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Variation in yield and yield components of different coconut cultivars in response to within year rainfall and temperature variation

C.R.K. Samarasinghe[a], M.K. Meegahakumbura[a,*], H.D.M.A.C. Dissanayaka[a], D. Kumarathunge[b], L. Perera[a]

[a] Genetics and Plant Breeding Division Coconut Research Institute, Lunuwila, Sri Lanka
[b] Plant Physiology Division, Coconut Research Institute, Lunuwila, Sri Lanka

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ABSTRACT

The yield (no. of nuts/palm/year) of coconut (*Cocos nucifera* L.) is highly influenced by the amount and distribution of rainfall and year-round temperature. This study was conducted to evaluate the variation in yield and yield components of two groups of coconuts; talls (two cultivars) and dwarf x tall hybrids (four hybrids) in response to within year variation of rainfall and temperature under average management conditions in Wanathawilluwa, dry zone (DL_3) of Sri Lanka. No. of inflorescence, no. of female flowers, no. of button nuts, and no. of mature nuts were recorded at monthly intervals from July 2013 to May 2015 at Wanathawilluwa. For comparison, no. of mature nuts was recorded at Raddegoda in the wet intermediate zone (IL1a) of Sri Lanka. Daily rainfall and temperature were collected from the nearest weather stations. The results revealed that the no. of inflorescences produced by a palm within a year is not different among cultivars. However, tall cultivars produced a significantly lower no. of female flowers/palm/year than hybrids but, no difference was observed within groups. The no. of female flowers/inflorescence showed a significantly positive correlation with the mean monthly rainfall received during 7, 8 and 9 months prior to opening of the respective inflorescence. This observation was recorded for the first time and can be used to mitigate the effect of drought. Number of nuts set/inflorescence varied significantly with the month in which the inflorescence opened. Both at Wanathawilluwa and Raddegoda, hybrids showed a significantly higher yield compared to that of tall cultivars, Raddegoda however, showed a higher yield in all cultivars attributing to the favourable soil and weather conditions. When the inflorescences were not exposed to temperature stress during the first three months, dwarf x tall hybrids showed a significantly higher nut set/inflorescence and mature nuts/bunch than tall cultivars. In conclusion, the main yield components affected by moisture and temperature stresses were the no. of female flowers/inflorescence and the no. of nut set/inflorescence. The moisture stress at the time of floral primordia initiation and the temperature stress at the time of nut setting are the most critical factors affecting the coconut yield.

1. Introduction

Global food production threatened by climate change is one of the most important challenges in the 21st century to supply sufficient food for the increasing population (Lal et al., 2005). The climate change driven temperature rise and variation in the rainfall patterns create abiotic stresses for many crops. Coconut (*Cocos nucifera* L.) is one of the major plantation crops with versatile uses. It plays a significant role in food security and economy of people in many developing countries. Among different abiotic stresses affecting coconut, drought and high temperature are considered as major stress factors with high negative impact on nut yield. Coconut could 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).

Coconut shows an indeterminate growth pattern and generally produces an inflorescence at each leaf axil at intervals varying from 25 to 30 days, depending on the environmental conditions and the age of the palm (Liyanage, 1950; Ranasinghe et al., 2015). However, some axils fail to throw out inflorescences due to abortion of inflorescences developed inside the leaf axil. The total number of female flowers in a coconut inflorescence is dependent on genetic and environmental factors and varies from zero to a few hundreds. However, normal inflorescence has several thousands of male flowers (Thomas and Josephrajkumar, 2013). Initial nut set (female flowers transformed into button nut three months after an inflorescence opened), in coconut can

* Corresponding author.
E-mail address: mkmeegahakumbura@gmail.com (M.K. Meegahakumbura).

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be low due to unfavourable environmental conditions such as high temperature, low light conditions and moisture stress (Kasturi Bai et al., 2003; Thomas et al., 2012; Ranasinghe et al., 2015). Abortion of female flowers and young fruits are a common phenomenon in coconut under unfavourable climatic conditions and to lesser extent even under favourable climatic conditions (Navarro et al., 2008; 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 based on various character differences (Liyanage, 1958). In Sri Lanka, the majority of the coconut lands are cultivated Talls, commonly known as Sri Lanka Tall. Dwarfs are not grown commercially, except for beverage purpose (Bourdeix et al., 1990), as copra from them is poor in quantity and quality. However, they are early bearing compared to Tall. The hybrids between Tall and Dwarf were highly successful as they bear early and high yield (Liyanage et al., 1988). Therefore, the dwarfs x tall hybrids are the preferred choice of the coconut growers today. Different forms of dwarfs (Liyanage, 1958) have been utilized in the coconut hybrid production in the world and among them; Sri Lanka Green Dwarf (SLGD) and Sri Lanka Yellow Dwarf (SLYD) took a prominent place in the breeding program in Sri Lanka. 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 are not recommended for cultivation in drought prone areas, as they require favourable conditions to show up full potential. However, farmers tend to grow hybrids in the dry zone of the Sri Lanka too with below optimum conditions. To date, none of the coconut cultivars recommended by Coconut Research Institute, Sri Lanka (CRISL) have been systematically evaluated in drought-prone areas where coconut cultivation is severely constrained by moisture, heat or both stresses. Therefore, the present study was conducted to investigate the performance of the recommended coconut cultivars under stress and non-stress conditions based on their yield and yield components; the number of inflorescences produced, a number of female flowers per inflorescence and number of nuts set. This paper discusses the results of a preliminary study on the response of different coconut cultivars to within year rainfall and temperature variation, based on their yield and yield components variation.

2. Materials and methods

2.1. Cultivars evaluated

Six different coconut cultivars were evaluated in this study (Table 1).

Table 1
Name of different coconut cultivars evaluated in this study and their respective parental varieties.

Cultivar name	Parents
CRIC60 (TxT)	Selection of Sri Lanka Tall
CRISL98 (TxSR)	Sri Lanka Tall x San Ramon Tall
CRIC65 (GDxT)	Sri Lanka Green Dwarf x Sri Lanka Tall,
CRISL2004 (GDxSR)	Sri Lanka Green Dwarf x San Ramon Tall
CRISL2012 (BDxT)	Sri Lanka Brown Dwarf x Sri Lanka Tall
Reciprocal cross of CRISL2012 (TxBD)	Sri Lanka Tall x Sri Lanka Brown Dwarf

2.2. Location of the experiment

The experiment was established in 2005 at Wanathawilluwa in Puttalam District belongs to the Low country Dry Zone (DL3), according to the classification of Agro-Ecological Regions of Sri Lanka (Punyawardane, 2008). The central coordinates of the location 8° 11′44.51″ N and 79° 50′ 2.01″ E and the average elevation is approximately 30 m above the mean sea level. 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 the period of October to January and experiences about four to seven months long dry period from February to September each year. The maximum monthly temperature of the site ranges from 29 °C to 38 °C (Department of Agriculture, Sri Lanka, 2006) which is beyond the optimum temperature for nut setting. The soil in the site is favorable for coconut and belongs to Mawillu soil series within the major soil group latosols (Dassanayake and De Silva et al., 2010). This soil is characterized by imperfectly drained deep sandy-clay.

Data in a simultaneously established experimental site at Raddegoda located in the wet intermediate zone of the low country (IL1a) (7°31′27.40″ N and 80°31′ 15.61″ E, approximately 146 m above the mean sea level) (Punyawardane, 2008) and conformed to the same experimental design was used for the comparison purpose. The 75% expectancy level of annual rainfall in Raddegoda is 1400 mm and is well distributed. The maximum temperature at the site ranges between 29 °C–35 °C (Department of Agriculture, Sri Lanka, 2006) and the site is characterized as a deep, well-drained loamy soil highly suitable for coconut cultivation belonging to Melsiripura soil series within the major soil group Reddish Brown Earth (Dassanayake et al., 2005).

2.3. Experimental design

Wanathawilluwa and Raddegoda replicated trial blocks comprise of the Randomized Complete Block Design (RCBD). However, the number of replicated blocks and plot sizes are different. At Wanathawilluwa, there are three replicated blocks and two blocks contain 9 palms per each cultivar (plot size) while the other one contains 6 palms. There are four replicated blocks at Raddegoda and each block has 9 palms per plot. We explicitly accounted for the unbalanced experimental design in data analysis. The planting design was 8 m × 8 m and the planting density was 158 palms/ha. The size of the seedling holes was 1 × 1 × 1 m and the holes were filled with top-soil mixed with organic manure prior to planting. The site was managed according to the management practices recommended by the CRISL (Coconut Research Institute of Sri Lanka, 2006). Irrigation was practiced until seedlings were well established and thereafter terminated.

2.4. Data collection

At Wanathawilluwa, data pertaining to three yield components; the number of inflorescences produced, the number of female flowers produced per inflorescence and the number of female flowers transformed to fruits (nut set) at three months and the final nut yield at the 11-month maturity were collected monthly during the period from July 2013 to May 2015. Daily rainfall and maximum temperature (day) (T_{max}) were obtained from the nearest meteorological station which is located about 5 km away from the experimental site.

Table 2
Inflorescence production, female flower production and resulting final nut yield by different coconut cultivars at Wanathawilluwa from July-2013 to June 2014.

Cultivar	Mean no. of inflorescences /Palm/Year	Mean no. of female flowers/ inflorescence	Mean no. of female flowers/ palm/year	Yield (no. of nuts/Palm/ Year)
GDxSR	14.4 ± 0.6[a]	35.1 ± 1.4 [ab]	502.6 ± 40.6 [a]	47.4 ± 5.4 [a]
GDxT	13.6 ± 0.6 [a]	31.5 ± 1.3 [b]	453.6 ± 41.6 [a]	46.9 ± 6.2 [a]
BDxT	12.6 ± 0.5 [a]	36.8 ± 1.2 [a]	418.1 ± 41.5 [a]	34.8 ± 5.2 [a]
TxBD	13.4 ± 0.4 [a]	32.6 ± 1.6 [b]	424.1 ± 55.4 [a]	41.4 ± 4.7 [a]
TxSR	13.2 ± 0.7 [a]	19.8 ± 0.8 [c]	238.7 ± 33.5 [b]	25.8 ± 4.9 [b]
TxT	12.1 ± 0.6 [a]	18.2 ± 0.8 [c]	239.4 ± 28.5 [b]	26.1 ± 4.0 [b]

(Means with the same letter within a column are not significantly different at P ≤ 0.05).

Table 3
Nested ANOVA (analysis of variance) for the site effect and cultivar effect on yield.

Source	SS	d.f	M.S	F	*p*
Site	143307.27	1	143307.26	188.16	< .0001
Cultivar (site)	57757.37	10	5775.73	7.58	< .0001
Error	243724.67	320	761.63		
Total	444789.31	331			

(Where SS = sum of squares, d.f. = degrees of freedom, MS = mean of squares, F = f-statistic and p = p-value).

However, at Raddegoda, final nut yield was the only data available for the comparison coincided with the data at Wanathawilluwa. The daily rainfall and maximum temperature (day) (T_{max}) were obtained from a meteorological station about 10 km away from the experimental site.

2.5. Data analysis

We considered each palm in a plot as individual replicate (Kularatne et al., 2006). Analysis of variance was performed to identify any significant differences among treatments (here, cultivars and cultivar groups). All data were analyzed in General Linear Model procedure (PROC GLM) in SAS 9.1 and mean separation was done by Duncan Multiple Range Test (DMRT). The GLM procedure effectively handle the unbalanced experimental designs therefore, the results are comparable. However, yield (no. of nuts/palm/year) was analysed by Nested ANOVA trough PROC GLM. Whenever interactions were present, they were further studied using response curves. Correlation analysis was done by using SPSS 19 portable version.

3. Results and discussion

Table 2 shows the mean no. of inflorescence/palm/year, the mean no. of female flowers/inflorescence and the mean no. of female flowers/palm/year produced by different coconut cultivars during the one year period between July-2013 to June-2014 at Wanathawilluwa. The mean nut yield (no. of nuts/palm/year) showed in Table 2 were obtained from the same inflorescences. The ANOVA showed that the total no. of inflorescences/palm/year was not significantly different between cultivars within groups or between groups. In contrast, the no. of female flowers/inflorescence was significantly ($P < 0.05$) lower in tall cultivars than in dwarf x tall hybrids at Wanathawilluwa. Among hybrids, BD x T and GD x SR were shown to be the best (Table 2). Corresponding to that, the mean no. of female flowers/palm/year also indicated a significant difference between cultivar groups ($P < 0.05$) but not within groups. Tall cultivars (T x T and T x SR) showed a significantly lower mean no. of female flowers/palm/year compared to that of dwarf x tall hybrids in Wanathawilluwa.

Results of the nested ANOVA (Table 3) showed that mean yield (no. of nuts/palm/year) significantly varied between the sites; Wanathawilluwa and Raddegoda, and the cultivars within those sites. Results of DMRT mean separation indicated that under favorable rainfall and temperature condition (Fig. 1) at Raddegoda, the mean yield at Raddegoda (79.85 ± 2.4) was significantly ($P < 0.05$) higher than that of at Wanathawilluwa (39.08 ± 2.3). Within each site, dwarfs x tall hybrids showed a significantly higher yield compared to that of tall cultivars, but the difference between cultivars within each group were not significant (Fig. 2).

A further analysis was carried out at the drought affected site Wanathawilluwa to identify monthly variation in female flower production among cultivars. The no. of female flowers/palm showed a significant ($P < 0.05$) Cultivar × Months interaction and responsive curves were used to identify the differential response of cultivars (Fig. 3). Dwarf x tall hybrids showed significantly higher no. of female flower production in each month compared to that of tall cultivars during the period from July 2013 to December 2013. However, that difference was not significant for a period of five months from January to May of 2014 irrespective of the changes in the climate. A correlation analysis was carried out to identify the effect of monthly rainfall received during pre-inflorescence opening on female flower production. Table 4 shows the correlation coefficient obtained for the relationship between the no. of female flowers/inflorescence and the rainfall received during each month prior to inflorescence opening. There were significant ($p < 0.05$) and positive correlations between mean monthly rainfall of preceding 7, 8 and 9 months of inflorescence opening and no. of female flowers/inflorescence in dwarf x tall hybrids. However, cultivars belong to the tall group did not show any significant correlation.

Variation of mean no. of female flowers remaining at 3 months after inflorescence opening or the female flowers turned into button nuts (no. of nut set/inflorescence) and the mean no. of mature nuts/bunch in different months at which the inflorescence opened is presented in Table 5. The mean no. of nut set/inflorescence was significant ($P < 0.05$) among months. Inflorescences opened in August, September, and December of 2013 and in January 2014 showed significantly higher mean no. of nut set/inflorescence than that of other months. Inflorescence opened in February, May, and June of 2014

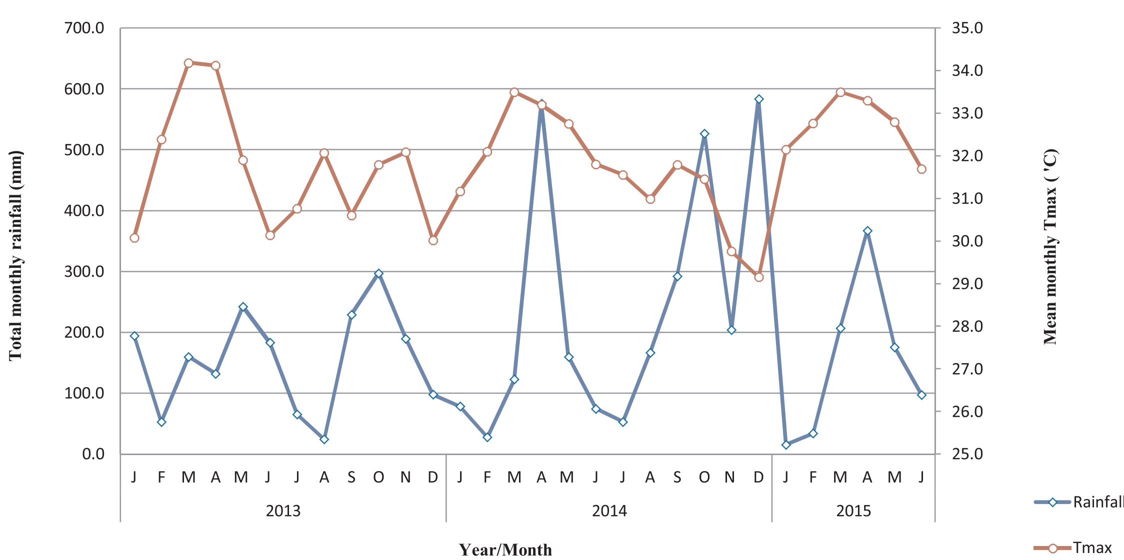

Fig. 1. Total monthly rainfall and mean maximum monthly temperature at Raddegoda from January-2013 to June-2015.

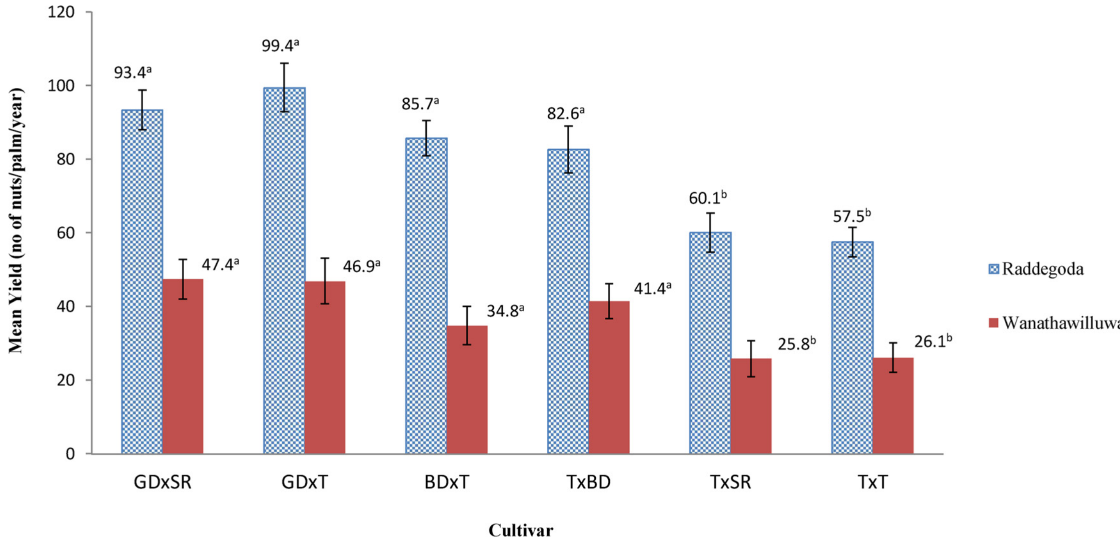

Fig. 2. Mean yield of different coconut cultivar at Raddegoda and Wanathawilluwa from July-2013 to June 2014. (Means with the same letter within a site is not significantly different at P ≤ 0.05).

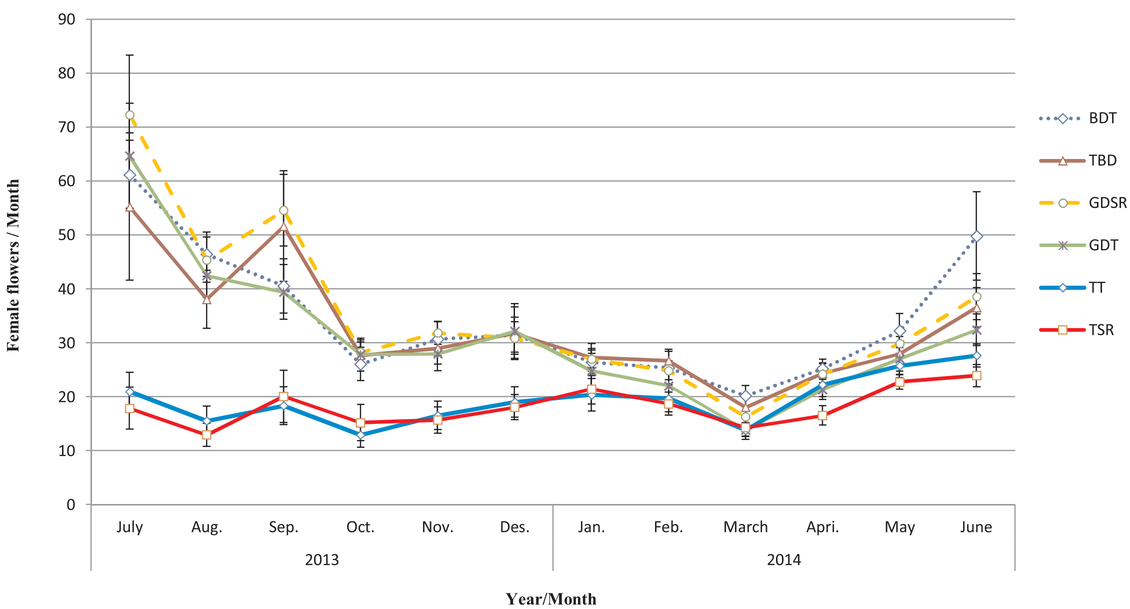

Fig. 3. Variation in female flower production with respect to cultivar and the month at which the inflorescence opened.

Table 4
Correlation coefficient (*r*) between the female flowers/ inflorescence of different cultivars and mean rainfall of months prior to inflorescence opening.

Month before inflorescence opening	Cultivar					
	GDxSR	GDxT	BDxT	TxBD	TxT	TxSR
1	−0.283	−0.214	−0.173	−0.226	0.372	0.442
2	−0.29	−0.293	−0.085	−0.274	0.212	0.38
3	−0.386	−0.356	−0.413	−0.356	0.11	−0.014
4	−0.3	−0.315	−0.311	−0.356	0.926	0.046
5	−0.129	−0.152	0.049	−0.158	0.369	−0.015
6	0.204	0.171	0.584	0.132	0.312	0.15
7	0.736*	0.754*	0.876*	0.659*	0.423	0.184
8	0.668*	0.686*	0.703*	0.605*	−0.087	−0.255
9	0.959*	0.918*	0.805*	0.953*	−0.062	−0.033
10	0.17	0.21	0.12	0.166	−0.615	-0.543

(* significantly different at P ≤ 0.05).

showed significantly lower no. of nut set/inflorescence and during these months, the experimental site has experienced an excessive temperature stress (Mean monthly Tmax was over 32 °C) (Fig. 4) suggesting an effect of excessive temperature on nut abortion. Similarly, Ranasinghe et al., (2015) reported that the maximum nut abortion in coconut occurs during the first three months after inflorescence opening and thereafter nut abortion is negligible. Moreover, they reported that excessive temperature is the main reason for nut abortion. The no. of nut set/inflorescence was significantly and positively correlated with the no. of mature nuts harvested from the same inflorescence ($P < 0.0001$, $R^2 = 0.74$). Accordingly, the inflorescences opened during the period from March to June 2014 have shown a significantly lower no. of mature nuts/bunch compared to that of other months. On the other hand, inflorescence opened in January 2014 and July, August, September, and December of 2013 have given significantly higher no. of mature nuts/bunch. Except January 2014, all the aforesaid months were followed by a temperature stress free three consecutive months from inflorescence opening (Fig. 4).

Variation of no. of mature nuts/bunch among cultivars

Table 5
Variation in mean no. of nuts set/inflorescence and mature nuts/bunch in response to the month of inflorescence opening.

Month	Mean no. of nut set*/ inflorescence	Mean no. of mature nuts**/ bunch
July-13	6.3 ± 0.5 [cd]	4.5 ± 0.4 [a]
August	8.3 ± 0.6 [ab]	4.3 ± 0.3 [a]
September	9.2 ± 0.9 [a]	4.2 ± 0.4 [a]
October	6.8 ± 0.5 [cd]	2.9 ± 0.3 [b]
November	6.3 ± 0.5 [cd]	3.2 ± 0.3 [b]
December	7.2 ± 0.5 [bc]	5.0 ± 0.4 [a]
Jan-14	9.1 ± 0.6 [a]	4.9 ± 0.4 [a]
February	4.4 ± 0.4 [e]	2.8 ± 0.3 [b]
March	5.6 ± 0.3 [d]	1.5 ± 0.2 [c]
April	5.9 ± 0.3 [cd]	1.5 ± 0.1 [c]
May	3.1 ± 0.3 [e]	1.1 ± 0.1 [c]
June	2.5 ± 0.2 [e]	0.8 ± 0.1 [c]

(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.

corresponding to the months in which the respective inflorescences were opened is presented in Table 6. No. of mature nuts/bunch resulted by inflorescences opened in the months of October 2013 and February, April and May of 2014 were not significantly ($P < 0.05$) different among cultivars. Similarly in the same months, except in February 2014, no. of nut set/inflorescence (Table 7) was not significantly different among cultivars.

The inflorescences opened in the months experiencing a temperature stress (Fig. 4) have not shown a significant ($P < 0.05$) difference between the two cultivar groups with respect to the no. of nut set/ inflorescence and the no. of mature nuts/bunch. However, dwarf x tall hybrids showed a higher no. of nut set/inflorescence and no. of mature nuts/bunch compared to tall cultivars in the months free from temperature stress.

Under better climatic conditions, dwarf x tall cultivars produced significantly higher mean no. of female flower/ inflorescence than tall cultivar. However, no. of female flowers/inflorescence was low when the field experienced a prolong moisture stress during the initial development stage of the inflorescence, particularly during nine to seven month prior to opening. The floral primordia initiation in coconut begins nine months prior to inflorescence opening (-9 stage) (Perera et al., 2010), and the field moisture condition during this period significantly affects the floral primordial initiation and subsequently mean no. of flowers/inflorescence. However, even under the effect of moisture stress, dwarf x tall hybrids were able to maintain its no. of female flowers/inflorescence above the tall cultivar and consequently, dwarf x tall hybrids produced significantly higher no. of female flowers/palm/ year compared to tall cultivars.

Generally, the number of female flowers produced by hybrids is higher than that of tall cultivars (Liyanage, 1959; Dissanayake et al., 2012) and it has been identified as a heritable character (Nambiar and Nambiar, 1970). The results of the present study clearly indicated that the no. of female flowers/inflorescence produced by hybrids was not only governed by genes, but also environmental factors prevailed in their early development stages.

4. Conclusion

The main yield components that were sensitive and affected by moisture and temperature stresses were found to be the no. of female flowers/inflorescence and the no. of nut set/inflorescence. The moisture stress at the time of floral primordia initiation and the temperature stress at the time of nut setting are the most critical factors affecting the coconut yield. As a result of the higher no. of female flower production at any given condition, the hybrids lead to higher nut yield than that of the tall cultivars. Therefore, this study concluded that the planting of dwarf x tall hybrids even under the moisture and temperature stress in dry zone gives farmers a comparatively more nut yield than planting tall cultivars, although the general perception of the growers is vice versa. This finding further elucidates that screening of existing cultivars is rather ineffective in identifying cultivars suitable for planting in severe moisture and heat stress conditions. The monthly yield data at the site with unfavourable weather conditions clearly showed that all the cultivars were performing better in the months receiving adequate rainfall which minimized the moisture stress and also to a certain extent mitigated the heat stress. Similarly, at the site with favourable weather conditions, all cultivars showed a significantly higher yield compared to the unfavourable site. Therefore, we recommend applying irrigation during the long dry spells especially in the dry zone if hybrid cultivars are planted in order to harness their true genetic potential.

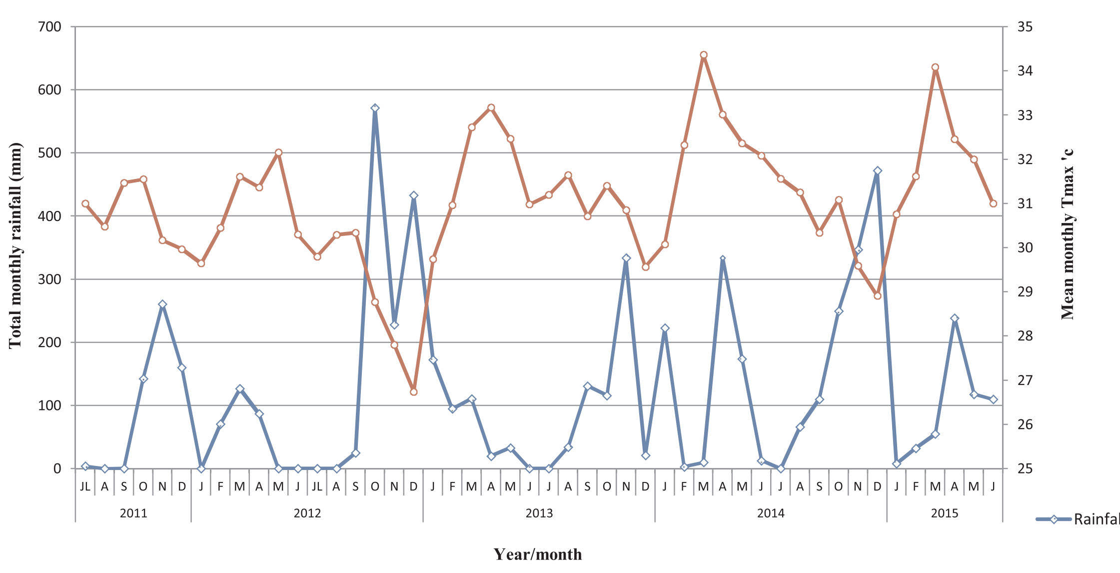

Fig. 4. Total monthly rainfall and mean maximum temperature at Wanathawilluwa from July-2011 to June-2015.

Table 6
Variation in mean no. of mature nuts/bunch among cultivars in response to the month of the inflorescence opening.

	2013						2014					
Cultivar	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
GDxSR	5.4 ± 1.1^{ab}	4.3 ± 0.8^{bc}	5.0 ± 1.0^{ab}	3.7 ± 0.8^{a}	5.0 ± 0.8^{a}	7.7 ± 1.0^{a}	6.2 ± 1.0^{a}	2.8 ± 0.7^{a}	0.7 ± 0.3^{b}	0.9 ± 0.3^{b}	1.0 ± 0.3^{a}	0.3 ± 0.1^{b}
GDxT	7.1 ± 1.0^{a}	7.1 ± 0.9^{a}	6.5 ± 1.1^{a}	3.0 ± 0.7^{a}	2.7 ± 0.6^{b}	4.2 ± 0.9^{b}	4.0 ± 0.7^{abc}	2.9 ± 0.6^{a}	2.3 ± 0.5^{a}	1.5 ± 0.4^{ab}	1.0 ± 0.3^{a}	0.9 ± 0.2^{a}
BDxT	3.5 ± 0.7^{bc}	2.9 ± 0.5^{cd}	3.6 ± 0.7^{b}	3.2 ± 0.8^{a}	3.6 ± 0.8^{ab}	5.2 ± 1.0^{ab}	5.7 ± 1.0^{ab}	2.4 ± 0.7^{a}	0.8 ± 0.3^{b}	1.1 ± 0.3^{ab}	0.9 ± 0.2^{a}	0.6 ± 0.2^{ab}
TxBD	4.7 ± 1.2^{abc}	5.5 ± 0.9^{ab}	3.8 ± 0.9^{ab}	3.0 ± 0.6^{a}	2.5 ± 0.5^{b}	4.2 ± 0.7^{b}	6.8 ± 1.1^{a}	4.0 ± 0.5^{a}	2.6 ± 0.5^{a}	1.9 ± 0.3^{ab}	1.6 ± 0.3^{a}	1.2 ± 0.3^{a}
TxSR	2.4 ± 0.6^{c}	1.7 ± 0.5^{d}	2.7 ± 0.6^{b}	1.7 ± 0.6^{a}	1.7 ± 0.5^{b}	3.7 ± 0.9^{b}	3.0 ± 0.7^{bc}	2.9 ± 0.7^{a}	1.9 ± 0.5^{ab}	1.3 ± 0.3^{ab}	0.9 ± 0.4^{a}	1.2 ± 0.2^{a}
TxT	2.9 ± 0.6^{bc}	3.1 ± 0.7^{cd}	2.2 ± 0.6^{b}	1.9 ± 0.7^{a}	2.2 ± 0.6^{b}	3.5 ± 0.8^{b}	2.5 ± 0.6^{c}	2.1 ± 0.5^{a}	1.3 ± 0.4^{ab}	2.3 ± 0.6^{a}	1.5 ± 0.4^{a}	1.0 ± 0.2^{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	*0.0123*	*< 0.0001*	*0.014*	*0.475*	*0.022*	*0.015*	*0.0123*	*0.375*	*0.003*	*0.143*	*0.369*	*0.014*

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

Table 7
Variation of mean no. of nut set/inflorescence among cultivars corresponding to the month of the inflorescence opening.

	2013						2014					
Cultivar	July	Aug.	Sep.	Oct.	Nov.	Dec	Jan.	Feb.	Mar.	Apr.	May	June
GDxSR	6.7 ± 1.2^{ab}	8.3 ± 1.2^{b}	15.0 ± 3.4^{a}	7.5 ± 1.4^{ab}	9.8 ± 1.5^{a}	10.9 ± 1.4^{a}	11.2 ± 1.1^{a}	8.6 ± 1.2^{a}	5.8 ± 0.5^{a}	5.4 ± 0.5^{ab}	2.5 ± 0.5^{a}	1.2 ± 0.3^{b}
GDxT	9.6 ± 1.4^{a}	12.9 ± 1.6^{a}	10.9 ± 1.8^{ab}	8.3 ± 1.1^{a}	6.0 ± 1.0^{b}	6.9 ± 1.0^{bc}	7.5 ± 1.0^{ab}	4.6 ± 1.0^{bc}	5.6 ± 0.7^{a}	6.4 ± 0.8^{ab}	3.4 ± 0.8^{a}	3.4 ± 0.5^{a}
BDxT	6.3 ± 1.9^{ab}	8.2 ± 1.2^{b}	9.3 ± 1.8^{ab}	8.6 ± 1.2^{a}	6.5 ± 1.0^{ab}	8.0 ± 1.0^{ab}	10.5 ± 1.6^{a}	4.6 ± 0.9^{bc}	5.5 ± 0.8^{a}	6.3 ± 1.0^{ab}	3.4 ± 0.7^{a}	3.5 ± 0.5^{a}
TxBD	6.5 ± 1.5^{ab}	9.2 ± 1.3^{ab}	7.3 ± 1.8^{b}	5.7 ± 0.9^{ab}	5.6 ± 1.3^{b}	6.0 ± 0.9^{bc}	11.1 ± 1.6^{a}	6.5 ± 1.0^{b}	5.3 ± 0.7^{a}	7.6 ± 0.6^{a}	3.4 ± 0.5^{a}	2.3 ± 0.3^{ab}
TxSR	3.4 ± 0.7^{b}	3.4 ± 0.8^{c}	4.3 ± 1.7^{b}	3.9 ± 1.2^{b}	3.9 ± 0.8^{b}	4.9 ± 1.1^{bc}	7.2 ± 1.1^{ab}	4.3 ± 0.9^{bc}	5.3 ± 0.7^{a}	4.3 ± 0.8^{b}	2.9 ± 0.6^{a}	2.4 ± 0.4^{ab}
TxT	3.7 ± 0.9^{b}	5.3 ± 1.0^{bc}	3.8 ± 0.9^{b}	3.7 ± 1.0^{b}	3.7 ± 0.8^{b}	4.3 ± 0.8^{c}	5.4 ± 0.9^{b}	3.3 ± 0.6^{c}	6.5 ± 0.5^{a}	4.9 ± 0.9^{b}	2.4 ± 0.6^{a}	2.3 ± 0.6^{ab}
F value	*3.16*	*5.22*	*3.44*	*2.8*	*3.49*	*4.75*	*3.64*	*6.5*	*0.47*	*2.05*	*0.6*	*4.58*
Pr > F	*0.0099*	*0.0002*	*0.0058*	*0.0196*	*0.005*	*0.0005*	*0.0042*	*< 0.0001*	*0.797*	*0.074*	*0.7*	*0.0005*

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

References

Abid, R., Sharmeen, S., Praveen, A., 2007. Stomata type of monocots within the flora of Karachi, Pakistan. Pak. Bot. 39, 15–21.

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

Coconut Research Institute of Sri Lanka, 2006. Advisory Circulars Series A. Coconut Research Institute, Lunuwila, Sri Lanka.

Dassanayake, A.R., Somasiri, L.L.W., De Silva, G.G.R., 2005. Soils of the low country intermediate zone. In: Mapa, R.B., Nayakekorale, H.B., Dassanayake, A.R. (Eds.), Soils of Intermediate Zone of Sri Lanka. Soil Science Society of Sri Lanka, Peradeniya, Sri Lanka, pp. 128–130.

Dassanayake, A.R., De Silva, G.G.R., 2010. Soils of the coastal plain of the dry zone. In: Mapa, R.B., Somasiri, S., Dassanayake, A.R. (Eds.), Soils of Dry Zone of Sri Lanka. Soil Science Society of Sri Lanka., Peradeniya, Sri Lanka pp.204-208.

Department of Agriculture, Sri Lanka, 2006. Climate of Rice Growing Regions in Sri Lanka. (accessed 2012.04.22). http://www.agridept.gov.lk/index.php/en/component/content/article/207/903/.

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., Perera, L., 2012. Development of promising coconut hybrids utilizing novel brown dwarf coconut variety. In: Hettiarachchi, L.S.K., Abeysinghe, I.S.B. (Eds.), Proceeding of 4th Plantation Crop Research Symposium. Technology innovation for plantation economy, Tea research Institute of Sri Lanka, Coombs, Talawakelle, 22100, Sri Lanka pp 11-25.

Kasturi Bai, K.V., Raddy, S.D.V., Ratnambal, M.J., Laxman, R.H., 2003. Factors contributing to flower production and button shedding in coconut. J. Plant. Crops 31 (2), 33–36.

Kularatne, J.D.J.S., Peiris, T.S.G., Samita, S., 2006. Feasibility of single palm plot in coconut experimentation. Trop. Agric. Res. 18, 1–9.

Lal, R., et al., 2005. Climate change, soil carbon dynamics and global food security. In: Lal, R., Stewart, B., Uphoff, N. (Eds.), Climate Change and Global Food Security. CRC Press, Boca Raton (FL) pp. 113–143.

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

Liyanage, D.V., 1958. Varieties and forms of the coconut palm grown in ceylon. Ceylon Coconut Q. 9, 1–10.

Liyanage, D.V., 1959. Report of botanist. In: Salgado, M.L.M. (Ed.), Ceylon Seasonal Papers. Coconut Research Institute, Lunuwila, Sri Lanka pp. 29-33.

Liyanage, D.V., Wickramaratne, M.R.T., Jayasekara, C., 1988. Coconut breeding in Sri Lanka: a review. Cocos 6, 1–26.

Nambiar, M.C., Nambiar, K.P.P., 1970. Genetic analysis of yield attributes in *Cocos nucifera* var. West Coast Tall. Euphytica 19, 543–551.

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., Roupsard, O., 2008. Fruit development, not GPP, drives seasonal variation in NPP in a tropical palm plantation. Tree Physiol. 28, 1661–1674.

Perera, L., Peries, R.R.A., Padmasiri, M.H.L., 2002. Sri Lanka Brown Dwarf (SLBD) coconuts: a potential variety for future breeding. Plant Genet. Resour. Newsl. 131, 70–72.

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

Perera, P.I.P., Hocher, V., Weerakoon, L.K., Vakandawala, D.M.D., Fernando, S.C., Verdeil, J.L., 2010. Early inflorescence and floral development in Cocos nucifera L. (Arecaceae). S. Afr J. Bot. 76, 482–492.

Punyawardane, B.V.R., 2008. Evolution of climatic zones in Sri Lanka. In: Punyawardane, B.V.R. (Ed.), Agro-climatological Zones and Rainfall Pattern in Sri Lanka (in Sinhalese). Department of Agriculture, Sri Lanka pp. 44-113.

Ranasinghe, C.S., Silva, L.R.S., Premasiri, R.D.N., 2015. Major determinants of fruit set and yield fluctuation in coconut (Cocos nucifera L.). J. National Sci. Found. Sri Lanka 43 (3), 253–264.

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

Thomas, Regi J., Josephrajkumar, A., 2013. Flowering and pollination biology in coconut. J. Plant. Crop 41 (2), 109–117.