Evaluation of the Comparative Performance of Five Commercial Cultivars under Two Different Agro-ecological Zones in Sri Lanka

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ABSTRACT

A multilocational trial was established in 1983 for evaluating the comparative performance of five recommended coconut cultivars; CRIC60 (TT), green dwarf x tall (GDT) and yellow dwarf x tall (YDT) forms of CRIC65 and two estate selections; Moorock tall (MT) and Plus palm tall (PPT) under average management in different agro-ecological regions. This paper discusses the time taken for first flowering, nut and kernel yields of the cultivars in two locations, Bandirippuwa (BE) in a favourable soil in the wet intermediate zone and Suriyapura (SE) in marginal soils in the wet zone. The results demonstrated the precocity of hybrids, as they flowered 21 months earlier compared to talls. Yield data revealed the superiority of hybrids with 44% yield increase over the tall cultivars with a recorded maximum yield of 20,506 for GDT compared to 15,475 nuts/ha/year in TT. Data further revealed that GDT outperform YDT. All cultivars responded positively for favourable environments but the genetically improved cultivars; GDT, YDT and TT at a greater rate. Although talls produced higher kernel weight per nut compared to hybrids, lower kernel weight of hybrids was compensated by the higher nut yield for the hybrid to become the highest kernel producer per unit area (4.7 Mt/ha). CRIC60 demonstrated its response to selection for husked nut weight over PPT. MT is recommend as a suitable cultivar for marginal soils in Gampaha district as MT performed well at SE. Based on the overall results of this experiment hybrids previously recommended for home gardens are also recommended for wider scale planting. However, directing improved cultivars (GDT, YDT & TT) for better environment is suggested in order to harness their genetic potential to meet the country's requirement.

Key words: *Sri Lanka, coconut, improved cultivars, cultivar evaluation, precocity, yield*

INTRODUCTION

The coconut palm, *Cocos nucifera* L. is a major plantation crop and the most important palm of the wet tropics. Coconut is renowned for its multiple uses and for its significant contribution to the economy of over 80 coconut growing countries (Fernando *et al.*, 1997). Coconut is also one of the important plantation crops in Sri Lanka, 80% of its production being consumed domestically as food and beverage while significantly contributing to the foreign exchange earnings in the agriculture sector of the country and providing more than 135,000 people direct and indirect employments (Anon, 2006). Although, coconut cultivation has a very long history in Sri Lanka, the commercial cultivation has begun after the arrival of the Europeans. The British gave a boost to the coconut industry by extending systematic cultivation along the coast and to the interior.

During early periods of the industry, planting materials of coconut, *Cocos nucifera* L. were collected from high yielding and vigorous Sri Lankan tall variety as it was the most abundant coconut variety available locally and exhibited the most commercially interested traits at that time; the quality and quantity of copra. However, cross pollinating and highly heterozygous nature of the coconut palm coupled with no viable vegetative propagation method, limited the expected yield improvement. This had led to the initiation of a systematic coconut breeding programme under the Coconut Research Scheme in 1929 targeting for improved coconut cultivars for higher yield, precocity and tolerance to biotic and abiotic stresses (Liyanage, 1949 - 1966). Several inter and intra-varietal crosses were attempted in 1940's (Liyanage, 1949–1966; Manthriratne, 1970 – 1979; Liyanage, 1954) and as a result two improved coconut cultivars were released to the industry during early 1960's (Liyanage, 1972). The first cultivar named as CRIC60, popularly known as tall x tall or Ambakelle tall was a selection of Sri Lankan tall while the second cultivar named as CRIC65 or dwarf x tall was a hybrid between either green form or yellow form of dwarf and selected superior Sri Lankan tall. However, the total demand for improved cultivars could not be met with these two cultivars, and thus the remainder was supplied as Moorock tall and Plus palm talls. Moorock tall is an estate selection from Moorock estate, Mawathagama where parent palms are a progeny of specially selected seed nuts for kernel thickness (Wickramaratne, 1983). Plus palm tall is selected from different high yielding estates island wide (Wickramaratne, 1983).

CRIC60 has been recommended for island wide cultivation and it is assumed to have tolerance to moisture stress. In contrast, cultivar CRIC65 which is a combination of either green dwarf x tall or yellow dwarf x tall has been recommended for home gardens. However as there had not been a systematic evaluation of the comparative performance of these cultivars, a systematic multilocational cultivar evaluation trial at different agro-climatic zones was established during 1983-1986 (Wickramaratne, 1980 - 1989). The results pertaining to two sites; Bandirippuwa estate in Lunuwila (BE) in the Wet Intermediate zone and Suriyapura estate in Gampaha (SE) in the Wet zone are discussed in this paper.

MATERIALS AND METHODS

Cultivars evaluated

Five cultivars, CRIC60 [tall x tall (TT)], the two forms of CRIC65 [green dwarf x tall (GDT) and yellow dwarf x tall (YDT), Moorock tall (MT) and Plus palm tall (PPT) were used for the experiment. GDT, YDT and TT were produced at the Isolated Seed Garden (ISG), Ambakelle by artificial hand pollination. MT seed nuts were collected from Moorock estate, Mawathagama and PPT seed nuts were collected from Midland, St Annes, Dispensary, Walahapitiya, Daisy Valley, Andigedara, Walpolayaya, Siringapatha and Keenakelle estates and seed nuts were mixed before use (Wickramaratne, 1983).

Experimental sites and design

The experiment initially aimed to assess the performance of the five cultivars in five locations; Bandirippuwa, (Lunuwila), Thammenna (Puttalam), Dambakanada (Kurunegala), Suriyapura (Gampaha) and Palugaswewa (Chilaw) representing five different agro-ecological zones in coconut growing areas of the country. However later, the sites at Dambakanada and Palugaswewa were abandoned due to various reasons. Site at Thammenna was also not considered for this analysis as there was no sufficient data available for a comparative data analysis. Therefore this paper only considers the two sites; Bandirippuwa (BE) and Suriyapura (SE). Both BE and SE were established as re-plantings in 1984 and 1986 respectively.

The trial at BE was planted in a Randomized Complete Block Design with four replicates. Twenty palms each from each cultivar were allocated per replicate. The planting design was 7.6 m equilateral triangular and the plant density was 198 palms per hectare which was the recommended planting density at that time (Wickramaratne, 1983). In contrast, the trial at SE was planted in an Incomplete Block Design with six replicates and four plots per block. Cultivar GDT, YDT, TT, and MT appeared once in each of five replicates and PPT appeared once in each of four replicates (Wickramaratne, 1985). The same planting design and density of BE was used at SE too. The size of seed-hole was 1 x 1 x 1 m at both sites.

The BE site is located in the Wet Intermediate zone representing the agro-ecological zone IL_{1a}. The 75% expectancy of annual rainfall of the site is greater than 1400mm and the main soil type of the site is sandy loam to sandy clay loam. A major part of the site is thus classified as class S2 and class S3 under land suitability classification for coconut cultivation. The site at SE is located in Wet zone representing agro-ecological region WL_3. The 75% expectancy of annual rainfall in this site is greater than 1700mm and the main soil types of the site are sandy clay loam to clay loam mixed with ironstone gravel and a few quartz in sub soil. Therefore this site is classified as class S4 and S5 under land suitability classification for coconut cultivation.

The sites were managed only with standard basic management practices such as annual application of recommended dosage of YPM or APM fertilizer depending on the age, mulching of manure circle, two to three cycles of weeding. No irrigation was done during rain free period after the initial establishment period (Wickramaratne, 1980 - 1989).

Data collection and analysis

Growth rate of seedlings up to 5 years, time taken for first flowering in number of months from the date of planting to the first flowering, nut yield and fruit component data (fresh nut weight, husked nut weight and kernel weight) starting from 10 years after planting were recorded. Nut yield data were recorded in each pick (6 harvests per year) for 14 consecutive years at BE and for 10 years at SE. Data pertaining to year 2001 and 2002 at SE could not be recorded due to financial constraints and thus these data were eliminated from the data analysis. For fruit component analysis each cultivar was represented by 20 fruits per harvest. Only the time taken for first flowering, yield and the kernel weight were analyzed for this paper to compare the comparative performance of the cultivars under evaluation in the two sites to reveal any genotype environment interaction.

Repeated measure analysis, General Linear Model (GLM) procedure, Mean separation techniques (orthogonal contrasts, least square mean difference and Duncan's multiple range test) in SAS version 8.2 were used in the analysis of data. The average response of the cultivars to changes in the weather within the site was analysed using a method similar to that of Finlay and Wilkinson (1963). Regression lines were developed for each cultivar at both sites taking individual mean annual yields of each cultivar as the dependent variable and the environmental means ranked from lowest to highest as the independent variable.

RESULTS AND DISCUSSION

Precocity

Hybrids are more precocious than any of the tall cultivars under evaluation at both BE and SE (Table 1). This result is similar to the findings of a hybrid evaluation trial conducted in Ivory Coast using Malayan yellow dwarf, Cameroon red dwarf and West African tall (Taffin *et al,* 1991). The hybrids recorded a mean flowering time of 57 months which is 2 years earlier than that of talls which recorded 78 months on an average at both sites. Generally the dwarfs take much less time for flower initiation which is about 36-48 months after planting (Liyanage *et al*, 1988). As hybrids take an intermediate time between dwarf and tall for first flowering, it is suggested that combined effect of Quantitative Triat Loci (QTLs) for flowering time present in the dwarfs and the talls are expressed in hybrids.

Table 1: *Comparison of flowering at BE & SE (measured in months)*

	Mean St. Dev)		25% in flowering		75% in flowering	
	BE	SE	BE	SE	BE	SE
GDT	55 a (12.1)	55 a (10.5)	48	47	60	60
YDT	58a (11.9)	64 b (13.8)	49	54	62	73
TT	71 b (15.37)	81 c (10.5)	62	73	78	88
MT	71 b (15.0)	85 c (12.3)	62	73	78	90
PPT	74 b (16.1)	84 c (10.9)	62	75	78	90

At BE the mean time period taken for first flowering was not statistically different between two hybrids. However the difference between GDT and YDT was significant at SE, GDT being 9 months faster in flower initiation at SE indicating a genotype x environment interaction for flowering period. Generally both hybrids initiate flowering around four years after planting and nearly 75% of palms initiate flowering before the 5th year. On the contrary the time taken for flower initiation was not significantly different among tall cultivars at both sites but the mean time taken for flower initiation at BE was nearly 6 years while at SE it was nearly 7 years. All the cultivars in general have taken greater period of time to initiate flowering at SE than at BE except the cultivar GDT. These findings can be explained by the comparative disadvantage of the marginal environment at SE site.

Nut yield

Mean annual nut yield of all cultivars at both sites varied greatly over the years, but all cultivars followed a similar trend. Fig. 1 and 2 show the annual variation of nut yield over the years at BE and SE respectively (note the missing data for 2001 and 2002 at SE site) Though the year to year yield variation could be generally explained by the variation of the rainfall (Abeywardene, 1966), no concrete direct relationship between rainfall and yield variation could be established in some years in this experiment indicating that various other climatic and soil factors too are involved in influencing the final yield (i.e. yield during 2005)

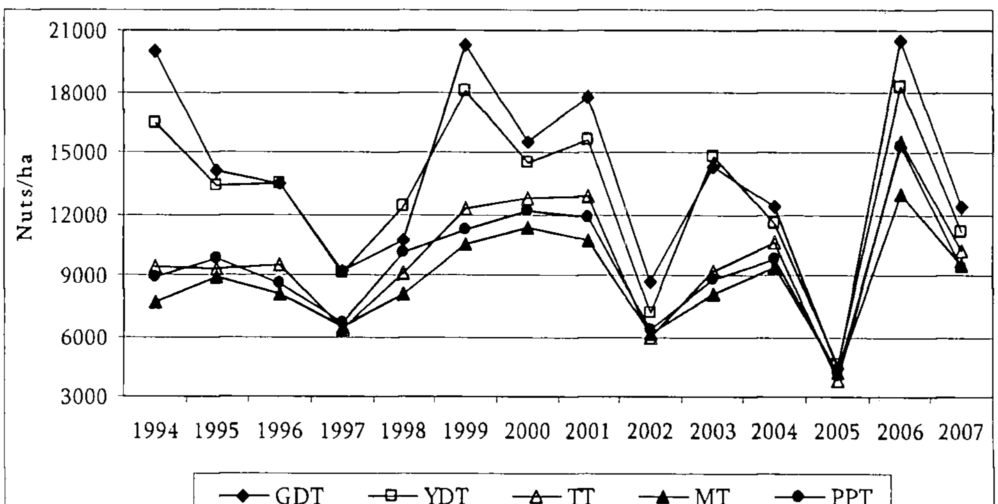

Fig. 1. *Mean annual nut yield variation at BE from 1994 to 2007*

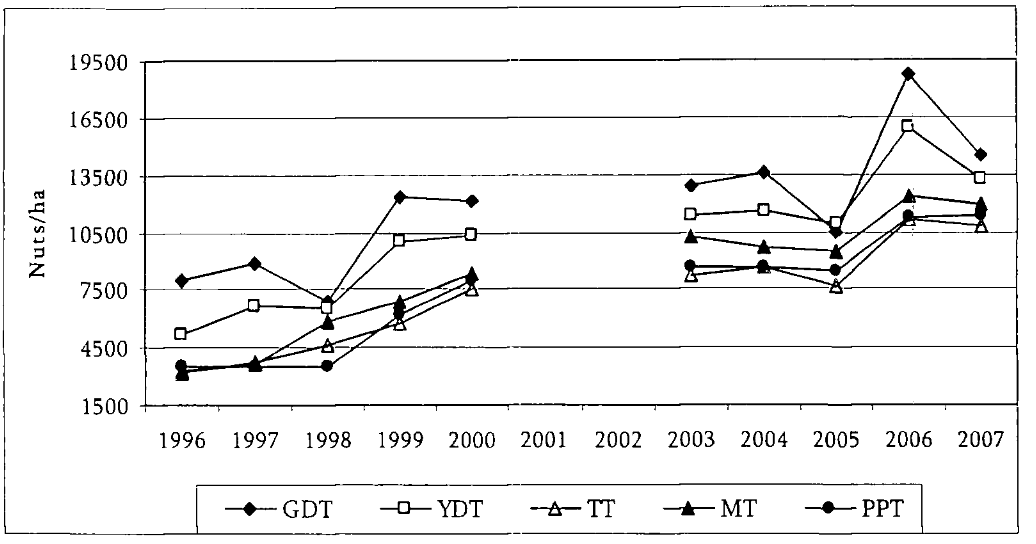

Fig. 2. *Mean annual nut yield variation at SE from 1996 to 2007*

which warrants further investigations. Comprehensive analysis of nut yield data at both sites confirmed the superiority of both hybrids over the tall cultivars and this is in agreement with the results of a similar study conducted in Ivory Coast (Taffin *et al.*, 1991). In the current study GDT and YDT produced an average of 13,838 and 12,895 nuts/ha/year respectively compared to 9764, 9509 and 8741 nuts/ha/year respectively for TT, PPT and MT at BE site and 11844, 10168 nuts/ha/year for GDT and YDT and 7141, 7319 and 8141 nuts/ha/year for TT, PPT and MT at SE site under average management conditions. Among the two hybrids the combining ability of Green dwarf was better than Yellow dwarf with Sri Lanka tall, GDT producing 7.3% and 16% more yield than YDT at BE and SE site respectively. GDT showed the highest nut yield almost in every year at both sites and in several years the nut yield difference between GDT and YDT was statistically significant especially at SE (Fig. 3).

An overall reduction in yield in all cultivars at the SE site was evident and that can again be explained by the comparative disadvantage of the class 4 and 5 soils which are marginal for coconut growing at the SE site compared to class 2 and 3 soils at BE. The data indicates that the highest achievable yield

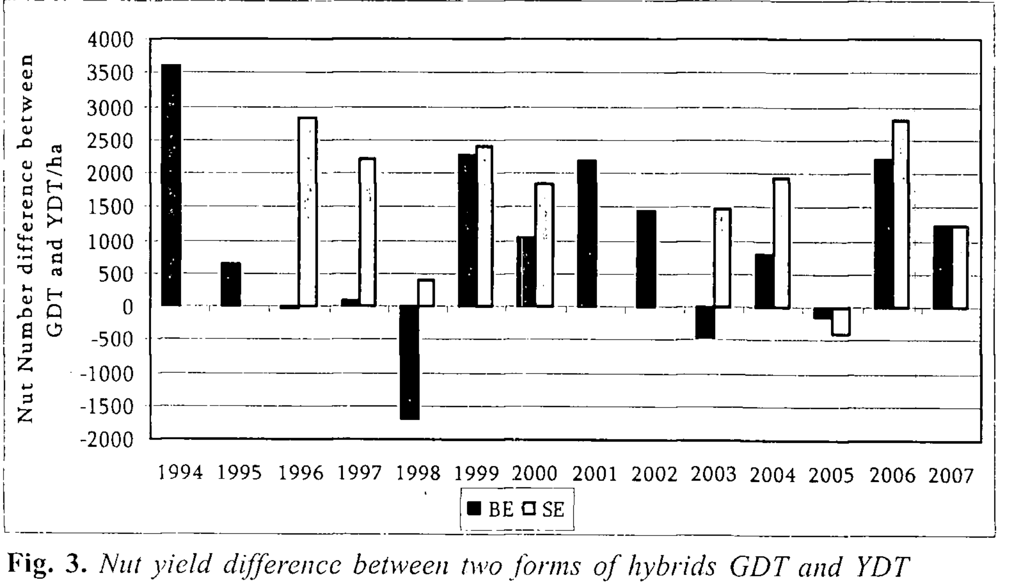

Fig. 3. *Nut yield difference between two forms of hybrids GDT and YDT*

of GDT and YDT at the BE site were 20,506 and 18,296 nuts/ha/year while it was 18,768 and 15,967 at the SE site. The highest achievable yield of TT, MT, PPT at the BE site was 9764, 8741 and 9509 respectively while the same cultivars recorded 7141, 8141 and 7319 as the maximum yield at the SE site. The nut yield differences between hybrids and tall cultivars at BE and SE site are given in Fig.4. The mean yield increase of hybrids compared to that of tall cultivars was 44% and this is a great achievement of the coconut improvement programme. Hybrid was controversial from the very outset of its issue to growers because of the growers' misconception that the hybrid is drought sensitive and not suitable for rain-fed farming as limited information was available at the time of its release. This may be due to the fact that CRIC65 limited, it is important to grow hybrids in favourable environments and harness its full potential in order to address the national need of the country.

The year 1996 and 2001 were drought years at the BE site and a high level of sensitivity to moisture stress was observed in all cultivars under evaluation at BE as reflected by about 37% average yield reduction compared to that of favourable years. The sensitivity of hybrids to moisture stress was observed to be marginally higher compared to tall cultivars as was evident by the percentage mean yield reduction, which was 40% in hybrids compared to 36% in tall cultivars. However as hybrids are producing 44% more yield than tall cultivars on an average, this marginal yield reduction during unfavourable situations does not seem to critically affect the overall performance of hybrids.

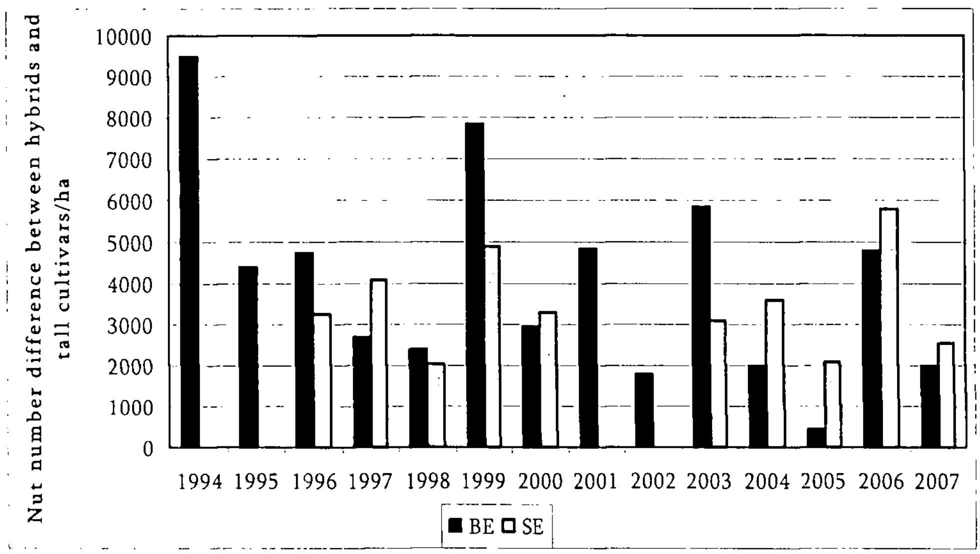

Fig. 4. *Nut yield difference between two hybrid forms and tall cultivars at BE and SE*

exhibit certain undesirable features such as snapping of bunches and as a result premature nut fall during the very early stage of its reproductive life (Wickremaratne, 1994). These results confirm that hybrids can be grown even under less favourable soils under rain fed condition. Similar observations have been made in Ivory Coast on the ability of hybrids (i.e MAWA or PB121) to withstand moisture stress indicating the suitability of hybrids even for wider scale plantations (Taffin *et al.*, 1991). However, in situations where demand for coconut is very high and hybrid seed nuts are

These results indicate that hybrids can withstand moisture stress at least in the class 2 and 3 soils in the wet intermediate zone, but more data is needed from different soil types in order to make a firm conclusion on this fact.

Annual nut yield of three tall cultivars TT, MT and PPT at BE were not significantly different to each other however, the MT which was an estate selection from wet intermediate zone showed higher nut production compared to other two tall cultivars at SE and this difference was significant in 1998, 2003 and 2005. The nut number difference between MT and other tall cultivars are given in Fig. 5. These results imply that MT which is a selection from wet intermediate zone has been able to harness its potential yields at SE which is located in wet zone compared to TT and PPT although the soil is marginal for coconut cultivation. Hence Moorock tall is identified as a suitable cultivar for marginal soils in Gampaha district (wet zone). TT and PPT did not show any significant difference in terms of nut yield over the years at both sites.

as measured by the slope of the regression line compared to tall cultivars. Furthermore, the results at BE show that YDT outperform GDT under less favourable conditions while GDT outperforms YDT under favourable situations indicating a strong G x E interaction. A similar situation is observed between TT and other tall cultivars at BE. This G x E interaction was not evident at SE. This implies the importance of ideal combination of all environment components and soil characters for achieving the highest potential yield from hybrids

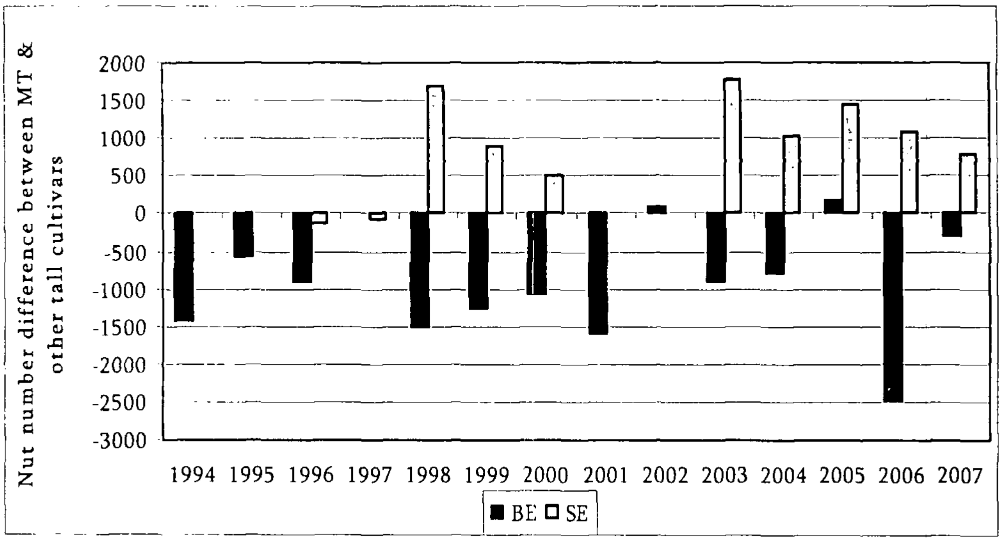

Fig.5. *Nut yield difference between MT, TT & PPT at BE and SE*

The regression lines developed as described in materials and methods for each cultivar at both sites are given in Fig. 6 and 7. According to the regression analysis all cultivars at both sites have positively responded to favourable weather conditions, but a significantly greater yield response of improved cultivars can be seen at BE compared to SE. This finding can be explained by the fact that BE site does not have a fixed limitation for the hybrids and TT achieving the potential yield. At the same time the marginal soils for coconut cultivation at SE restricts achieving the potential yield of improved cultivars even under favorable weather and management conditions.

The regression analysis further explains that hybrids at both sites highly responded for better environment and TT. This envisages the need of directing hybrids and TT planting programmes to high potential areas for exploiting the maximum yield from hybrids and TT. Furthermore this analysis indicated that GDT was more capable in exploiting the improved weather and soil conditions than YDT.

Kernel production

Fig. 8 summarizes the data obtained for kernel weight production at two sites. At BE, the highest kernel weights per nut were given by MT followed by TT. PPT recorded the lowest kernel weights among the tall cultivars. At SE, the highest kernel weight was recorded in TT and it was significantly higher than that of PPT and MT. This indicates that TT has significantly responded to selection for

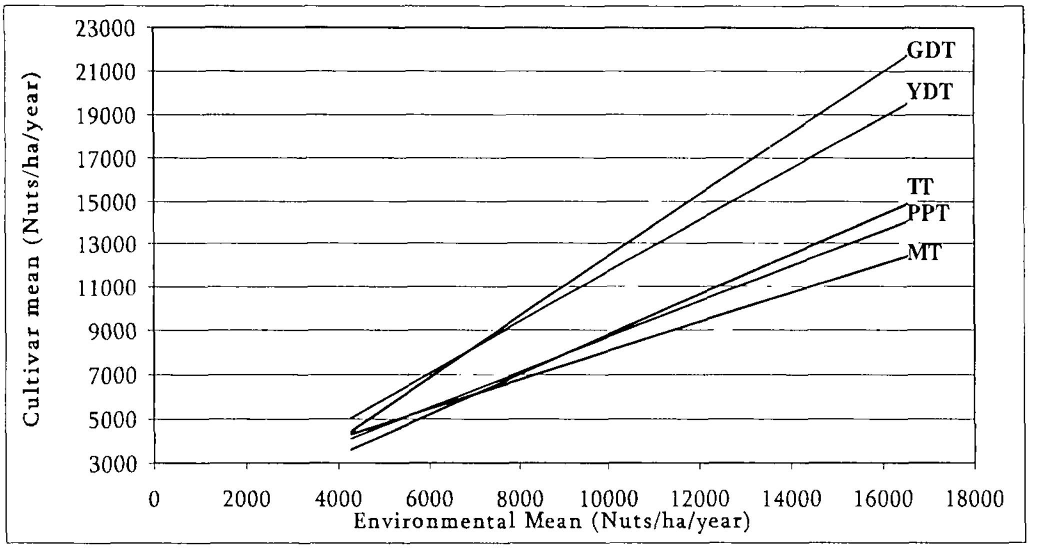

Fig. 6. *Regression lines showing the relative performances of cultivars over the years at BE*

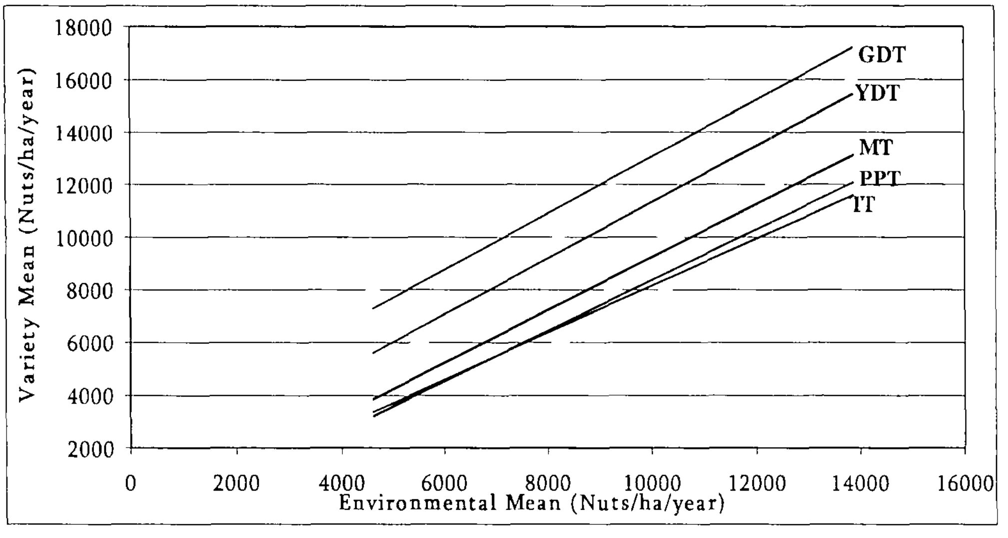

Fig. 7. *Regression lines showing the relative performances of cultivars over the years at SE*

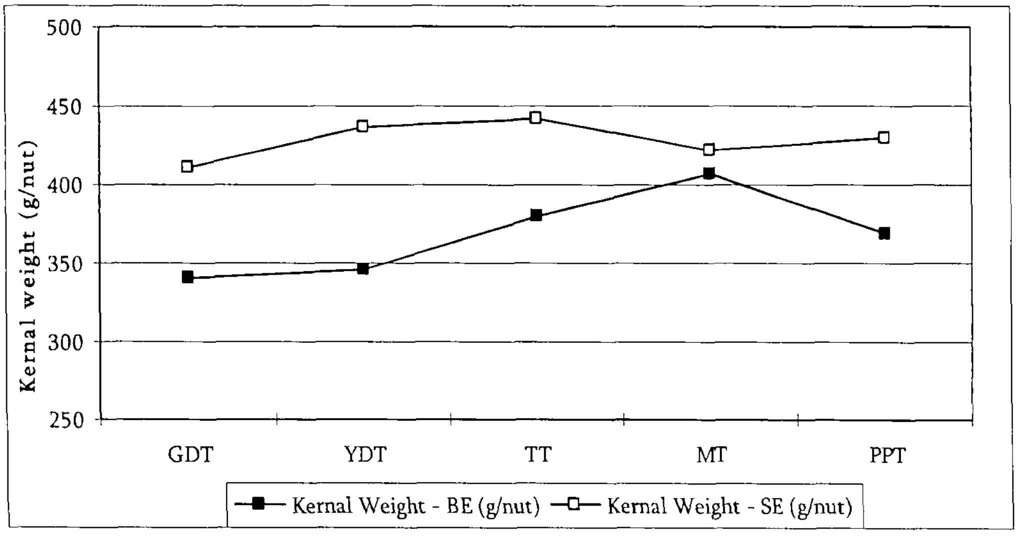

Fig.8. *Per nut kernel weight of five cultivars at BE and SE*

kernel weight. Husked nut weight, which has a direct linear relationship with per nut kernel content, has been one of the main selection criteria for parents in TT. Husked nut weight has also recorded a higher heritability value 0.45 (Fernando, 1996) and this explains the superiority of TT in per nut kernel production compared to PPT. This finding along with the finding that TT respond to better environment at a higher rate than PPT (Fig. 6) in terms of nut number indicates the superiority of TT over PPT. This envisages the need of high input agriculture for TT cultivation in order to exploit its high genetic potential for yield. The estate selection Moorock tall has been specifically selected for its higher kernel thickness and that explains the higher kernel production of MT. Generally an inverse relationship was observed between the nut number and the per nut kernel content especially for MT at BE and TT at SE. This can be explained by the negative correlation of the nut number and the husked nut weight in coconut (Liyanage *et al*, 1988). The hybrids on the other hand produced comparatively lower kernel weight per nut (383 g/nut) than tall cultivars (408 g/nut). However this lower kernel content is more than compensated by the higher nut number produced by the hybrids. As a result hybrids remain the highest producers of kernel per unit land area (4.7 Mt/ha for DT and 3.5 Mt/ha for talls respectively). (Fig. 9) indicating the presence of 'heterosis' for per unit area kernel production in the hybrids.

CONCLUSIONS

The hybrids, both GDT and YDT are more precocious and are higher yielders in terms of both nut number and total kernel content per unit area than tall cultivars (TT, MT and PPT) at both marginal soils in wet zone and better soils at wet intermediate zone under average management and rain-fed situation. On average hybrids produce about 44% more nuts than tall cultivars and 34% kernel per unit land area. Therefore hybrids can be recommended for wider scale cultivation both in better soils in the wet intermediate zone and in the marginal soils in the Gampaha district in the wet zone under average management and rain-fed situation. Among two hybrids, GDT was superior to YDT and therefore GDT is recommended for both wet and wet intermediate zones. Furthermore out of the two hybrids, YDT seems to be better suited for planting in marginal environments.

The tall cultivars are not different in terms of precocity in both the environments tested. However, these cultivars show differences in nut production and the results indicate the higher potential of intensively selected TT for nut and kernel production when compared with PPT which had less intense selection criteria, although the potential of TT has not been fully realized under

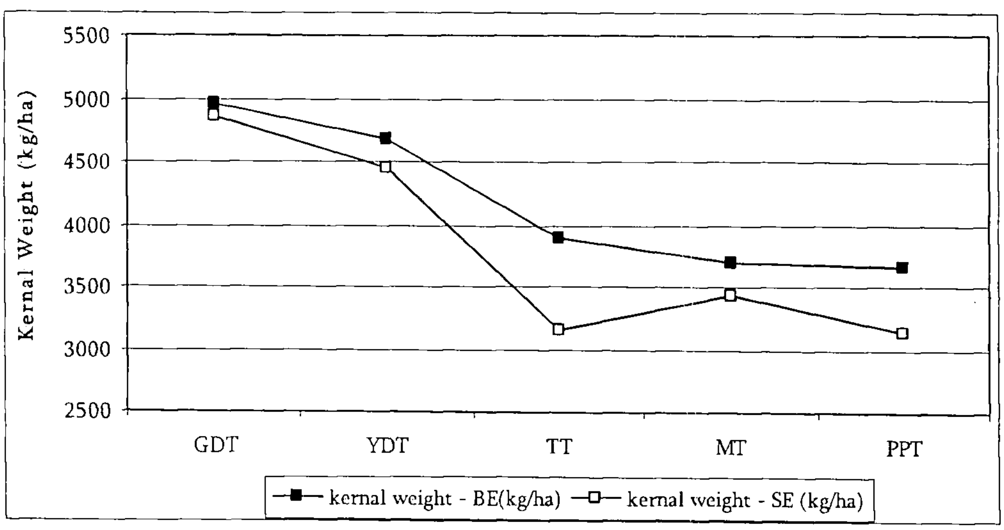

Fig. 9. *Total kernel production of five cultivars at BE and SE*

the average conditions of the experimental sites. MT is a selection from the wet intermediate zone based on kernel thickness and as expected this cultivar shows its potential as a nut and kernel producer in the wet zone.

Annual nut yield of three tall cultivars TT, MT and PPT at class 2 and class 3 soils at wet intermediate zone is not significantly different to each other. Therefore any of these cultivars can be recommended to grow in the class 2 and 3 soils in the wet intermediate zone under average management and under rain fed situation. However, MT is better at marginal soils in wet zone and hence Moorock tall is identified as a suitable cultivar for marginal soils in Gampaha district (wet zone).

Although hybrids and highly improved tall cultivar TT can be recommended for most of the coconut growing environments, these cultivars should be directed to the best suited environments for coconut cultivation coupled with proper management in order to harness their maximum potential with the view of increasing the national coconut production in the country.

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Annex 1. *Average annual nut yield of each cultivar at BE (per hectare)*

Year	GDT	YDT	TT	MT	PPT
1994	20009 a	16407 b	9396 c	7726 c	8934 c
1995	14045 a	13395 a	9262 b	8940 b	9777 b
1996	13476 a	13507 a	9505 b	8124 b	8569 b
1997	9238 a	9140 a	6312 b	6487 b	6637 b
1998	10683 ab	12384 a	9111 bc	8112 c	10119 b
1999	20331 a	18061 a	12240 b	10487 b	11243 b
2000	15546 a	14485 ab	12721 bc	11341 c	12110 c
2001	17791 a	15595 b	12884 c	10749 d	11825 cd
2002	8644 a	7186 b	5901 c	6198 bc	6315 c
2003	14326 a	14803 a	9245 b	8108 b	8772 b
2004	12315 a	11527 ab	10601 bc	9423 c	9811 bc
2005	4471 a	4638 a	3807 a	4206 a	4236 a
2006	20506 a	18296 a	15475 b	12938 b	15342 b
2007	12355 a	11113 ab	10231 b	9537 b	9430 b

Annex 2. *Average annual nut yield of each cultivar at SE (per hectare)*

Year	GDT	YDT	TT	MT	PPT
1996	8019 a	5189 b	3183 c	3258 c	3565 c
1997	8840 a	6631 b	3773 c	3604 c	3564 c
1998	6908 a	6514 a	4654 bc	5808 ab	3568 c
1999	12376 a	9968 b	5710 c	6879 c	6233 c
2000	12174 a	10319 b	7581 c	8289 c	7960 c
2001	Not recorded				
2002	Not recorded				
2003	12874 a	11383 ab	8220 d	10224 bc	3684cd
2004	13551 a	11615 b	8686 c	9701 bc	8623 c
2005	10437 a	10838 ab	7623 c	9492 bc	8449 c
2006	18768 a	15967 b	11164 c	12298 c	11241 c
2007	14495 a	13252 ab	10819 c	11855 bc	11306 bc