Screening of Coconut (*Cocos nucifera*) For Drought Tolerance

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Abstract
Drought causes a substantial reduction in the national yield of coconut and also loss of coconut palms in severe droughts, thus resulting in serious economic consequences in the coconut industry of Sri Lanka. Therefore, it is of prime importance to identify some putative drought tolerant genotypes for planting in drought prone areas. As the long generation and maturation periods of coconut restrict the selection of genotypes based on yield, a knowledge on the physiological responses to water deficit conditions plays an important role in developing a rapid selection criterion. Therefore, the objective of this research was to identify drought tolerant genotypes by using the effects of drought on gas exchange parameters of selected coconut genotypes. Four genotypes were selected. The accession Clovis (CL) is believed to be tolerant to drought while the rest (Dwarf Green [DG], Dwarf Brown [DB] and Cameron Red Dwarf [CRD]) are considered to be sensitive. All palms were about 15 years of age and managed according to the recommended practices, in adjacent plots at the Poththukulama Research Station, Pallama in IL_1 Agro-Ecological Region (Aquic Quartzipsamments, uncoated sandy, non calcareous soil). Eight adjacent palms from each of four genotypes were selected from experimental plots arranged in Completely Randomized Design. Palms were monitored throughout the 80-day natural drought experienced in early 2005. Stomatal conductance (g_s), rate of photosynthesis (A), and rate of transpiration (E), were measured during the drought period along with the corresponding soil moisture contents.
The reduction in g_s in response to drought occurred in all four genotypes. CL and DB appeared more drought tolerant by maintaining higher A even under lower g_s during drought. Moreover, CL and DB recovered quickly after subsequent rains. CRD showed highest rate of reduction of g_s (63%) with the inception of drought indicating its greater sensitivity to water deficit conditions. The susceptibility index (SI) calculated using g_s, E and A/E also showed that CRD was the most sensitive genotype to drought while CL being the most tolerant out of four genotypes. Although DB and DG appeared sensitive to drought in terms of SI, DB showed a degree of tolerance, quick recovery, and higher rates of A and thus showed a greater potential for higher productivity which was important in a commercial cultivation. These four genotypes can be ranked in order of drought tolerance as CL>DG>DB>CRD.
Key words: Coconut, Drought tolerance, Susceptibility Index, Stomatal conductance

Introduction

Coconut (*Cocos nucifera* L.) is the most widely grown plantation crop in Sri Lanka (Fernando *et al.*, 1997). The total land area under coconut is approximately 440,000 ha (Liyanage, 1999). A large number of coconut palms are annually lost due to drought in Sri Lanka, resulting in severe economic consequences to the coconut industry. For example, nearly 200,000 palms in the South coast in 1988/89 were lost due to drought (Fernando, 1997). The development of an inflorescence in coconut occurs over a period of nearly 44 months (Rajagopal and Ramadasan, 1999). Environmental variations during this period may influence the yield and yield components of coconut. Therefore, depending on the intensity and duration of drought, manifestation of its adverse effects on the yield may last up to two and a half years. About 16% of coconut lands are in the dry zone while as much as 69% distributed in the intermediate zone. The annual rainfall in the intermediate dry and dry zones is 1000-1500 mm and 1000 mm respectively, with four to seven month-long dry periods and one major monsoon rainy period. Shortage of available soil water and high temperature are the main limiting factors to plants growing in these regions. Therefore, selection and breeding of drought tolerant genotypes of coconut is very important. The coconut palm possesses certain physiological mechanisms, which makes it particularly susceptible or tolerant to drought. Stomatal regulation and osmotic adjustment are possible physiological mechanisms responsible for the drought tolerance or susceptibility in coconut. Milburn and Zimmermann (1977) found that stomatal regulation is the major mechanism that controls the water balance in coconut during dry season, with osmotic adjustment being less effective.

Various drought screening techniques have been proposed based on physiological, biochemical and vegetative changes occurring in plants in response to drought. Fischer and Maurer (1978) defined drought tolerance of different spring wheat cultivars in terms of a Susceptibility Index as the ratio between the yield loss (relative to an irrigated control) of a given genotype and the mean yield loss of all tested genotypes. Ober and Luterbacher (2002) used a similar index based on relative leaf expansion rate (*RLER*) and relative growth rate (*RGR*) for sugar beet. The basic physiological principle adopted in improving drought tolerance of coconut is to look for genotypes, which can conserve water and maintain leaf turgidity during drought. This can be assessed by measuring relevant physiological parameters (i.e. photosynthesis, stomatal conductance, transpiration etc.) during the periods of soil water deficit. Therefore, the objectives of this investigation were to compare drought tolerance of selected set of coconut genotypes using the susceptibility index, which was calculated by the effects of drought on gas exchange parameters.

Methodology

The work was carried out at the Plant Physiology Division, Coconut Research Institute of Sri Lanka (*CRISL*). Four different coconut genotypes *viz.* Clovis (*CL*), Sri Lankan Brown Dwarf (*DB*), Sri Lankan Green Dwarf (*DG*) and Cameroon Red Dwarf (*CRD*) were selected for the field experiment. They were a part of the *ex situ* coconut gene bank, with approximately 15 years of age and planted at Poththukulama Research Station (*PRS*), situated in the IL_1 (Semi-wet, intermediate low country region) Agro-Ecological Region. According to the USDA soil taxonomy this zone consists of Aquic Quartzipsamments, uncoated sandy, non calcareous soil (Dissanayake *et al.*, 2005). All palms were managed according to the recommended practices by the *CRISL,* from the time of planting. Eight adjacent palms from each of four genotypes were selected from the experimental plots arranged in Completely Randomized Design (*CRD*). Data were collected from October 2004 to April 2005. Physiological measurements were taken once a month during the rainy season and the frequency was increased to once a week during the drought. Leaflets from the middle portion of the ninth leaf from top (Braconnier and Bonneau, 1998) were used for all physiological measurements. Measurements were conducted on excised leaves immediately after the excision and completed within two minutes during the period from 10.00 am to 12.00 noon. Gas exchange technique was used to measure stomatal conductance (g_s) (mol m^{-2} s^{-1}), rate of photosynthesis (A) (μmol m^{-2} s^{-1}) and rate of transpiration (E) (mmol m^{-2} s^{-1}) employing a closed system portable photosynthesis System (LI-COR Inc., Lincoln, Nebraska, USA). Daily rainfall (mm) and other relevant meteorological data were obtained from the weather station maintained at *PRS.* Soil moisture content (%) at 50 cm and 100 cm depths was determined gravimetrically at each measuring time simultaneously with other gas exchange measurements. Preliminary data analysis for each parameter was performed using Analysis of Variance (ANOVA) and the Duncan's New Multiple Range Test (*DNMRT*) was used as the mean separation technique to identify the difference between genotypes.

Susceptibility index (*SI*) was used as a tool for screening of drought tolerant genotypes which was first introduced by Fischer and Maurer (1978) for the same in spring wheat cultivars. *SI* is the relative yield loss of a particular genotype with respect to the mean yield loss of all tested genotypes in the experiment as shown below.

$YL = (1-[Y_d/Y_i])$

Where, YL is the relative yield loss, Y_d is the yield under drought and Y_i is the irrigated yield.

$SI = YL / (1- [X_d / X_i])$

Where, X_d is the mean yield under drought conditions of all tested genotypes, and X_i is the mean irrigated yield of all genotypes. The horizontal line $SI = 1$ indicates the mean response and genotype with SI less than 1 were more drought tolerant than average.

The instantaneous water use efficiency (ω_{inst}) (A/E) which represents the production efficiency of plants with respect to the consumption of water was used as reference parameter for the calculation of SI. E and g_s which occur concurrently with the assimilation were also used as reference parameters for calculating SI.

Results and Discussion

Previous rainfall data of the experimental site showed a bimodal distribution pattern, with two peaks representing two monsoonal rains (i.e. South-West and North-East). The South-West monsoon is received during May and June while the North-East monsoonal rains fall during

October and November. More than 65% of the annual rainfall at the research site is accounted for by the rainfall during these four months (Peiris and Thattil, 1997). Accordingly, the highest rainfall during the experimental period was observed during October and November (Fig.1). Drought commenced 78 days after starting data collection and it continued up to day 159. Therefore, palms were subjected to an 80-day period of natural drought (from 18th December 2004 to 7th March 2005) during the experiment. However, three brief sporadic rainfalls also occurred during this period. The marked reduction in monthly rainfall from 416.22 mm in November to just 16.2 in January indicated the intensity of the drought in the area.

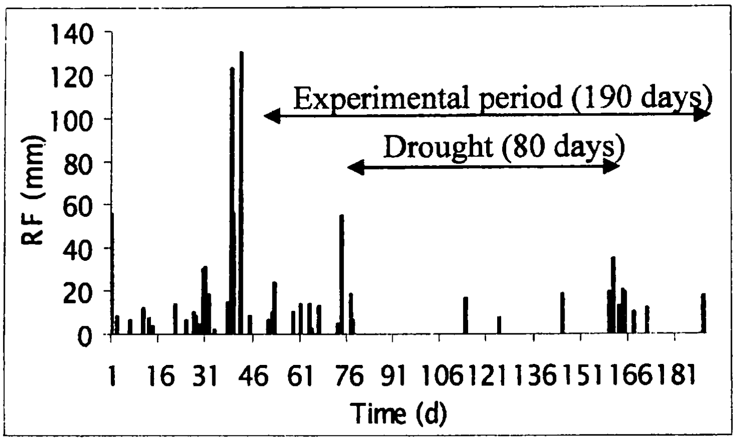


Figure 1 Variation of rainfall during the experimental period. The experiment started on 01/10/2004 and this date corresponded to day 1.

The soil was sufficiently wet due to the heavy rains received prior to the drought (Fig. 1) and the soil moisture content (θ, %) varied only from 9.2 to 10.8 % among four plots of coconut genotypes prior to the drought which indicated that all palms were under more or less similar soil moisture conditions at the inception of the drought. The soil moisture content was reduced to levels as low as 3.5 to 2.5 % during the drought period.

Gas exchange measurements

Gas exchange parameters are important because they are directly associated with carbon and water economy of plants. Stomatal conductance (g_s, mol m^{-2} s^{-1}), rate of transpiration (E, mmol m^{-2} s^{-1}) and rate of photosynthesis (A, µmol m^{-2} s^{-1}) of these four coconut genotypes decreased during the water stress period (i.e. from 79 to 159 days) (Fig. 2). This is in accordance with previous results, which showed that all palms irrespective of the genotype were equally sensitive to soil water depletion and responded to water deficit by decreasing the g_s (Rajagopal, 1990).

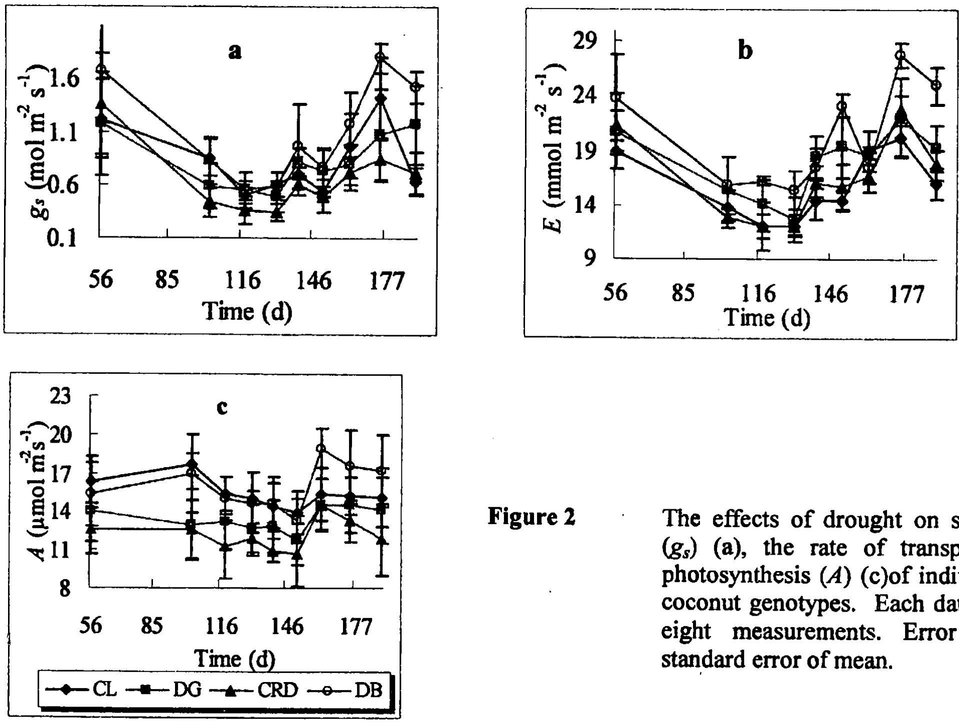
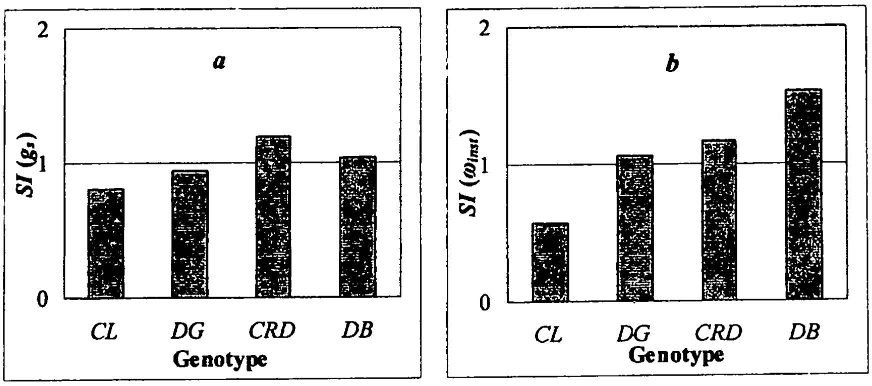


Figure 2 The effects of drought on stomatal conductance (g_s) (a), the rate of transpiration (E) (b) and photosynthesis (A) (c)of individual leaves of four coconut genotypes. Each data point is a mean of eight measurements. Error bars indicate the standard error of mean.

As shown by Rajagopal (1990) g_s is a discriminative parameter for screening adult coconut palms under drought. Jayasekara *et al.* (1993) and Ranasinghe *et al.* (2003) also confirmed that stomatal regulation is the key factor controlling the water balance of coconut. The quick and significant reductions observed in g_s in comparison to the response of *A*, in the present experiment (Fig 2), suggests the general tendency of coconut to conserve water by reducing the water loss through the reduced g_s. In the present experiment, *DB* and *CRD* showed higher g_s (1.67 and 1.36 mol m^{-2} s^{-1} respectively) under well-watered conditions (i.e. day 56), while *CL* and *DG* showed similar values (approx. 1.2 mol m^{-2} s^{-1}) (Fig. 2a). But there was no statistically significant difference ($P<0.05$) between the g_s of different genotypes. The rate of reduction of g_s was greater in *CRD* (63%) (from day 56 to 103) than the rest (Fig. 2a). Therefore, out of the tested genotypes, *CRD* can be considered as more sensitive to water stress. *DB* and *CL* maintained higher g_s (1.18 and 0.98 mol m^{-2} s^{-1} respectively) as compared to the other two genotypes at the end of the drought (i.e. day 162). *DB* and *CL* showed a quick recovery of g_s with re-wetting after rains, with *DB* being the quickest (Fig. 2a). This is an important characteristic of a plant better adapted to intermittent droughts. The rate of *E* also declined with decreasing g_s and the good correlation (approx. r = 0.87) between *E* and g_s clearly showed a close relationship between those two parameters (Fig. 2a and 2b).
All genotypes showed a reduction in *A* with the progress of drought (Fig. 2c). However, both *CL* and *DB* maintained significantly higher *A* ($P<0.05$) than the other two genotypes throughout the drought (i.e. from day 103 to 151). In contrast, *CRD* maintained the lowest *A* (approx. 11 μmol m^{-2} s^{-1}). Photosynthesis of all four genotypes showed a rapid response to rewetting with subsequent rains (the day 160 rain was started) and *DB* was the quickest in regaining the initial rates. Stomata are the main pathway for exchange of CO_2 and water. Net fixation of atmospheric CO_2 is rapidly inhibited by stomatal closure. Therefore, when water stress sets in, stomatal closure seems to be the main carbon assimilation-limiting factor in coconut palms. Palms with lower g_s and higher *A* are superior to withstand water stress conditions.

Susceptibility index

The susceptibility Index (*SI*) was first used by Fischer and Maurer (1978) to identify drought tolerance of different spring wheat cultivars using yield as the reference parameter. The same approach was used in this study also, using variations of g_s, *E* and ω_{inst} during drought as reference parameters, instead of yield. Data collected on 131st day after commencing the experiment represented the growth performance of palms under drought while the data collected on the 56th represented the performance of palms under non-stressed conditions.
According to Fischer and Maurer (1978) $SI = 1$ is the mean response and a genotype with $SI < 1$ would be less susceptible (i.e. more tolerant) to drought with respect to other genotypes. Genotypes with $SI > 1$ would be more susceptible under water-limited conditions.
According to the susceptibility index calculated on the basis of ω_{inst}, *DG*, *DB* and *CRD* were drought susceptible ($SI > 1$) but *CL* was less susceptible (or more tolerant) ($SI < 1$) (Fig. 2b). However, the *SI* calculated using *E* (Fig. 2c) selected *DB* and *CL* as more tolerant genotypes and *CRD* as the most susceptible. g_s based *SI* also showed *CL* as the least susceptible genotype, while *DG* was around the mean with almost 1. In contrast, *DB* and *CRD* with $SI > 1$ can be categorized as drought-sensitive (Fig. 2a). Thus, the broadly similar pattern observed for *SI* with different parameters indicated the possibility of using *SI* for classifying coconut palms for drought tolerance.
The degree of stability under drought in the four genotypes based on susceptibility index proposed by Fischer and Maurer (1978) was *CL*, *DG*, *DB* and *CRD* in ascending order. It is interesting to note that according to this varietal classification method, *SI* of *DG* was lower than that of *DB*, indicating that *DG* was more drought resistant than *DB*. *SI* was either above or closer to the mean ($SI = 1$) in *CRD*, *DB* and *DG* when g_s, *E* or ω_{inst} were used as reference parameters. The only genotype, which showed a substantially lower *SI* at least with some of these reference parameters, was *CL*, which proved its tolerance ability, compared to the rest of the genotypes tested. Out of the three dwarf genotypes tested, *DG* appeared to show a certain degree of ability to withstand moisture stress.



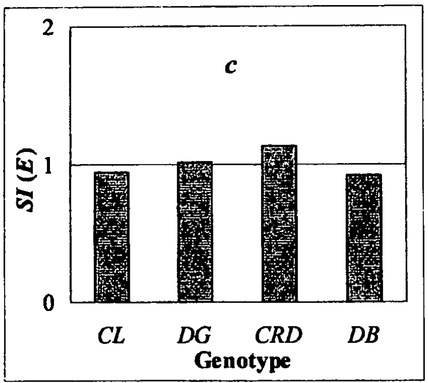


Figure 4.21 Susceptibility index (*SI*) for g_s (a), ω_{inst} (b) and *E* (c) of four genotypes.

Conclusions

Most of the differences in the pattern of gas exchange parameters with the progress of drought were approximately similar among genotypes. However, some differences that were observed can be used to identify genotypic variation in drought tolerance in the coconut varieties used in the present study. The eighty-day drought period during which physiological performance of coconut palms were evaluated, appeared not so critical. This was probably because their general hardy behaviour and the drought-relieving effect of the brief rains experienced towards the end of the drought. More or less similar pattern observed with *SI* calculated from different gas exchange parameters indicated that *SI* is a reliable physiological indicator for screening coconut palms for drought tolerance.

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