

Drought Tolerance in Coconut and Cocoa



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IN
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Front Cover: Drought tolerant WCT x COD coconut hybrid
Back Cover: Drought tolerant NC 23/43 cocoa accession

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DROUGHT TOLERANCE IN COCONUT AND COCOA

1. INTRODUCTION

Coconut and cocoa which are perennial plantation crops require well distributed rainfall (1300 to 2500 mm or above) throughout the year. Coconut (*Cocos nucifera* L., Family - Arecaceae), a monocot tree crop grow well in warm humid weather with an estimated 120 sunshine hours per month. The ideal temperature is around 27°C. A prolonged dry spell lasting over six months, from December to May, adversely affects the palms (see inside back cover). Such severe drought occur once in every 3 or 4 years in Northern Kerala and Coastal Karnataka. The adverse effect of drought on coconut palms has also been reported in Tamil Nadu. Cocoa (*Theobroma cacao* L. Family - Sterculiaceae) was introduced in Southern India during the present century mainly as an intercrop of palms. Severe moisture stress affects the yield significantly when cocoa trees are grown as intercrop in coconut garden.

2. GERMPLASM HOLDINGS

In India, the Central Plantation Crops Research Institute (CPCRI) Kasaragod, with its World Coconut Germplasm Centre in Andaman Islands, maintains the largest number of coconut germplasm. It consists of 86 exotic and 40 indigenous accessions which include 103 tall, 20 dwarfs, two semi-talls and one hybrid. Similarly, cocoa accessions consist of 94 accessions from Malaysia, Nigeria

and England. With the vast heterozygous nature of these germplasm collections, yield improvement can be achieved only through evaluation under different management conditions. Since these crops are mainly grown under rainfed or under conditions of limited water availability, the approach for increasing productivity has to be through identification of varieties/ accessions which can withstand moisture stress in the field and still yield well. This led to the systematic investigations on screening for drought tolerance in both coconut and cocoa and resulted in identifying the genotypes with desirable traits to withstand moisture stress.

3. DATA COLLECTION

While screening for drought tolerance, there are different steps to be followed for collection of data:

A) Agro-meteorological variables: The parameters like radiation, temperature and relative humidity at the vicinity of experimental plants i.e., microclimate, are measured using the steady state prometer, which is fitted with sensors for recording the above parameters (Fig. 1).

B) Soil water deficit: The gravimetric method of estimation of soil moisture content in the basins of experimental palms is adopted. From the soil characteristics, the available soil water and then the soil water deficit between the periods of experiments are computed.

C) Sampling: The first and foremost step is to fix the index leaf for the determination of sensitive physiological parameters and secondly the time of the day for recording the observations. In coconut the sixth leaf from the spindle and in cocoa the youngest fully developed leaf, i.e., 3rd or 4th from the bud are found to be the index leaf. In both cases, the optimum time for recording observations is between 9.30 to 11.30 hours of the day.

4. SCREENING TECHNIQUES

The following techniques are employed to screen both coconut and cocoa for drought tolerance under field conditions.

A) Leaf water status: Maintenance of leaf water at optimum level in summer months is the most important requisite for plants to cope up with the evaporative demand imposed by both the atmospheric

drought and soil drought. This is usually achieved by the effective stomatal regulation which controls transpiration rates, thus maintaining the water balance in the tissues. Another important parameter which helps to check water loss from leaf surface is the epicuticular wax coating on the leaf. The table below summarizes the techniques used to estimate the leaf water status in plants, the equipments employed and desirable traits for drought tolerance.

B) Cell membrane integrity: With increase in radiation, temperature and vapour pressure deficit during summer months, accentuated by soil water deficit, tissues in drought tolerant plants maintain cell membrane integrity better than those in drought susceptible plants. The less the leakage of electrolytes from the tissues the greater the membrane integrity. This is usually measured by the conductivity of electrolyte leachate.

Parameters studied	Equipments used	Desirable trait for drought tolerance
i) Stomatal resistance - gives an indication of the degree of stomatal closure	Steady state porometer (Li-Cor 1600 USA) / Portable photosynthesis system (Li-COR/ADC, U.K.)	Relatively high stomatal resistance
ii) Transpiration rate - gives an indication of water loss from leaf surface	-do-	Low transpiration rate
iii) Leaf water potential-indicates leaf water status and turgidity of tissues	Plant water console 3000 (Soil Moisture Co. USA)	High leaf water potential
iv) Epicuticular wax content - indicates cuticular loss of water from leaf surface	Spectrophotometer (Shimadzu, Japan)	High wax content
v) Relative water content-indicates the level of tissue turgidity	Electronic balance and hot air oven	High RWC values

Further evidence on these aspects can be obtained through the assay of related enzymes which reflect on peroxidation of cell

wall lipids. The following table depicts the biochemical parameters studied in coconut and cocoa in relation to drought tolerance:

Parameters studied	Desirable trait for drought tolerance
Lipid peroxidation	Low
Superoxide dismutase	High activity
Peroxidase	High activity
Polyphenol oxidase	Low activity
Catalase	High activity
Acid phosphatase	Low activity
Nitrate reductase	High stability

When the genotypes showed the above trend under stress conditions, they are grouped as drought tolerant.

An index of the threshold values above (>) or below (<) which plants show tolerance/susceptibility to drought situations in the two crops is given in the table below :

	Coconut	Cocoa
i) Agro-meteorological variables		
Soil moisture content (%)	< 9.0	< 12.5
Radiation (W.m ⁻²)	> 265	> 290
Temperature (°C)	> 33.5	> 35.0
Vapour pressure deficit (mbar)	> 27	> 27
ii) Physiological parameters (threshold for drought tolerance)		
Stomatal resistance (s.cm ⁻¹)	> 10.0	> 10.0
Transpiration rate (µg. cm ⁻¹ s ⁻¹)	< 2.5	< 2.0
Leaf water potential (MPa)	> -1.20	> -0.9
Epicuticular wax (µg. cm ²)	> 95	> 50

5. GERMPLASM SCREENED FOR DROUGHT TOLERANCE (ADULT PLANTS)

COCONUT

TALLS		DWARFS
West Coast Tall	(WCT)	SS Green
SS Apricot		Malayan Green Dwarf (MGD)
Andaman Ordinary	(AO)	Malayan Orange Dwarf (MOD)
Laccadive Micro	(LM)	Malayan Yellow Dwarf (MYD)
Andaman Giant	(AG)	Gangabondam (GB)
Federated Malay States	(FMS)	Chowghat Orange Dwarf (COD)
Fiji		
Philippines Ordinary	(PO)	
Cochin China	(CC)	
Java Giant	(JG)	
Laccadive Ordinary	(LO)	

HYBRIDS

T x D Hybrids

WCT x COD (Kerasankara)

WCT x GB (Keraganga)

LO x GB (Lakshaganga)

LO x COD (Chandralaksha)

ECT x CGD

PO x GB

SSG x GB

CC x GB

WCT x Andaman Dwarf

WCT x MGD

WCT x MOD

WCT x Laccadive Dwarf

Most promising drought tolerant genotypes:

LOxCOD, LOxGB, WCTxCOD, WCT, LO, PO.

T x T Hybrids

WCT x Cochin China

WCT x Kappadam

WCT x SS Green

WCT x Fiji

WCT x Philippines Ordinary

WCT x WCT

D x T Hybrids

MYD x Kenya

MYD x Zanzibar

MYD x WCT

MYD x West African Tall

COD x WCT

Most drought susceptible genotypes: MOD,

MYD, GB, CODxWCT, COD

COCOA

Sixty five cocoa accessions have been screened for drought tolerance and is given in the following list. Five of them have been identified as drought tolerant based on leaf characteristics and field testing. These are NC 23, NC 29, NC 39, NC 42 and NC 31.

NC 16 (P6 x P6)

NC 20 (P4 x P1)

NC 21 (P176 x 719/5)

NC 23 (P3 x P)

NC 24 (P6 x P11A)

NC 25 (T30/10xNa32)

NC 29 (P6 x P4)

NC 30 (P3 x P4)

NC 31 (P12 x P2)

NC 32 (P9 x P4)

NC 36 (T85/5 x NA32)

NC 37 (P7 x P6)

NC 38 (P10 x P1)

Na 33

Na 242

IMC 10

IMC 67

ICS1

ICS 6

ICS 89

ICS 95

SCA 6

SCA 12

SIAL 93

EET 272

MOQ 413

Red axil

NC 39 (17/12)

NC 40 (CW5/18 (T63/884)

NC 41 (T65/7)

NC 42 (T86/2)

NC 43 (W6/56 (T63/9/10)

NC 46 (W5/1 (T63/884)

NC 48 (Unknown)

NC 51 (C44)

NC 52 (C83)

NC 53 (C76)

NC 55 (T17/11)

NC 56 (C42)

Na 31

Amel x Na 33

PA7 x Na 32

Amel x Na 32

Landas 364

PA7 x SCA 6

PA35 x NA 31

UIT x Na 33

Landas 357

Landas 361

Landas 356

Landas 365

Landas 358

Amel x PA 7

6. CHARACTERIZATION OF DROUGHT TOLERANT TYPES

A) Photosynthetic efficiency:

Further evidence on the efficiency of stomatal regulation was obtained by evaluating the net carbon assimilation rate. This was estimated by using portable photosynthesis system (Li Cor 6200, USA and LCA 4, ADC, UK) (Fig. 3). Studies revealed no significant difference in the photosynthetic rate between the drought tolerant and susceptible plants in both coconut and cocoa.

B) Chlorophyll fluorescence: Some of the light energy absorbed by chlorophyll is remitted as red and far red light and is termed as fluorescence of chlorophyll. This technique has proved to be a sensitive tool for assessing damage due to stress and has been used to screen coconut and cocoa. This was measured by using the Plant efficiency analyzer (Hansatech UK, and Morgan Co. USA). The ratio of variable to maximum fluorescence (F_v/F_m) was found to be higher in the drought tolerant than drought susceptible types in both the crops.

C) Water Use Efficiency (WUE): It is the net carbon assimilation per mm of water used. The drought tolerant types exhibited higher productivity, than the susceptible types. This shows that stomatal responses are primary events in stressed plants and once the stress is relieved, either through irrigation or rainfall, stomata

resume their original open condition immediately in the drought tolerant than in susceptible types. The following table shows the photosynthetic rate and WUE in coconut and cocoa during stress period.

Crop	P_n ($\mu\text{mol Co}_2, \text{m}^{-2}, \text{s}^{-1}$)	WUE ($\mu\text{mol.m. mol}^{-1}$)
Coconut	7.82	1.62
Cocoa	2.23	1.03

D) Harvest Index (HI): Detailed evaluation of coconut cultivars and hybrids for this parameter revealed that the tall cultivars excel in vegetative dry matter (VDM) production and the hybrids in the reproductive dry matter (RDM) production and nut yield. VDM and RDM production was obtained by the non-destructive method employing the regression equations. Partitioning of total dry matter towards the economic produce is the HI. In coconut HI gave correlation with WUE and DM production. This can be attributed to the efficient regulation of stomata in lowering the transpiration rate thus increasing the WUE. Some of the identified drought tolerant hybrids viz., LO x GB and LO x COD maintained higher WUE and HI which reflected on their yield stability during stress period.

In cocoa the annual pod yield was higher in the tolerant than the susceptible accessions. This emphasises the point that efficient stomatal regulation in the drought tolerant types during stress period will not hamper productivity.

7. SEEDLING TOLERANCE:

Further screening of selected crosses from the drought tolerant and susceptible cultivars as well as cocoa accessions, along with the parents have been initiated at the nursery, for the selection of promising drought tolerant types at the seedling stage.

The parents and the crosses are:

Coconut

Parents : Talls:- WCT, LO, AO, PO, FMS
Dwarfs:- MYD, CGD

Hybrids: T x D's:- WCT crossed with CGD*,
MYD*, COD & GB;
FMS x MYD*, LO x CGD,
AO x CGD, PO x CGD

D x T's:-

Female parents

Male parents

	WCT	PO	LO	Fiji	FMS	Java
CGD x	*	-	-	-	*	-
MYD x	*	-	-	-	*	-
COD x	-	-	-	-	-	-
GB x	-	-	-	-	*	*

Cocoa

Hybrids: II-67xNC 29/66, II-67xNC 31/108, II-67xNC 42/94,

I-21xNC 23/43, I-21xNC 29/66, I-21xNC 42/94*,

I-14xNC 29/66, I-14xNC 42/94, I-29xNC 42/94*,

I-29xNC 23/43*.

* Denotes relative tolerance to water stress.

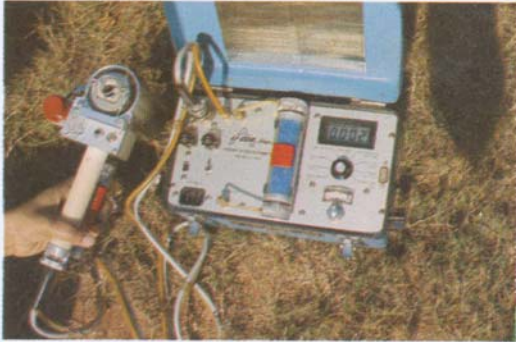


Fig. 1 : The steady state porometer used to measure weather variables, stomatal resistance and transpiration rate. Note the sensors held on the right hand side with clip for inserting the leaf. Values are displayed on the screen right upper corner of the instrument.

Fig. 2 : Scholander's pressure chamber. The method of inserting the leaflet into the holder held in left hand is shown. After insertion the holder will be fitted to the cylindrical tube. Note that the reading on the meter is still zero.

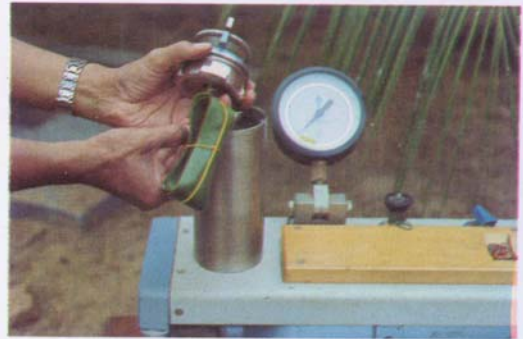


Fig. 3 : Portable photosynthesis system (LCA-4) measures both CO_2 fixation and H_2O transpired. Note the leaflet clipped to the chamber held with the right hand. The values are displayed on the screen.

