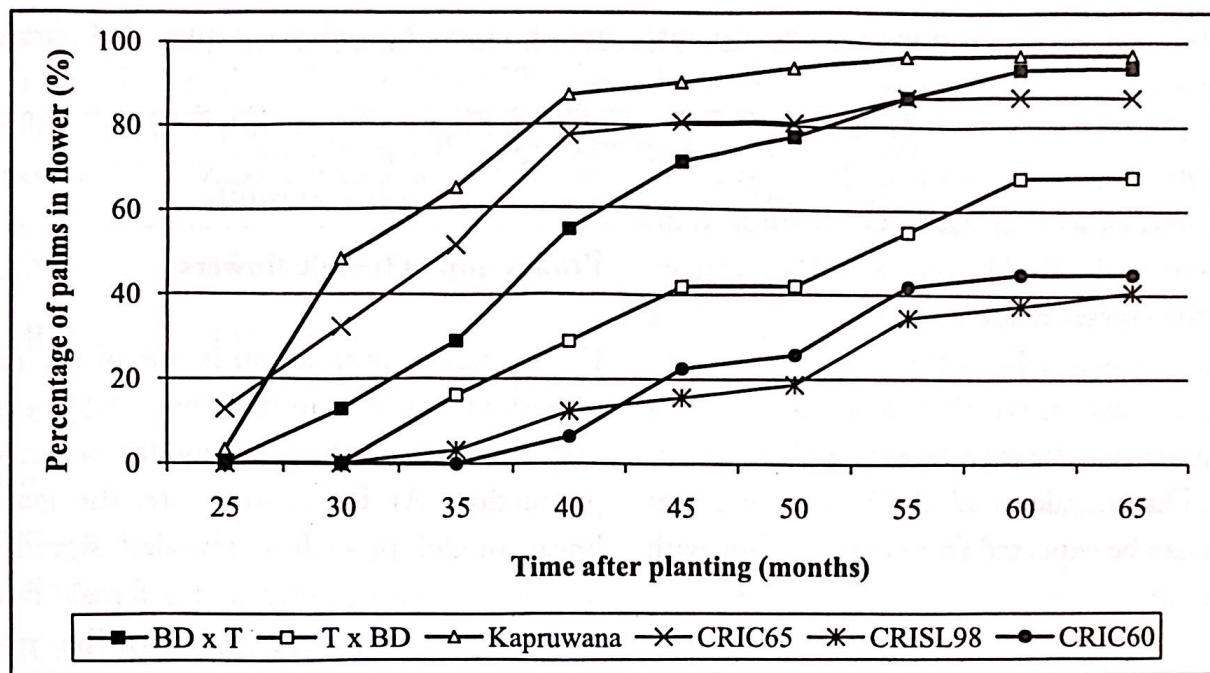


Fig. 4 - Cumulative percentages of palms in flower over the time at Wanathawilluwa site

Table 3 - Mean time taken for first flowering (measured in months)

Cultivar	Raddegoda	Ratmalagara	Wanathawilluwa
BD x T	43.8 a b	49.7 a	40.1 b
T x BD	43.9 a b	52.4 a	43.7 b
BD x SR	43.7 a b	47.5 a	-
CRIC65	45.3 b	52.4 a	33.6 a
Kapruwana	41.1 a	50.0 a	32.9 a
CRISL98	59.3 c	-	-
CRIC60	63.8 d	-	-

(Means with the same letter across each column are not significantly different at $p \leq 0.05$)

As observed in other previous experiments on coconut cultivar evaluation (Perera *et al.*, 2010; Dissanayaka *et al.*, 2008 and Taffin *et al.*, 1991), hybrids between dwarf and tall were precocious than tall x tall hybrids at all three sites. At Raddegoda and Ratmalagara sites, the crosses made with brown dwarf were precocious as equally as the crosses made with the green dwarf, which was so far the best parental variety for early flowering (Perera *et al.*, 2010; Dissanayaka *et al.*, 2008). Hence, better yields can be expected from crosses made with brown dwarf during early production years because, it has been recorded that precocious material give better yields during early years of production (Bourdeix *et al.*, 1992). At Raddegoda site, the time taken by CRISL98 to initiate flowering was statistically lower than the time taken by CRIC60 revealing that CRISL98 has inherited the early flowering character of its male parent; San Ramon tall. At Wanathawilluwa site the two crosses; CRIC65 and Kapruwana, where the common female parent is green dwarf showed a noticeably lower time for first flowering compared to brown dwarf crosses. The mean values were less than three years and the difference is 9 months as against for brown dwarf crosses. In addition, it was a general observation that inflorescence production was not continuous in these palms at Wanathawilluwa site. Shortening of the vegetative stage under high temperature has been recorded for annuals (Craufurd *et al.*, 2009) and this observation again support the hypothesis of high responsiveness of crosses made with green dwarf to higher temperatures. At all three sites no statistically significant difference was observed between BD x T and T x BD revealing the absence of maternal effect for flowering time. Furthermore, these

two crosses showed no statistical differences with BD x SR revealing the equal combining ability of brown dwarf with Sri Lanka tall and San Ramon tall for precocity.

Production of female flowers

Female flower production is one of the most important yield components in coconut and also one of the limiting factors in nut production. At Raddegoda site, the general linear model procedure revealed significant differences among cultivars for female flower production during 2011 (Table 4). The crosses between dwarf and tall were better female flower producers compared to crosses between tall in this experiment. The results revealed that there were no significant differences between BD x T and T x BD for number of female flowers produced revealing the absence of maternal effect for female flower production. BD x T cross produced significantly higher number of female flowers (155 palm/year) than other crosses. Sri Lanka brown dwarf is characterised by high female flower production capacity (Perera *et al.*, 2002) and interestingly this study revealed that during hybridization the female flower production capacity of brown dwarf has inherited into its progenies. However, in BD x SR the comparative advantage of brown dwarf seen in BD x T and T x BD has not been achieved.

Nut yield

As shown in table 4, crosses between dwarf and tall were superior to crosses between tall and tall in terms of nut yield. The results of the current study are in agreement with the findings of previous coconut hybrid evaluation

Table 4 - Annual production of female flowers and mature nuts at Raddegoda Estate

Cultivar	Annual female flower production (flowers/Palm)	Annual nut production (nuts/ha)
BD x T	155 (a)	9924 (a)
T x BD	131 (a, b)	8469 (a)
BD x SR	114 (b)	8016 (a)
CRIC65	110 (b)	8183 (a)
Kapruwana	126 (b)	8938 (a)
CRISL98	71 (c)	4744 (b)
CRIC60	54 (c)	3553 (b)

(Means with the same letter across each column are not significantly different at $p \leq 0.05$)

experiments (Dissananayka *et al.*, 2008 and Bourdeix *et al.*, 1990). However, no statistically significant differences were observed among hybrids between dwarf and tall indicating a similar combining ability of brown dwarf and green dwarf with either Sri Lanka tall or San Ramon tall for early nut production. No statistical difference was observed between BD x T and T x BD showing the absence of maternal effect on early nut production too. The data of current study revealed that the crosses involving brown dwarf variety performed equally well with other high yielding hybrids; CRIC65 and Kapruwana, at Raddegoda site during early production years. As a high correlation between initial nut yield and nut yield of adult palm has been reported in coconut in previous studies (Liyanage *et al.*, 1988), early yields of brown dwarfs indicate high yield potential in the long run.

Fruit components

Fruit component data revealed significant differences among different crosses with respect to all fruit components; fresh weight (FW), husked nut weight (HNW), husk weight (HW), split nut weight (SNW), kernel weight (KW) and shell weight (SW). Superiority of the crosses involving San Ramon tall with respect to fruit components was recorded previously in a separate cultivar evaluation experiment (Perera *et al.*, 2010) and the results of the current study reconfirm the previous results. CRISL98 outperformed all the crosses in all fruit components measured (Fig. 5). The other tall cultivar, CRIC60 was superior to crosses between dwarf and tall with respect to FW and HW, but performances were equal with BD x SR and Kapruwana in terms of kernel content (KW). Although, Kapruwana

has previously been identified as the best cross between dwarf and tall with respect to all fruit components (Perera *et al.*, 2010), in current study BD x SR has exceeded the weights recorded for Kapruwana with respect to FW, HNW and SW. Moreover, BD x SR has performed equally well with Kapruwana with respect to more economically important fruit components, KW and HW. According to orthogonal contrasts, the crosses between brown dwarf and Sri Lanka tall were much superior to the cross between green dwarf and Sri Lanka tall (CRIC65) for all fruit components except for the HW revealing the superiority of brown dwarf over green dwarf in crosses with Sri Lanka tall in terms of fruit components.

The economic value of different coconut cultivars largely depends on their productivity

in terms of kernel content per unit land area. Table 5 summarizes the kernel productivity of different crosses evaluated at Raddegoda site.

In previous hybrid evaluation experiments conducted in Sri Lanka the highest productivity was observed in Kapruwana (Perera *et al.*, 2010). However, in this study BD x T has shown the same high productivity as Kapruwana and these two crosses were superior to the widely grown hybrid CRIC65. Therefore in this experiment it was evident that the highest productivity observed for Kapruwana, can also be achieved by utilizing the local coconut germplasm. No statistically significant difference was observed between BD x T and T x BD showing the absence of maternal effect on kernel productivity too. Because of the high kernel content per nut in CRISL98, it has shown the same productivity

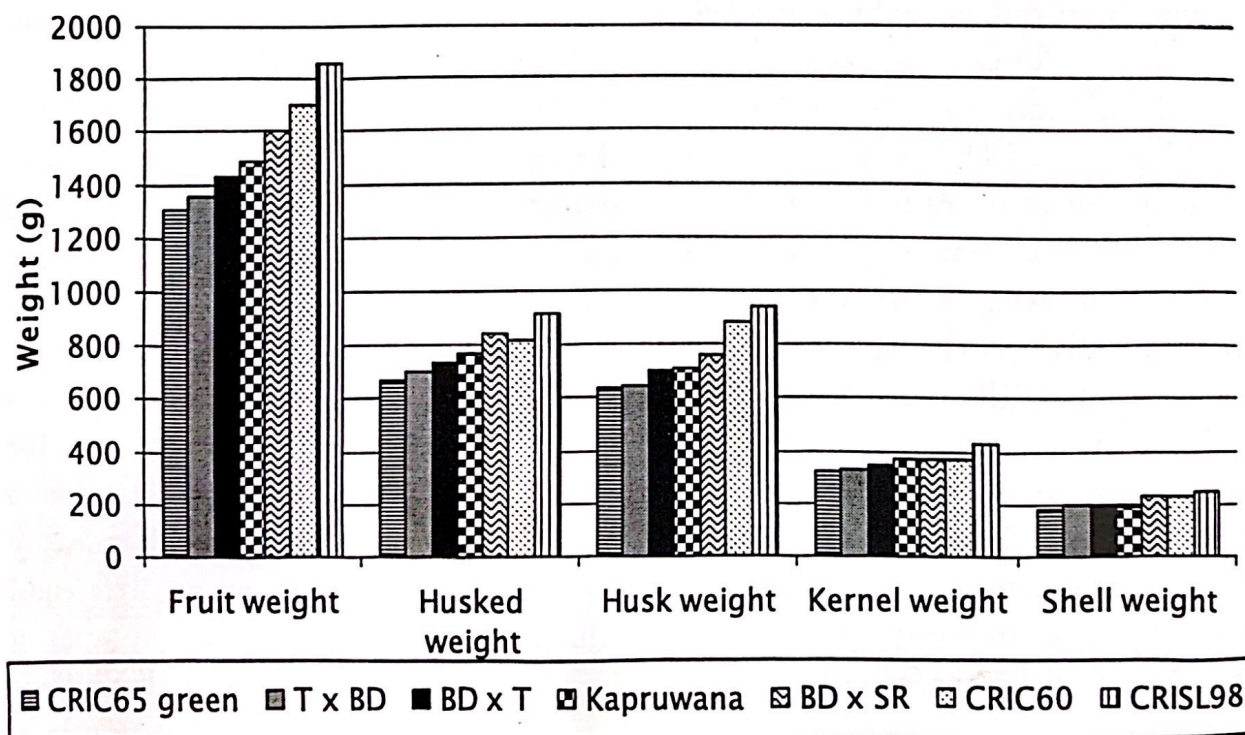


Fig. 5 - Weights of fruit components at Raddegoda site

Table 5 - Kernel Productivity of different cultivars at Raddegoda site

Cultivar	Kernel Production (kg/palm/year)	Kernel Productivity (kg/ha/year)
BD x T	21 kg (a)	3462 kg/ha/year
T x BD	17.9 kg (a, b)	2954 kg/ha/year
BD x SR	18.7 kg (a, b)	3092 kg/ha/year
CRIC65	16.5 kg (b)	2730 kg/ha/year
Kapruwana	20.8 kg (a)	3436 kg/ha/year
CRISL98	14.3 kg (b)	2367 kg/ha/year
CRIC60	9.4 kg (c)	1552 kg/ha/year

(Means with the same letter across each column are not significantly different at $p \leq 0.05$)

with dwarf x tall hybrids; BD x SR, T x BD and CRIC65. The least productivity was observed in CRIC60. Hence, the results of the current study revealed that new crosses involving brown dwarf has performed better or equally well with other recommended cultivars with regard to productivity during early years of production indicating the potential use of local brown dwarf in hybrid coconut breeding to contribute to increased national coconut production.

CONCLUSION

Brown dwarf crosses were comparable or better to all the other high yielding recommended coconut cultivars in Sri Lanka with respect to early growth, time taken for first flowering, early nut production and fruit characters. With respect to total kernel production per unit land area, brown dwarf crosses were equally good as Kapruwana, which is so far the best coconut hybrid in Sri Lanka for productivity.

Hence, recommending brown dwarf crosses as new improved coconut cultivars will not only enhance the productivity of coconut lands but also will provide more options for growers and enhance the diversity of planting materials available for a sustainable coconut production during calamities.

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