

Drought: Effects, mechanisms and mitigation strategies in coconut

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Abstract

Coconut (*Cocos nucifera* L.) is an important palm that plays a significant economic role in most of the South Asian countries including India. It is mostly grown in coastal areas and hilly terrain which is highly vulnerable to climate change. The coconut palm generally grows well in areas receiving an annual rainfall of 1300 to 2500 mm or more. A prolonged dry season lasting for up to four months may adversely affect the palms. This constraint occurs recently in various coconut growing countries. This erratic behaviour of monsoon has made the sustainability of coconut production dangerous. The drought stress not only causes decline in productivity and also could be the reason for mortality of palms in extreme cases. Drought management practices such as cultivation of drought tolerant genotypes, soil moisture conservation measures and crop management measures have to be adopted efficiently in order to have better social, economic and environmental sustainability under the pressure of climate change.

Introduction

Global food security is being vulnerable on account of the rapid increase in population and drastic changes in the climate. Drought is one of the most important limiting factors for crop productivity and ultimately the food security in the wake of changing climate. The reduced precipitation and changed rainfall patterns are causing the frequent onset of droughts around the world. Severe droughts cause considerable decline in crop yields through negative impacts on plant growth, physiology and reproduction. Average global combined temperature of land and ocean surface has increased by 0.85°C between 1880 and 2012 (IPCC, 2014). An average increase of at least 0.2°C per decade is projected from now onwards. The rising concentration of the greenhouse gasses is becoming a major cause of the global warming. Over the past 250 years a 30 and 150% rise in the concentration of the CO₂ and methane has been observed (Lal, 2004; Friedlingstein *et al.*, 2010). These stresses limit the plant growth and productivity rather than any other environmental factor.

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Plants are subjected to the drought conditions when either the water supply to the root is limited or the loss of water through transpiration is very high (Anjum *et al.*, 2011). The severity of the damage caused by the drought is generally unpredictable as it is driven by various factors including, the rainfall patterns, moisture holding capacity of the soil, and water loss through evapotranspiration. Drought interferes with growth, nutrient and water relations, photosynthesis, assimilate partitioning and ultimately causes a significant reduction in crop yields (Farooq *et al.*, 2009b; Praba *et al.*, 2009). The plant response to drought stress generally varies from species to species depending on plant growth stage and other environmental factors.

Coconut, *Cocos nucifera* Linnaeus, (family Arecaceae) is a pantropical plant. The coconut plantations are usually located in the lowlands just above sea level. The trees are tall, reaching up to 30 m in height, with a slender trunk. As every part of the coconut palm is of some use, the coconut palm has been described as 'one of Nature's greatest gifts to man' (Burkill, 1966). The weather conditions for optimum growth and development of coconut are well distributed rainfall of 130 and 230 cm, mean annual temperature of 27°C, abundant sunlight ranging from 250 to 350 Wm⁻² with at least 120 hours per month of sun shine period. The coconut palm experiences moisture stress when exposed to irradiation above 265 Wm⁻², temperature of 33°C and vapour pressure deficit of 26 m bar.

Coconut is mainly grown as a rainfed crop and the productivity is 50% more when cultivated under well irrigated areas. Coconut is a perennial crop with long duration of inflorescence primordia initiation to nut maturity (about 44 months duration). Pre fertilization period is about 32 months and post fertilization period are around 12 months. Hence drought occurred in any of these critical stages of the inflorescence development stages affects the nut yield. The effects of drought could be observed in next three years. In worst affected situations, it takes four years to recover. Drought at early stages affects the growth and lead to seedling mortality. Depending on the soil type and the critical level of soil moisture, the water stress on coconut varies. In sandy loam soil water deficit of 110 mm is a critical level at which coconut suffer most as indicated by the stomatal closure. In general, palms suffered more in red sandy loam than in laterite soil as indicated

by the stomatal resistance and leaf water potential components.

The recurrent droughts in the main coconut growing areas, experienced in recent decades, have led to heavy yield losses and sometimes in severely affected areas, the death of adult coconut palms.

Effect of drought on coconut palm

Drought stress in plants is characterized by reduced leaf water potential and turgor pressure, stomatal closure, decreased cell growth and enlargement (Farooq *et al.*, 2009). Drought stress reduces the plant growth by influencing various physiological as well as biochemical functions such as photosynthesis, chlorophyll synthesis, nutrient metabolism, iron uptake and translocation, respiration and carbohydrates metabolism (Jaleel *et al.*, 2008 and Farooq *et al.*, 2009)

Drought slows down the activity of the growing point of stem. Leaf production is reduced and causes early aging and collapse. Palms without a minimum of about twenty leaves lack the vitality to produce nuts. Droughts arrest spikelet formation in the inflorescence bud, resulting in loss of female flowers. Heavy button shedding and immature nut fall is observed. Weight of fruit, husk and endosperm is reduced. When soils dry up for prolonged periods, outer cells in the absorbing region of roots develop thickened walls through which water cannot enter.

The typical symptoms of drought affected coconut palm is bending and breaking of dry leaves, poor spathe development and bunches with one or two nuts. Activity of roots and transpirational rates also show marked variations.

Drought Mechanisms in coconut palm

The tolerant palms extract more soil moisture from the entire soil profile but they conserve water in the tissues by reducing the transpiration rate through effective control of stomata. The root: shoot ratio in seedlings was higher in tolerant cultivars than in susceptible ones.

The increase in leaflet thickness is one of the mechanisms and it is mainly due to increase in parenchyma cell size. It is also associated with lowered stomatal frequency, an indication of adaptation to drought stress. Xeromorphic characteristics such as increased leaf thickness and thick cuticle are observed in some coconut varieties. Increase in thickness of leaflet causes decrease in the ratio of the external surface to its volume. Increased

parenchyma cell size indicates less intercellular space/unit area. This may help in reducing the water conductance towards epidermis thus reducing the transpirational rates and maintaining high water potentials. Stomatal frequency and stomatal index play a major role in plant water relations. Variations was observed among tall, dwarfs and hybrids with regard to stomatal characteristics. The tolerant palms have thick leaflet, thick cuticle on both sides, larger parenchyma, hypodermal and water cells compared to less tolerant ones. Coconut cultivar having thick cuticle are able to maintain higher leaf water potentials. Drought tolerant types also have more scalariform thickening on xylem tracheids in vascular bundles and large sub-stomatal cavities. Size of the epidermal cell (upper and lower) and guard cell are related to the drought tolerance characteristic of a cultivar. Hence collective effect of all these traits contributes for adaptation to drought stress.

Coconut palm responds to drought stress in terms of stomatal regulation and epicuticular wax content to maintain leaf water potentials. The leaf to air temperature difference influence the stomatal conductance and water relations during day time and thereby predominantly determine the variations in photosynthetic efficiency of coconut in irrigated and rainfed conditions. About 3-4 fold increase in epicuticular wax (ECW) during dry season was observed in some coconut hybrids. The physiological age of palms and leaves influence the formation of wax on leaf surface. Coconut palms accumulate organic solutes such as sugars and amino acids during stress period. Accumulation of these solutes was found to be more in the tolerant types than in the susceptible types during stress period. Hence osmotic adjustment plays an important role in the drought tolerance mechanism in coconut. Under drought stress conditions, where high evaporative demand in the atmosphere prevails, genotypes exhibit differential adaptability through stomatal regulation. In general, dwarf coconut types exhibit higher transpiration loss of water than tall and hybrids. Upregulation of scavenging enzymes to maintain cell membrane integrity is another important mechanism thereby enabling cells to tolerate stress. Drought stress was found to increase the activities of some of the stress sensitive enzymes namely peroxidase, polyphenol oxidase, superoxide dismutase, acid phosphatase and L-aspartate: 2- oxoglutarate amino transferase in adult stress tolerant coconut palms while activities of Malic dehydrogenase (MDH) and nitrate reductase (NR) were found to be decreasing.

Drought tolerant coconut varieties are capable with a biochemical mechanism to prevent the adverse effects of drought by appropriate regulation of enzyme activities. Drought tolerant cultivar had higher stability of membranes. Stress tolerant coconut cultivars characterized by higher activities of the protective enzymes like SOD, catalase and peroxidase and lower level of lipid peroxidation and higher membrane integrity.

Cell size and number, sub-stomatal cavity size, stomatal frequency, epicuticular wax content and thickness, leaf thickness, stomatal resistance, water potential components, cell membrane stability, water use efficiency and activity levels of scavenging enzymes are the essential anatomical and physiological traits for assessing moisture stress in palms.

Mitigation strategies

Recovery after a severe drought is a slow process. In coconut palms, normal root absorption does not commence with the onset of first rains. Initially, growing points of roots have to be reactivated. This is followed by root elongation and formation of a new absorbing region. With the resumption of water supply, shoot activity begins and new leaves and inflorescences are formed. In extreme cases up to about two years may be necessary for a full recovery after a prolonged drought.

The development of drought tolerant coconut varieties has been recognized in the mid-1990s as an important and urgent area of research. With worsening climatic conditions, the need for drought tolerant varieties has become critical. Several attempts were taken to develop drought tolerant coconut cultivars through inter and intra varietal hybridization worldwide. New drought tolerant hybrid coconut varieties showing stable and higher yield under changing climatic condition and that could be produced by crossing selected drought tolerant tall parent with dwarf parents need to be developed. However, improvement of quantitative traits such as drought tolerance or yield in a cross-pollinated crop cannot be achieved through simple selection. To gather favorable alleles responsible for those quantitative traits, genotypic recurrent selection techniques that combine several generations of selections followed by recombination are required. *Rajagopal et al. (1990)* standardised the techniques on screening coconut varieties for drought tolerance using epicuticular wax, stomatal frequency and leaf water potential. The West Coast Tall (WCT) and

Federated Malaya States (FMS), which are tolerant to water stress, had thick leaflets, thick cuticle on both surfaces and larger parenchyma, hypodermal and water cells compared to less-tolerant ones (COD × WCT, GBGD and MYD). Tall palms and tall hybrids showed relatively high stomatal resistance resulting in effective conservation of water in the tissues, whereas the dwarfs were sensitive to stress with a tendency to lose more water. Few genotypes tolerant to drought were reported viz., West Coast Tall (WCT) × WCT, Federated Malay States (FMS) and Java Giant. Apart from WCT and FMS, PHOT, WCT×COD, LCT, LCT×GBGD and LCT×COD also reported as drought tolerant genotypes/hybrids (Rajagopal et al., 2000).

Soil moisture conservation measures like mulching around palms by spreading vegetable material, e.g. coconut fronds, husks, lopping of trees and shrubs can be undertaken. Mulching should be carried out regularly so that soil is not exposed. It protects soil from direct solar radiation and wind effects reduce water loss and controls weed growth. Burying husks in trenches in the proximity of palms would be of help. Husks can absorb and retain water about six times its weight. Increase infiltration of water into the soil by terracing, contour drains and/or contour bunds. Build bunds across folds on the ground of undulating land to form mini tanks. They retain water flowing from, the higher land which can be used for at least a part of the dry season. This technique could be used on more clayey and lateric soils. Irrigation of seedlings during dry seasons results in rapid establishment and vigorous growth. Mulching with green leaf manures like Glyricidia or with other suitable green manure crops and organic manure crops should be followed either alone or in combination.

Crop management measures include removal of senescent (drying) leaves to reduce transpiration loss and planting drought tolerant cultivars/hybrids can be done. Water management includes drip irrigation, mulching the irrigated area, avoiding flooding, recycling of water from backyard and application of lifesaving irrigation once in 15 days may reduce the impact of drought.

Conclusion

Drought is a multidimensional factor of stress affecting the plants at various levels from cell to organ and to whole plant. Drought induces various biochemical and physiological responses in plants, and it is one of the most adverse environmental factors of plant growth and production.

Coconut palm is influenced both by atmospheric and soil droughts, as the palms are mainly cultivated on the coastal sandy, red sandy loam and laterite soils. As coconut is perennial in nature, the impact of drought stress will be having long-standing ill effects, consequently, which may adversely affect the economy of coconut sector. Hence research on identification of drought stress tolerant, high yielding coconut genotypes and adoption of other mitigation measures for soil moisture conservation have to be further strengthened. These strategies should be effectively transferred to the farmers to minimize socio-economic losses of the coconut sector.

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