Preliminary Investigation of the Variation in Yield and Yield Components of Coconut Cultivars in Response to within Year Climatic Variation in the Dry Zone of Sri Lanka

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Abstract

Yield of coconut (*Cocos nucifera* L.) is highly influenced by rainfall and temperature. This study assessed the response in yield and yield components of different coconut cultivars to within year climatic variation in the dry zone (DL_3) of Sri Lanka. Two groups of cultivars; two tall cultivars and four Dwarf x Tall hybrids were evaluated under average management conditions in Wanathawilluwa. Data were collected through female flower, button nut, and mature nut counting monthly between July, 2013 and May, 2015. Daily rainfall and maximum temperature were collected from the nearest weather station. The total inflorescence/palm/year had not shown significant difference between cultivars and between cultivar groups. However, the total female flower production was not significantly different within each cultivar but significantly different between two cultivar groups. Tall cultivars showed significantly a lower total female flower production (239.38/palm/year and 238.34/palm/year respectively for CRIC60 and CRISL98) compared to that of Dwarf x Tall hybrids (> 400/year). Dwarf x Tall hybrids showed a significantly higher nut yield than tall cultivars, but not within any cultivar group. The number of nut set at 3 months after inflorescence opened was found to be significantly different (P<0.0001) among months and it positively correlated with the nut yield of the corresponding inflorescences ($P < 0.0001$, $R^2 = 0.74$). Nut set and resulting nut yield of the inflorescences which were subjected to temperature stress, had not shown any significant difference between cultivar groups. However, Dwarf x Tall cultivars showed higher nut set and higher resulting nut yield than tall cultivars in the months that were not subjected to temperature stress. The overall results of this experiment indicated that the major problem associated with the poor yield in the dry zone is the lower nut set. None of the cultivars under evaluation were shown tolerance to both moisture as well as heat stresses.

Keywords: *Cocos nucifera, Drought, Dwarf x Tall hybrids, Heat stress, Tall cultivars, Within year climatic variation, Yield and yield components.*

Introduction

Coconut (*Cocos nucifera* L.) can be successfully grown in areas where the annual rainfall is 1300 mm or above (Abid *et al.,* 2007), under conditions of high humidity, at temperatures between 27 - 30 °C and on moderately to well-aerated soils (Perera *et al.,* 2009). The extent of coconut lands distributed in the dry, intermediate, and wet zones of Sri Lanka are 15 %, 69 %, and 16 %, respectively (Department of Census and Statistics, 2002; Lakmini *et al.,* 2006). The annual rainfall in the intermediate zone and the dry zone are between 1000-1500 mm or below and 1000 mm or below, respectively. Apart from the low amount of rainfall, the uneven distribution of the rainfall within the year also poses a constraint for coconut cultivation in those areas, where comparatively more rains are received during two major monsoons experiencing a four to seven months long dry period, depending on the locality.

An average coconut palm produces approximately twelve or more inflorescence in a year or in other words, one inflorescence per month (Loyola, 1896 and Furtado, 1924). Coconut shows indeterminate growth pattern and normally produces an inflorescence at each leaf axil at intervals varying from 25 to 30 days, depending on the environment conditions and the age of the palm (Liyanage, 1950). However, some axils fail to throw out inflorescences due to abortion of inflorescences despite that the inflorescences have been developed within the leaf axil. The male flowers in an inflorescence of coconut are numerous and range from a few hundred to thousands (Murray, 1977). On the contrary, the female flowers are extremely a few and varies from 1 to 30 depending on the variety, management conditions and the prevailing weather conditions (Furtado, 1924). Initial fruit set; female flowers transformed into a nut (fruits), in perennial crops such as coconut can be low due to unfavorable environmental factors such as high temperature, low light conditions and moisture stress (Kasturi Bai *et al.,* 2003; Thomas *et al.,* 2012 and Ranasinghe *et al.,* 2015). Abortion of female flowers and young fruits are a common phenomenon in coconut even under favorable climatic conditions (Navarro *et al.,* 2008 and Ranasinghe *et al.,* 2015)

There are three main coconut varieties in Sri Lanka; Talls (Typica), Dwarfs (Nana), and King Coconut (Aurantiaca). Within each variety, there are several forms (Liyanage, 1958). In Sri Lanka majority of the coconut lands are cultivated with Sri Lanka Tall coconut cultivar. Dwarfs are not grown as commercial cultivation, except for beverage purpose (Bourdeix *et al.,* 1990). The hybrid between Tall and Dwarf was highly successful in terms of early flowering and high yield (Liyanage *et al.,* 1988). Therefore, Dwarf x Tall hybrid is the preferred choice of coconut cultivar of the coconut growers today. Different forms of dwarfs (Liynage, 1958) have been utilized in the coconut hybrid production and among them; Sri Lanka Green Dwarf (SLGD) and Sri Lanka Yellow Dwarf (SLYD) took a prominent place. Sri Lanka Brown Dwarf (SLBD) was identified recently (Perera *et al.,* 2002) and it has not been utilized for hybrid production prior to 2000. In general, Dwarf x Tall hybrids were not recommended for cultivation in drought prone areas, as it requires favourable conditions to show up its potential, although farmers tend to grow hybrids in the dry zone of the Sri Lanka too. To date, none of the coconut cultivars recommended by the Coconut Research Institute Sri Lanka (CRISL), has never been systematically evaluated under drought prone areas, where coconut cultivation is severely constrained by both moisture and heat stresses. The present study was conducted to investigate the performance of recommended coconut cultivars under stress conditions, based on their yield and yield components; number of inflorescence produced, number of female flowers per inflorescence and number of nuts set. This paper discusses the preliminary results of the study particularly on the influence of year round climatic variation on yield and yield components of different coconut cultivars.

Materials and Methods

Cultivars evaluated

The coconut cultivars CRIC60 (TT), CRISL98 (TSR), CRIC65 (DT), Kapruwana (DGSR), Kapsuwaya (DBT), and the reciprocal cross of Kapsuwaya (TDB) were used in the present study. Among them CRIC60, which is a selection of Sri Lanka tall variety and CRISL98 which is a cross between Sri Lanka tall and San Ramon Tall were tall type of coconut cultivars. CRIC65, a cross between Green dwarf and Sri Lanka Tall, Kapruwana, a cross between Sri Lanka Green dwarf and San Ramon tall and Kapsuwaya, a cross between Sri Lanka Brown dwarf, and Sri Lanka tall were Dwarf by Tall hybrids.

Location of the experiment

The trial was established in Wanathawilluwa in 2005. Wanathawilluwa is located in the low country dry zone (DL_3) and in about 20 km off from Puttalam in the Puttalam to Mannar road along the costal line. This site experiences about four to seven months long dry period from February to September each year. The 75 % expectancy level of annual rainfall in this site is 800 mm which is lower than the optimum annual rainfall requirement of coconut. This site receives most of the rainfall during October to January. The maximum monthly temperature of the site ranges from 29 °C to 38 °C (Department of Agriculture, Sri Lanka, 2006) and it is beyond optimum for nut setting. The soil in the site is favourable for coconut and belongs to Mawillu soil series within the major soil group latozols. This soil is characterized by imperfectly drained deep sandy-clay soil.

Experimental design

The experimental design of the experiment was Randomized Complete Block Design (RCBD) with three replications. The plot size varied from 6 to 9 palms. The planting design was 8m x 8m and the planting density was 165 palms/ha. The seedling-holes were dug to the size of 1 x 1 x 1 m and filled with top-soil mixed with organic manure before planting. The site was managed according to the management practices recommended by the Coconut Research Institute (CRI). Irrigation was practiced until seedlings were well established and terminated thereafter.

Data collection

Data pertaining to three yield components; number of inflorescence produced, number of female flowers produced per inflorescence and number of female flowers transformed to fruits (nut set) through button nut counting at 11 month maturing stage collected monthly during the period between July, 2013 and May, 2015. Daily rainfall and maximum temperature (day) (T_{max}) were collected from the nearest meteorological station, maintaned by Sadaharitha Plantations Pvt. Ltd., about 5 Km from the experimental site.

Data analysis

Data were analysed by General Linear Model (GLM) procedure and mean separation was done by Least Square Mean Difference in SAS 9.1.3 portable version. Whenever, interactions were present, they were further studied using response curves. Correlation analysis was done by using SPSS 19 portable version.

Results and Discussion

Table 1 shows the mean number of inflorescence produced/palm/year, mean number of female flowers produced/palm/year, and mean number of female flowers produced per inflorescence of different coconut cultivars in the one year period between July-2013 to June-2014. The mean number of nuts/palm/year presented in the Table 1 is the nuts resulted from the total female flowers produced during the above period. The ANOVA conducted for total female flower production/palm indicated that cultivar variation with respect to total female flower production was highly significant ($P<0.0001$). Total female flower production was not significantly different within the Dwarf x Tall hybrid group as well as within the Tall group, but significant between the two cultivar groups. Tall cultivars (CRIC60 and CRISL98) showed significantly a lower total female flowers/palm/year compared to that of Dwarf x Tall hybrids (rest of four cultivars). However, the total no. of inflorescence/palm/year had no significant difference between any two cultivars and also between tall and hybrid cultivar groups although usually Dwarf x Tall hybrids tend to produce higher number of inflorescence/palm/year than that of tall cultivars under favorable conditions (Dissanayake *et al.,* 2012). In contrast, female flowers/inflorescence was significantly lower in tall cultivars than in Dwarf x Tall cultivars. Among hybrids, Kapsuwaya, and Kapruwana showed significantly higher female flowers/inflorescence (Table 1).

Table 1. Inflorescence production, female flower production and final nut yield from inflorescence produced in that period of different coconut varieties in Wanathawilluwa from July-2013 to June 2015.

Variety	Mean No. of inflorescences produced/Palm/Year	Mean No. of female Flowers Produced		Yield (Nuts/Palm/Year)
		(Female flower/palm/year)	(Female flower/Inflores.)	
DGSR	14.03^{a}	502.62^{a}	35.12^{ab}	47.41^{a}
DGT	13.50^{a}	453.66^{a}	31.47^{b}	46.88^{a}
TDB	13.29^{a}	424.12^{a}	32.56^{b}	41.37^{a}
DBT	12.72^{a}	418.08^{a}	36.78^{a}	34.76^{a}
TT	13.19^{a}	239.38^{b}	18.19^{c}	26.06^{b}
TSR	12.22^{a}	238.74^{b}	19.76^{c}	25.78^{b}

(Means with the same letter within a column are not significantly different at $P \leq 0.05$)

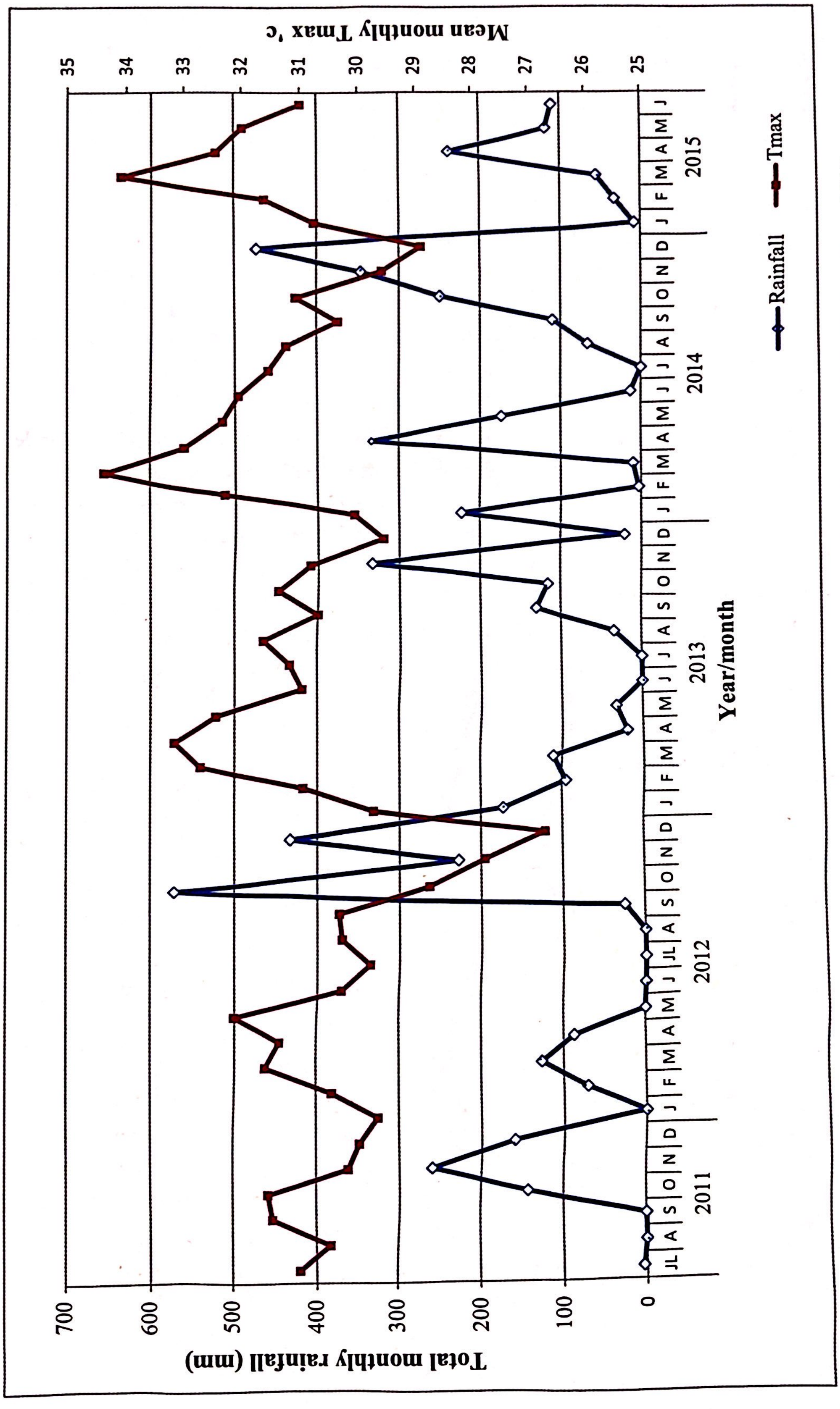

Figure 1. Total monthly rainfall and mean maximum monthly temperature in Wanathawilluwa from July-2011 to June-2015.

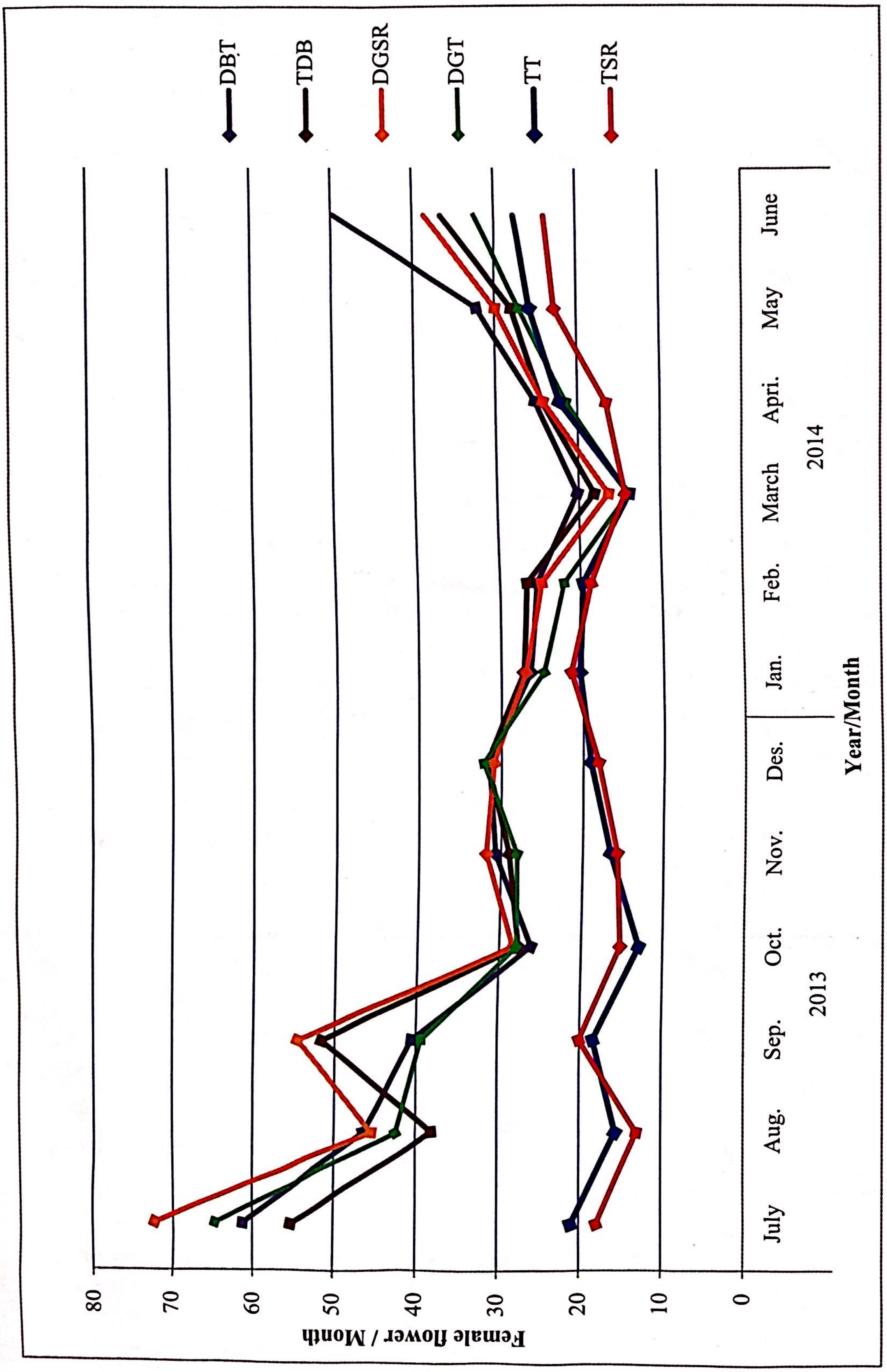

Figure 2. Variation of Female flower production with respect to cultivar and month

The ANOVA performed for total nut yield in the given period indicated that effect of cultivar was highly significant ($P< 0.0001$). All dwarfs x tall hybrids showed a significantly higher nut yield than tall cultivars, but not within the two groups (Table 1). Variation in female flower production/ palm over months of different cultivars was studied and the interaction effect of Cultivar × Months for female flowers/palm was found to be significant so that the interaction effect was further studied using response curves. Differential response of different cultivars to different months for female flowers/palm is shown in Figure 2. Dwarf x Tall hybrids showed a significantly higher female flower production in each month compared to that of tall cultivars in the period from July 2013 to December 2013. However, in January, February, and April in 2014 in particular and in March and May of the same year, female flowers/palm had not shown a drastic difference among cultivars irrespective of the climate. The female flower production depends on the climatic conditions prevailed during the time period in which the flower primordial initiation and development of the corresponding inflorescence take place. However, in order to interpret the results in terms of climatic conditions is difficult as the necessary information is not yet available.

Nut set at 3 months after inflorescence opened (here after referred to as nut set) and the resulted nut yield in different months averaged over cultivars are presented in Table 2. The mean number of nut set/palm was highly significant ($P<0.0001$) among months. The mean nut set of inflorescences opened in August, September, and December in 2013 and January in 2014 were significantly higher than that of other months. Inflorescence opened in February, May, and June in 2014 gave significantly a lower nut set. Ranasinghe *et al.*, (2015) reported that the maximum nut abortion in coconut occurs during the first three months after inflorescence opened and nut abortion was negligible after that and the main reason for nut abortion is the excessive temperature. In the present study February, May, and June of 2014 experienced an excessive temperature stress (Mean monthly T_{max} was over 32 °C) (Figure 1). In addition, the number of nuts set was significantly and positively correlated with the final nut yield of the corresponding inflorescence ($P < 0.0001$, $R^2 = 0.74$). The inflorescences opened from March to June, 2014 have given significantly lower nut yield compared to that of other months. In contrary, inflorescence opened in January, 2014 and July, August, September, and December of 2013 has given significantly higher nut yield. When considering climatic conditions of the time period under consideration, January, 2014 and July, August, September and December of 2013 have followed consecutive three months without temperature stress (Figure 1).

Table 2. Variation of mean nut set and resulting mean nut yield in different months in which the inflorescence opened.

Month	Mean nut yield**/palm	Mean nut set* / palm)
July-2013	4.45[a]	6.26[cd]
August	4.29[a]	8.34[ab]
September	4.22[a]	9.21[a]
October	2.92[b]	6.77[cd]
November	3.19[b]	6.32[cd]
December	4.97[a]	7.18[bc]
January-2014	4.95[a]	9.13[a]
February	2.85[b]	4.36[e]
March	1.55[c]	5.61[d]
April	1.47[c]	5.96[cd]
May	1.13[c]	3.04[e]
June	0.79[c]	2.49[e]

(Means with the same letter within a column are not significantly different at $P \leq 0.05$)

* Button nuts counted at 3month after the inflorescence opened

** Mature nuts harvested resulting from button nuts

Variation of nut yield among cultivars corresponding to the months in which the respective inflorescences were opened is presented in Table 3. Inflorescence open in the month of October, 2013 and February, April and May of 2014, showed no significant difference among cultivars. In the same months, except in February, 2014, nut set (Table 4) were also not significantly deferent among cultivars.

In relation to climatic condition (Figure 1), the nut set and resulting final nut yield from inflorescences opened in the months experiencing temperature stress had not shown any significant difference between the two cultivar groups; Dwarf x Tall hybrids and tall cultivars. However, Dwarf x Tall hybrids showed higher nut set and higher resulting nut yield compared to that of tall cultivars in the months not having temperature stress.

Table 3. Variation in final nut yield among cultivars corresponding to the month of the inflorescence opening

	2013						2014					
Variety	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**
DGSR	5.43^{ab}	4.33^{bc}	5.03^{ab}	3.67^{a}	4.97^{a}	7.66^{a}	6.15^{a}	2.79^{a}	0.71^{b}	0.95^{b}	0.97^{a}	0.28^{b}
DGT	7.08^{a}	7.09^{a}	6.52^{a}	3.00^{a}	2.68^{b}	4.24^{b}	4.00^{abc}	2.88^{a}	2.26^{a}	1.51^{ab}	0.97^{a}	0.95^{a}
DBT	3.46^{bc}	2.93^{cd}	3.60^{b}	3.21^{a}	3.65^{ab}	5.15^{ab}	5.74^{ab}	2.42^{a}	0.76^{b}	1.14^{ab}	0.88^{a}	0.[illegible]3^{ab}
TDB	4.75^{abc}	5.55^{ab}	3.83^{ab}	3.00^{a}	2.48^{b}	4.24^{b}	6.83^{a}	4.01^{a}	2.57^{a}	1.92^{ab}	1.63^{a}	1.23^{a}
TSR	2.40^{c}	1.74^{d}	2.73^{b}	1.67^{a}	1.69^{b}	3.75^{b}	3.00^{bc}	2.88^{a}	1.95^{ab}	1.29^{ab}	0.90^{a}	1.08^{a}
TT	2.92^{bc}	3.12^{cd}	2.20^{b}	1.93^{a}	2.22^{b}	3.50^{b}	2.52^{c}	2.09^{a}	1.29^{ab}	2.26^{a}	1.50^{a}	1.00^{ab}
F value	*3.06*	*5.71*	*2.97*	*0.91*	*2.71*	*2.94*	*3.06*	*1.08*	*3.75*	*1.68*	*1.09*	*2.92*
Pr>F	*.0123*	*<.0001*	*.014*	*.475*	*.022*	*.015*	*.0123*	*.375*	*.003*	*.143*	*.369*	*.014*

Table 4. Variation in nut set among cultivars corresponding to the month of the inflorescence opening

Variety	2013						2014					
	July	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**
DGSR	6.71^{ab}	8.28^{b}	15.03^{a}	7.52^{ab}	9.83^{a}	10.90^{a}	11.15^{a}	8.57^{a}	5.76^{a}	5.37^{ab}	2.48^{a}	1.19^{b}
DGT	9.61^{a}	12.88^{a}	10.93^{ab}	8.32^{a}	6.04^{b}	6.88^{bc}	7.52^{ab}	4.56^{bc}	5.55^{a}	6.37^{ab}	3.41^{a}	3.37^{a}
TDB	6.50^{ab}	9.21^{ab}	7.33^{b}	5.70^{ab}	5.56^{b}	5.96^{bc}	11.06^{a}	6.46^{b}	5.29^{a}	7.58^{a}	3.43^{a}	2.26^{ab}
DBT	6.32^{ab}	8.17^{b}	9.27^{ab}	8.65^{a}	6.46^{ab}	8.04^{ab}	10.48^{a}	4.56^{bc}	5.52^{a}	6.27^{ab}	3.40^{a}	3.53^{a}
TT	3.68^{b}	5.27^{bc}	3.80^{b}	3.71^{b}	3.70^{b}	4.32^{c}	5.43^{b}	3.34^{c}	6.52^{a}	4.87^{b}	2.36^{a}	2.29^{ab}
TSR	3.40^{b}	3.37^{c}	4.33^{b}	3.93^{b}	3.94^{b}	4.94^{bc}	7.18^{ab}	4.32^{bc}	5.33^{a}	4.33^{b}	2.90^{a}	2.40^{ab}
F value	*3.16*	*5.22*	*3.44*	*2.80*	*3.49*	*4.75*	*3.64*	*6.50*	*.47*	*2.05*	*.60*	*4.58*
Pr>F	*.0099*	*.0002*	*.0058*	*.0196*	*.005*	*.0005*	*.0042*	*<.0001*	*.797*	*.074*	*.70*	*.0005*

In the dry zone, the number of inflorescence produced/palm/year by different coconut cultivars was not different irrespective of whether they were tall cultivars or Dwarf x Tall hybrids. However, the number of female flowers produced/inflorescence and as a result the number of total female flowers produced/palm/year had significant varietal effects. This comparison is confined only to between the tall and the Dwarf x Tall hybrid cultivar groups. This clearly indicated that even under heat and water stress conditions, the number of female flowers produced by hybrids was significantly higher and it may be because it is a highly heritable varietal characteristic controlled by genes rather than environmental factors. As a result of the higher female flower production, obviously the hybrids have shown higher annual yield than that of tall cultivars. It is clear that the temperature and moisture stress highly affect nut setting stage of fruit development. As a result, affected main yield component was found to be nut set. No cultivar under evaluation was capable of tolerating the moisture and heat stresses, in controlling the fertilization and the abortion of the fruits. The overall results of this experiment, suggests that still planting of Dwarf x Tall hybrids in the dry zone give farmers comparatively more year end total yield than planting tall cultivars, although the general perception of the growers is *vice versa*. This finding further, elucidate the fact that screening of existing cultivars within tall or hybrids is rather ineffective in combating the severe stress conditions. The monthly yield data in this experiment clearly showed that all cultivars were better in months receiving rainfall which minimized the water stress and also to a certain extent mitigated the heat stress. Thus manipulation of the environment by practicing better agronomic care (moisture conservation and irrigation) would be very effective in improving the nut setting and thereby increasing the final total yield.

References

Abid, R., Sharmeen, S., and Praveen, A. (2007). Stomata type of monocots within the flora of Karachi, Pakistan. Pakistan Bot. 39: 15-21.

Bourdeix, R., N'Cho, Y. P., Lesaint, J. P., and Sangare, A. (1990). A coconut (*Cocos nucifera* L.) selection strategy I Rundow of achievements. Oleagineux 45: 359-371.

Department of Agriculture, Sri Lanka. Climate of rice growing regions in Sri Lanka. (2006). Available at: < http:www.agridept.gov.lk/index.php/en/component/content/article/207/903> [Accessed 22 April 2012].

Dissanayake, H. D. M. A., Attanayake, R. B., Fernando, A. A., Jayathilake, R., Padmasiri, M. H. L., Herath, H. M. N. B., Chandrasiri, S. A. S., Perera, S. A. C. N. Meegahakumbura, M. K., and Perera, L. (2012). Development of promising coconut hybrids utilizing novel brown dwarf coconut variety, (*In*) proceeding of 4th Plantation Crop Research Symposium. L. S. K. Hettiarachchi and I. S. B. Abeysinghe (Eds). Technology innovation for plantation economy, Tea Research Institute of Sri Lanka, St. Coombs, Talawakelle, 22100, Sri Lanka. Pp 11-25.

Department of Census and Statistics Sri Lanka (2002). Agriculture survey. Available at: < http: http://www.statistics.gov.lk/agriculture/index.htm> [Accessed 12 February 2007].

Furtado, C. X., (1924) A study of coconut flower and it's relation to fruit production. Gard Bul 3(7-8):261-273.

Lakmini, W. G. D., Nainanayake, N. P. A. D., and De Costa, W. A. J. M. (2006). Physiological responses for moisture stress and development of an index for screening coconut (*Cocos nucifera* L.) genotypes for drought. Trop. Agric. Res. &

Ext., 9: 17-26.

Liyanage, D. V. (1950). Sex life of the coconut palm. Ceylon Coconut Quart. 11 (2): 33-35.

Liyanage, D. V. 1958. Varieties and forms of the coconut palm grown in Ceylon. *Ceylon Coconut Quart*. 9: 1-10.

Liyanage, D. V., Wickramaratne, M. R. T., and Jayasekara, C. (1988). Coconut breeding in Sri Lanka: A Review. Cocos 6: 1-26.

Loyola, J. I. de. (1896). Cullurias Indianas, Orlim, Goa.

Murray., D. B. (1977). Coconut palm. In: Ecophysiology of tropical crops (Eds Alvin, P. de T., Kozlowki,T.T) Acadamic press, Landon. pp. 383-406.

Navarro, M. N., Jourdan, C., Sileye, T., Braconnier, S., Mialet-Serra, I., Saint-Andre, L., Dauzat. J., Nouvellon, Y., Epron, D., Bonnefond, J. M., Berbigier, P., Rouziere, A., Bouillet, J. P., and Roupsard, O. (2008). Fruit development, not GPP, drives seasonal variation in NPP in a tropical palm plantation. Tree physiology 28: 1661-1674.

Kasturi Bai K. V., Raddy S. D. V., Ratnambal M. J., and Laxman R.H. (2003). Factores contributing to flower production and button shedding in coconut. Journal of Plantation Crops 31(2): 33-36.

Perera, L., Peries, R. R. A., Padmasiri, M. H. L. (2002). Sri Lanka Brown Dwarf (SLBD) coconuts: a potential variety for future breeding. Plant Genetic Resources Newsletter 131: 70-72

Perera, L., Perera, S. A. C. N., Bandaranayake, C.K., and Harries, H.C. (2009). Coconut. (In) Oil Crop Breeding. J. Vollman and I. Rajcan (Eds.) . Springer, Verlag. pp. 369-369

Ranasinghe C. S., Silva, L. R. S., and Premasiri, R. D. N. (2015). Major determinants of fruit set and yield fluctuation in coconut *(Cocos nucifera L.)*. Journal of the National Science Foundation of Sri Lanka, 43(3): 253-264

Thomas, R. J., Nair, R.V., Mathews, C., Ajithkumar, R., Sasikala, M., and Nampoothiri, C. K. (2012).Studies on fruit set in coconut upon artificial pollination in various cross combination Indian Jaurnal of Horticulture 69(1): 7-12.