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CULTIVAR BY ENVIRONMENT INTERACTION OF COCONUT UNDER DIFFERENT WATER AND HEAT REGIMES AT THEIR EARLY STAGE OF GROWTH

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Abstract

Four coconut hybrids (brown dwarf x Sri Lanka tall, Sri Lanka tall x brown dwarf, green dwarf x San Ramon and green dwarf x Sri Lanka tall) arising with two parental dwarf coconut varieties; green dwarf and brown dwarf were evaluated for their early vegetative growth and for duration to reproduction at two sites; Raddegoda and Wanathawilluwa. At Raddegoda, a site with optimum condition for growth of coconut, the overall leaf production rate was 9.4 leaves per palm per year during the first 3 year period. In contrast, at Wanathawilluwa, a site subject to severe and prolong drought and heat stress produced 11.3 leaves per palm per year. Moreover, at Wanathawilluwa crosses made with green dwarf produced a remarkably higher number of leaves compared to crosses made with brown dwarf. However, this trend was not noticeable for stem girth indicating that the higher photosynthetic assimilates in green dwarf crosses resulting from higher leaf area were not used for stem growth. When time to attain reproduction is considered, the crosses made with green and brown dwarfs were similar at Raddegoda (43.2 Vs 43.8 months). However, green dwarf crosses at Wanathawilluwa were markedly precocious attaining early maturity (33.25 Vs 41.9 months), but resulting in a large number of stunted palms. This situation was severe in green dwarf x San Ramon. The overall results suggested that early vegetative phase of coconut hybrids resulting from green dwarf parent is more susceptible to drought and heat stress conditions. This phenomenon indicated a differential physiological response of different coconut cultivars under moisture and heat stress.

Key words: Coconut, *Cocos nucifera,* Drought stress, Hybrid evaluation, Physiological response.

Introduction

The coconut palm, *Cocos nucifera* L. has a pan-tropical distribution, occurring in areas between the latitudes 20º north and south of the equator and at altitudes between sea level and 1200m. Coconut grows best under conditions of high humidity, at temperatures of 27-30ºC and on moderately to well-aerated soils (Perera *et al*., 2009). Coconut is renowned as the "Tree of Life" in the tropics, due to its versatile uses.

Coconut can be successfully grown in areas where annual rainfall is between 1300 mm to 2500 mm or above (Abid *et al*., 2007). However, with the changing climate, the majority of coconut growing areas presently is severely constrained by drought and heat stress. Yield loss of coconut is one of the main causes for the gap between national coconut production and demand of the industry in many countries. Coconut improvement programme, particularly breeding for drought tolerance plays an important role in reducing this gap between demand and supply to mitigate short supply of coconut during dry periods.

The coconut gene pool mainly comprises of two groups of coconut; the tall coconut (*Typica*) and dwarf coconut (*Nana*) (Perera *et al*., 2002; Perera *et al*., 2009). The dwarf varieties are not commercially grown, but are extensively used in national coconut breeding programmes. The hybrids between dwarf and tall were highly successful in terms of precocity and yield (Liyanage *et al*., 1988; Perera *et al*., 2010). Hence, different forms of dwarfs; green dwarf, yellow dwarf, red dwarf and brown dwarf, have been used as breeding material for coconut hybrid production. In Sri Lanka, the Sri Lanka green dwarf is a preferential choice of parent in the breeding programme. The Sri Lanka brown dwarf was identified recently (Perera *et al.*, 2002) and it was not utilized for hybrid production prior to the current study. Sri Lanka brown dwarf variety proved to be less susceptible to drought stress (Ranasinghe, 2005) and produced very large number of female flowers per inflorescence (Perera *et al.*, 2002) indicating its usefulness in the coconut breeding for high yield and adaptation to stress conditions. This paper discusses a discrepancy in behavioural response of different coconut hybrids resulting from brown dwarf and green dwarf as parents under diverse soil and environmental conditions and potential use of brown dwarf crosses under drought and heat stress conditions.

Materials and Methods

Cultivars: Sri Lanka brown dwarf x Sri Lanka tall (BD x T), its reciprocal (T x BD), Sri Lanka green dwarf x Sri Lanka tall (GD x T) and Sri Lanka green dwarf x San Ramon tall (GD x SR) were evaluated at two different sites; Raddegoda and Wanathawilluwa in Sri Lanka established during the period of 2004-2005.

Environments: Raddegoda site is located in the wet intermediate zone in the low country (IL_{1a}) and receives a well distributed annual rainfall of over 1400 mm. The maximum temperature ranges between 29ºC–35ºC and the site is characterized as a deep, well-drained loamy soil. This site is in overall considered a highly favourable site for coconut cultivation. In contrast, site at Wanathawilluwa is located in the dry zone of the low country (DL_3) 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 October to January. The temperature ranges from 29ºC–38ºC in this region is too high for optimum coconut growth and nut production. Coconut palms in this site therefore suffer drought and heat stress for a considerable period of the year. The soil in this site is characterized by imperfectly drained deep sandy-clay soil. Therefore, this site favours better root growth.

Experimental design: The experiments were planted in a Randomized Complete Block Design (RCBD) with four replicates at Raddegoda and three replicates at Wanathawilluwa. The plot size varied from 6-9 palms. The planting design was 8 m x 8 m and the planting density was 165 palms/ha. The seed-hole size was 1 x 1 x 1 m at both sites. The sites were managed under standard management practices.

Data collection: The data on new leaves produced at six monthly intervals up to 3 years from field planting were collected and accordingly leaf production rate per year was calculated. The stem girth in all the palms in the two sites was measured 5 years after field planting. Time taken in months for seedlings to produce the first flower (attain reproduction stage) was recorded at the two sites.

Data analysis: 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

Rate of leaf production: The ANOVA test carried out for mean leaf production rate was significant for site (F=79.92, p-value=<.0001), cultivar (F=4.34, p-value=0.0053) and for site x cultivar interaction (F=5.07, p-value=0.0020). At Raddegoda site the mean leaf production rate was 9.4 leaves/palm/year. In contrast, at Wanathawilluwa site the mean leaf production rate was greater and was 11.3 leaves/palm/year, indicating an enhanced early vegetative growth under drought and heat stress condition. There is a statistically significant difference between the cultivars within each site. Table 1 shows the mean leaf production rate of cultivars average over 36 and 31 palms/cultivar at Raddegoda and Wanathawilluwa respectively. At Wanathawilluwa, cultivars (hybrids) resulting from green dwarf (GD x SR and GD x T) exhibited a significantly higher rate of leaf production (12.4 and 11.6 respectively) than hybrids resulting from brown dwarf (11.1 and 10.2 respectively for BD x T & T x BD). Between the two hybrids resulted from green dwarfs, GD x SR was the highest leaf producer. However, at Raddegoda, differences among hybrids were statistically not significant.

Stem girth: The mean stem girth at Raddegoda and Wanathawilluwa is presented in the table 2. With respect to mean stem girth also, a statistically significant site (F=28.97, p-value=<.0001), cultivar (F=13.15, p-value=<.0001) and site x cultivar interaction (F=3.47, p-value=<.017) was observed. The site mean stem girth for Raddegoda and Wanathawilluwa was recorded as 107.38 cm and 93.56 cm respectively and they were statistically significant. The ANOVA test was significant for between cultivars at both Wanathawilluwa (F=10.76, p-value=<.0001) and Raddegoda (F=3.2, p-value=<.0257). The highest mean stem girth at Wanathawilluwa was shown by T x BD (113.79 cm) when the lowest was shown by GD x SR (84.52 cm). Among the four cultivars, BD x T, GD x T and GD x SR showed significantly lower stem girth at Wanathawilluwa compared to Raddegoda (Table 2). However, interestingly, T x BD in both Wanathawilluwa and Raddegoda sites showed comparable stem girth (113.79 cm Vs 113.84 cm). This indicated that drought and heat stress had a little effect on T x BD with respect to stem growth. The data indicated that BD x T and its reciprocal (T x BD) performed differently under stress and non-stressed condition, specifying a possible maternal effect which requires further investigation.

Time taken for first flowering: Table 3 shows the mean time taken for flowering of different hybrids at Raddegoda and Wanathawilluwa. Similar with rate of leaf production and mean stem girth, the ANOVA test was significant for site (F=32.45, p-value=<.0001), cultivar (F=9.81, p-value=0.0001) and for site x cultivar interaction (F=17.73, p-value=0.0001) for the mean time taken for first flowering. The mean time taken for first flowering was less at environmentally stressed Wanathawilluwa (37.5 months) compared to favorable site at Raddegoda (42.7 months). At Raddegoda, the crosses of brown dwarf and green dwarf showed similar performance in the time taken for first flowering. However, at Wanathawilluwa, GD x T and GD x SR showed a noticeably lesser time (7 months) to first flowering compared to that of brown dwarf crosses.

Table 1. Mean leaf production rate (leaves/palm/year) by different cultivars at Raddegoda and Wanathawilluwa.

Cultivar	Raddegoda (n=36)	Wanathawilluwa (n=31)
BD x T	9.14[a]	11.07[bc]
T x BD	9.64[a]	10.27[c]
GD x T	9.46[a]	11.63[ab]
GD x SR	9.48[a]	12.36[a]

(Means with the same letter in each column are not significantly different at p≤0.05)

Table 2. Mean stem girth (cm) in different hybrids five years after planting at Raddegoda and Wanathawilluwa.

Cultivar	Raddegoda (n=36)	Wanathawilluwa (n=31)
BD x T	110.03[ab]	90.67[b]
T x BD	113.84[a]	113.79[a]
GD x T	103.72[b]	89.34[b]
GD x SR	102.37[b]	84.52[c]

(Means with the same letter in each column are not significantly different at p≤0.05)

Table 3. Mean time taken for first flowering (months).

Cultivar	Raddegoda (n=36)	Wanathawilluwa (n=31)
BD x T	43.8ab	40.1b
T x BD	43.9ab	43.7b
GD x T	45.3b	33.6a
GD x SR	41.1a	32.9a

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

Correlation between time taken for flowering and stem girth: A correlation study conducted for both sites independently between time taken for flowering and stem girth showed significant positive correlation between them, elucidating a fact that palms that flowered early tend to develop lower stem girth. At Wanathawilluwa the correlation was very strong (r = 0.79) compared to Raddegoda (r = 0.21).

Discussion

The results of the statistically analysed data pertaining to the growth parameters of different cultivars of coconut; rate of leaf production and mean stem girth and the time taken for first flowering, suggested varying response of different coconut hybrids to different environments. The Wanathawilluwa site for a long period of the year is subjected drought and heat beyond the optimum limits. Earlier crop flowering and maturity have been observed and documented in recent decades, in determinate crops and these are often associated with warmer temperatures. Temperature is a major determinant of the rate of plant development and with seasonal variation; warmer temperatures that shorten development stages of determinate crops will most probably reduce the yield of a given variety (Craufurd *et al*., 2009). The poor stem girth when palms at high leaf production at Wanathawilluwa appeared contradictory. It may be suspect that Wanathawilluwa site had deprived soil nutrients status, but both sites under consideration were well fertilized and nutrient analysis reports confirmed that the palms at both sites were free from macro and micro nutrient deficiency symptoms.

Under stress conditions photosynthesis of the coconut palm is limited to a shorter period due to early closure of stomata and high stomatal resistance during drought (water stress) and high temperature (heat stress) conditions (Jayasekara *et al.*, 1996). A study conducted by Lakmini *et al*. (2006) comparing four different coconut varieties; Clovis, green dwarf, brown dwarf and Cameroon red dwarf, for their drought tolerant ability, concluded that among dwarf varieties, brown dwarf appeared to be more drought tolerant by maintaining a higher rate of photosynthesis despite low stomatal conductance under moister stress. The coconut palm can regulate certain physiological mechanisms which make it susceptible or tolerant to drought. Among these physiological mechanisms, stomatal regulation and osmotic adjustment are few possible physiological mechanisms (Lakmini *et al.*, 2006) responsible for the drought tolerant or susceptibility in coconut. The stomatal regulation is the major mechanism that controls the water balance in coconut during water stress (Milburn & Zimmermann, 1977). Lakmini *et al*. (2006) in another study, further revealed that brown dwarf posses a greater degree of tolerance to drought and high temperature thus showing their great potential for higher productivity in stress conditions. Kudugammulla *et al*. (2013) comparing response of stomatal characteristics of different coconut hybrids in different environmental conditions indicated that BD x T expressed the highest guard cell length of stomata during moderately dry period, thus concluding that BD x T hybrid has a mechanism to change the size of stomata as a response to the changes in environment which is an adaptation to stress conditions.

The positive correlation between time taken for flowering and stem girth at both sites indicated that palms flowered early tend to develop smaller stem girth. The high correlation coefficient observed at Wanathawilluwa (r = 0.79) signposted that this positive correlation enhanced by unfavorable climatic conditions for coconut growth. It appeared that net carbohydrate assimilates of green dwarf crosses especially GD x SR at environmentally stressed Wanathawilluwa site had not been adequately utilized for stem growth compared to brown dwarf cross. Instead, it appeared to have been exploited for development of reproductive organs attaining early maturity.

This phenomenon might be a physiological adaptation of coconut as a survival mechanism for unfavorable conditions similar to the drought scape mechanism in annual crops (Craufurd *et al.*, 2009). This has resulted in a significant number of underdeveloped palms of GD x T and GD x SR. This suggests that green dwarf crosses are vulnerable to stress conditions than brown dwarf crosses at their early stage of growth. The situation was observed to be worst in GD x SR. Sri Lanka green dwarf and San Ramon shared a similar genome of coconut. In contrast, Sri Lanka brown dwarf and Sri Lanka tall are of two divergent origins or two independent domesticating events (Perera *et al*., 2000). It may be possible that recombination of alleles during crossing between green dwarf and San Ramon, may favour combination of unfavourable alleles which could express when exposed to extreme environments during early vegetative growth. The phenomenon discussed in this paper is suggestive of differential genetic/ physiological response of coconut to stress conditions during their early vegetative growth. This is the first report of such an observation made for perennial crops like coconut. This has positive implication in site specific recommendation of coconut cultivars.

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