

DROUGHT MANAGEMENT IN PLANTATION CROPS

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ABSTRACT

Drought is major constraint for crop producing in plantation crops under rainfed conditions. In coconut soil water plant relationships have been worked out. In sandy loam soil, water deficit of 110 mm is the critical level at which coconut suffered most due to moisture stress. The drought tolerant characters has been identified by screening the germplasm for specific traits sensitive to stress conditions. The sensitive critical stages to drought stress has been identified in Coconut and Arecanut. The strategies for drought management like conservation of available soil moisture and efficient use of available water resources for higher productivity have been discussed in detail. Development of molecular makers for such desirable drought tolerant traits is one of the future goals, so as to transfer it into promising genotypes.

In world more than 80% of the cultivable land area is under rainfed condition (Table 1). In the rainfed areas, drought is the major constraint for the crop productivity, more so in plantation crops since they are widely grown in different soil types such as sandy, sandy loam, laterite and forest soils in the states of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh.

As these crops are mainly grown under rainfed condition, productivity is affected due to the dry summer months starting from December/January to April/May. During the period the soil water deficits coupled with the changes in atmospheric parameters aggravate the situation leading to soil as well as atmospheric drought. Increasing the crop area under irrigation has several limitations, the major one being the water resources. Being perennial in nature the water requirement of plantation crops is also fairly high. Since the water availability is becoming scarce, further increase in crop area under irrigation is difficult. The approach then has to be to use the available water source with high productivity efficiency. Thus it is important to identify the varieties which can withstand moisture stress conditions in the field, and to evolve management strategies for conserving available water sources in order to mitigate adverse effects of drought.

Agro-climatic variables

Most of the plantation crops grow well in tropical climate with abundant sunlight, well distributed rainfall, with moderate temperature. For coconut the ideal conditions will be an annual rainfall between 130 and 230 cm, mean annual temperature of 27° C and sunlight ranging from 250 to 350 wm^{-2} with annual sunshine of 2000 hrs (at least 120 hrs per month). (Child, 1974 and Murray 1977).

Among the meteorological variables rainfall is one of the important parameters which affect the production of crops. Hence conservation of available soil moisture is important for mitigating the water deficit during prolonged drought periods, at least to a certain extent. Various methods like contour bunding, trenching, pitting and construction of check-dams are used for the conservation of soil water. However for managing the atmospheric drought, crop plants which can adapt to the changing soil and atmospheric conditions and yield satisfactorily have to be recommended. Hence, before crop area expansion, a thorough knowledge of hydro-physical characteristics of soil as well as atmospheric condition of the locality is essential. As in many crops the microclimatic conditions influence the water relations of coconut

Table 1. Cultivable land in rainfed area in the World and in India

Land	World	India
Cultivable land	1474 m ha	142 m ha
Irrigated area	227 m ha	39.2 m ha
Rainfed area	1247 m ha	102.8 m ha
Irrigated area (%)	17.6%	28%
Rainfed area (%)	82.4%	72%

(Source: II International Crop Science Congress Proceedings (1998))

Table 2. Soil-plant water relationship in coconut

Irrigation levels (IIW/CPE)	Available soil water mm (0-120cm depth)	Stomatal resistance	Leaf Water Potential (Mpa)	Nut (yield) (No.)
1.00	51	3.07	-0.90	144
0.75	43.7	5.10	-1.20	125
0.50	14.2	7.60	-1.30	110
0.00	9.5	14.9	-1.45	87

(Kasturi Bai *et al* 1988). Based on irrigation levels a soil-water plant relationship in coconut has been worked out (Table 2). In sandy loam soil water deficit of 110 mm is the critical level at which coconut suffered most due to moisture stress. During extreme water scarcity palms shed most of the leaves except the spindle leaf, thus

Table 3. Agroclimatological variables during non stress and stress periods in Kasaragod range.

Variable	Non-stress	Stress
PAR($\mu\text{mol m}^{-2}\text{s}^{-1}$)	1000-1070	1350-1470
Air temperature ($^{\circ}\text{C}$)	31.4-34.1	34.7-37.3
VPP (KPa)	1.9-2.8	3.1-3.6
Pan evaporation (mm day^{-1})	3.3-3.8	5.2-5.5

Table 4. Response of coconut palms to high (North Kerala) and low (South Kerala) drought intensities

Characters	WCT		COD x WCT	
	N.Kerala	S. Kerala	N.Kerala	S. Kerala
No. of days for leaf opening	55	52	57	54
No. of days for spathe opening	72	66	55	77
Nut yield palm ⁻¹	78	96	106	116
Copra weight (g)	133	167	135	169

protecting the meristematic region. However, the severity of the morphological symptoms depend on the intensity of drought (Prasada Rao, 1985, Pomer and de Taffin 1982). As the same weather conditions do not always occur in any given location, the yield of coconut fluctuates depending on the intensity of the factor involved. Water deficit caused by the inadequate rainfall with poor distribution deserve special mention. These dry spells vary with the location and year. The influence of varying climate in South and North Kerala on coconut production emphasize this factor. The agro-climatic variables in the tropical areas varied significantly between the non-stress and stress period (Table 3).

Even the rainfall pattern in different parts of same place is found to vary significantly. For example the rainfall in Southern Kerala is evenly distributed whereas in the Northern Kerala, although annual rainfall averages 360 cm, 85% of it is received during the South-West monsoon (June to September), while 7.5% is received during the North-East monsoon, (October-November) and the remaining 8.5% is received as non-seasonal rainfall. Thus the rainless period ranges from 5 to 7 months in Northern Kerala as compared to 4 to 5 months in Southern Kerala due to early cessation of South West monsoon or failure of North-East monsoon. Coconut palms also respond differently to these changing

Table 5. Desirable traits for drought tolerance

Phenological
• Earliness, developmental plasticity
Morphological
• High root penetration
• High root: shoot ratio)
• Optimal Leaf Area Index
• High harvest index
• Leaf modifications (species specific)
• Thick leaflets
Anatomical
• Larger sub stomatal cavity
• Low stomatal frequency
• Thicker cuticle
• Large hypodermal cells
• Large parenchyma cells
Physiological
• High stomatal resistance
• High leaf water potential
• High Relative water content
• High membrane integrity
• High photosynthetic rate
• High Photosystem II efficiency
• Osmotic adjustment
Biochemical
• High wax content
• High leaf surface proline content
• Low lipid peroxidation
• High activity of superoxide dismutase,
peroxidase and catalase
• Stable RNA
• Stability of nitrate reductase activity
• Stress protein synthesis

environmental condition in terms of growth and nut production (Table 4).

Varietal differences in nut yield in response to severe stress conditions have been reported by Ramadasan *et al* (1991). Bhaskara Rao *et al* (1991) have explained the performance of same hybrids during good and drought influenced years in which some of the hybrids like LCT x COD and LCT x GBGD maintained high female flower production and high nut set than COD x WCT during drought years. The drought susceptible nature of COD x WCT and drought tolerant nature

of LCT x GBGD and LCT x COD were also reported by Rajagoapi *et al* (1990) based on water relation components and cuticular wax content.

Drought tolerant characters

Drought tolerant types can be identified by screening the germplasm for specific traits sensitive to stress conditions. Investigations have been carried out on physiological and biochemical mechanism of drought tolerance in plantation crops and identified the varieties with drought tolerant characteristics. Some of the desirable traits identified are large paranchyma cells, high stomatal resistance, high leaf water potential, low transpiration rate, high epicuticular wax content and higher activities of the stress sensitive scavenging enzymes. The exploitation of the identified varieties, with not only drought tolerance but also with the potential for high yield under limited water availability, in the breeding strategies would be an important step for the overall improvement of crop productivity in drought prone areas.. Mechanisms and strategies to be adopted in selection and breeding programmes depend not only on their effect on traits related to the productivity, but also on the type of drought likely to be encountered by the crop. Plants adapt to stress condition by the intervention of several inductive phenological, morphological, anatomical, physiological, and biochemical mechanisms. Some of the desirable traits for drought tolerance are listed in (Table 5).

Naresh Kumar *et al* (2000) have studied the leaflet anatomical adaptation to drought tolerance in coconut and the relation between the anatomical features and physiological parameters.(Table 6). The study indicated marked influence of leaflet anatomy on photosynthesis and transpiration. It is suggested that a leaf anatomy which favours high photosynthetic rates also favour high transpirational rates thus the drought susceptible types had higher photosynthetic rates associated with high transpirational rates compared to the tolerant ones. The reason for such trends can be explained on the basis of leaflet anatomy. Based on the physiological and environmental variables a drought index has been worked out in coconut (Table 6).

Table 6. Correlations between leaflet stress studied, anatomical features and physiological parameters in coconut.

Parameters		R value
Leaflet thickness	Palisade cell size	0.73
Spongy cell size	0.82	
Stomatal frequency	-0.67	
Photosynthetic rate (Pn)	-0.41	
Transpiration rate	-0.12	
Cuticle thickness Adaxial	Cuticular wax (ECW)	0.86
Transpiration rate	-0.69	
Pn	0.13	
Leaf Water Potential	0.64	
Abaxial	ECW	0.72
Transpiration rate	-0.79	
Pn	0.13	
Leaf water potential	0.50	
Sub-stomatal cavity (size)	Stomatal frequency	-0.54
ECW	0.61	
Transpiration rate	-0.15	
Photosynthetic rate	-0.11	
Palisade cell size	Pn	-0.77
Transpiration rate	-0.38	
Leaf water potential	0.11	
Spongy cell size	Pn	-0.67
Transpiration rate	-0.05	
Leaf water potential	0.10	

Source: Naresh Kumar *et al* 2000**Sensitive critical stages to drought stress**

Being perennial in nature production and productivity of plantation crops are considerably influenced by agro-meteorological variables. The sensitive critical stages which affect the yield in many crops are seedling establishment, inflorescence initiation, flowering, fruit set and fruit development stages. In addition to these in coconut and arecanut spikelet initiation and female flower primordia formation are also found to be stress sensitive stages where as in black pepper it is the spiking stage. Sucker and panicle initiation stages are sensitive in cardamom and in tea it is the vegetative growth, which is sensitive to moisture stress. Depending on the severity of the stress yield will be affected. Rajagopal *et al.* (1996) have explained the impact of drought on inflorescence and nut development in coconut by integrating the overall occurrence

of dry spell during the ontogeny of inflorescence and nuts.

Drought tolerant types

By employing screening techniques for desirable traits for drought tolerance, varieties have been selected and released for planting in drought prone areas. Using tolerant parents, hybrids have also been evolved. The important drought tolerant varieties/hybrids are:

Coconut - WCT, LCT, FMS, WCT x COD, LCTxGBGD, LCTxCOD

Cocoa - NC23, NC29, NC 31, NC 39

Cashew - BPT1, BPT2, H-2/16, H-1608

Black pepper - Arakalamunda, Kalluvally

Cardamom - Malabar

Tea - UPASI-1, 2, 20, 26, 27

Coffee - Sanramon hybrid

Rubber - GI 1, GT1, RRIM 600, RRII 18, RRII 105

Drought management

Drought occurs once in three to four years with different intensities in major plantation areas. Depending on the length of dry spell and its coincidence with the critical stages of crop growth the yield will be affected. In order to have sustained yields it is important to have strategies to manage drought, which includes the soil, as well as atmospheric droughts.

Drought management strategies mainly include the conservation of available soil moisture and efficient use of available water resources for high production. As the plantation crops are grown under different soil types having variation in hydrophysical characteristics different methods have to be adopted to conserve soil moisture. The following agronomic practices can be used for soil management for conservation of water during drought periods such as adoption of organic farming technologies and tillage practices like summer ploughing, soil mulching and addition of soil stabilizers.

a) Soil management in coconut include

- i) Mulching with coir dust, 50 kg/palm,
- ii) Burial of husks in 3 or 4 layers,
- iii) Application of green manures and organic manures (FYM) - 50 to 100 kg/palm,
- iv) Spreading dried coconut leaves and other organic residues (mulching effect),
- v) Addition of tank silt at 100 to 200 kg/palm (improves organic matter, water holding capacity),
- vi) Spreading of 2 kg NaCl around the palm basin.

b) Water management

- i) Bury 2 or 3 earthen pots/hollow bamboos and fill with water (sub-soil moistening),
- ii) Drip irrigation: 3 or 4 drippers may be placed per palm, (drippers to wet sub-soil layer),
- iii) If adequate water is available, irrigate with 200 lit. water/palm once in 4 days and mulch with dry leaves,

- iv) Avoid flooding the basins. If water resources are good, save for facing prolonged drought,
- v) Effective recycling of used water from backyards.

At large scale, some of the following are desirable to follow to conserve soil and water.

- i) In slopy lands, terracing the palm basins may be undertaken (intercepts run off water and enhance soil moisture),
- ii) Water harvesting devices in mildly sloped area to enable water to collect in between row,
- iii) Prepare bunds dividing the field into plots to prevent run off of water.

These measures would help to increase the ground water table and the increase the soil water availability.

Crop management also offers scope to reduce drought impact on crop mainly by the removal of senescent leaves to reduce transpiration loss. If late rains occur, pulses or fodder crops can be sown in between coconut rows. After harvest, these plant residues can be used as mulches. So also green manure crops can be raised in the plantations. Application of higher doses of fertilizers (eg. for each coconut palm 1 kg urea, 2 kg Super phosphate, 1.2 kg muriate of potash, 0.5 kg $MgSO_4$, 50 kg green leaf or FYM) will also help in alleviating the impact of water stress on production, by increasing the soil water holding capacity.

The above practices which lead to soil-water-plant management can be synerzised by planting suitable varieties/cultivars which can adapt to the changing environmental conditions. The nature of generation governing drought sensitive traits can be exploited by selecting proper breeding strategies.

Future thrust

- * Development of molecular markers for traits responsible for drought tolerance.
- * Development of marker assisted rapid screening methods.

Drought management in plantation crops

- * Understanding the stability of drought tolerance in plantation crops.
- * Evolving hybrids or clones with high stable yields coupled with high quality under rainfed conditions through innovative techniques.
- * Identification and conservation (*insitu* or on farm) of field tolerant high yielding plants for further use in crop improvement programmes.

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