

Strategies for evolving drought tolerance in palms

V.Rajagopal, K. V. Kasturi Bai and S. Naresh Kumar

Central Plantation Crops Research Institute, Kasaragod 671 124.

Introduction

The perennial plantation crops, both coconut and oil palm are of considerable economic importance in the world trade of edible oils. In the requirement of soil and climatic factors for optimum growth and productivity these two crops are more or less similar. Both grow well in the humid tropical countries and exhibit wide variability in growth and productivity. The expression of production potential in crop plants depends on its genetic make up and environmental factors. Among the constraints for production, drought ranks the first as most of the cultivable areas are under water-limited conditions. In the World more than 80% land area is under un-irrigated condition or limited water availability conditions. More so increasing the crop area under irrigation has several limitations. Hence there is a need to identify the varieties, which can withstand the moisture stress as well as the vagaries of natural conditions. Crop plants withstand the stress condition by the adaptation of several inductive morphological, anatomical, physiological and biochemical levels;

Water stress induced morphological changes:

Extension growth is generally more sensitive process than assimilation during the water stress. When exposed to severe moisture stress palms exhibit adverse effects such as dry and broken leaves, poor spathe development and empty bunches caused by heavy shedding of developing fruits. And

during extreme weather conditions palms shed most of the leaves except the spindle leaf thus protecting the sensitive meristematic region. Similarly in oil palm drought causes a longer immature period in other words delay in bearing period, a substantial reduction in annual productivity apart from, vegetative damage and in extreme cases palm death are noticed. As in coconut in the axil of each leaf, oil palm have a male or female inflorescence. Neither leaf nor the inflorescence productions are influenced by the climatic changes. However an increase in the sex ratio with an increase in the male inflorescence and a abortion in the female inflorescence following water deficit periods are noticed. Peak water requirement corresponds to inflorescence development thus making it critical stage.

Traits associated with drought resistance

Number of physiological characters is identified to assess the level of crops and varieties for drought tolerance. Since the emphasis is on the capacity of varieties to maintain water balance in the tissues even under field stress situations, the regulation of water loss by the stomata is an important character that has received maximum attention in different crops. The microclimate plays an important role in water relation and production in crop plants. The water balance in the palm depends on the rate of transpiration loss due to evaporative demand in the atmosphere on one hand and water mining capacity of root system on the other.

Stomatal regulation

The stomatal frequency and stomatal behaviour play a major role in water conservation in many plant species. Among the plantation crops, coconut exhibited variations in the stomatal frequency among the tall, dwarfs and hybrids differing in drought tolerance. Selection for stomatal characters potentially provides great scope for improvement in drought resistance. Crop plants exhibit a range of sensitivity of stomata to stress conditions. When exposed to stress conditions caused by high evaporative demand in the atmosphere, the varieties in a crop exhibit differential adaptability in stomatal regulation. Under these conditions, the selection of varieties with high stomatal resistance (low conductance) assumes importance as it reveals degree of tolerance. In terms of water loss from leaf tissues, it means the varieties with low transpiration rate are tolerant to moisture stress conditions. The efficacy of the oil palm's stomatal apparatus enables it to maintain tissue moisture for relatively long periods. It has been observed that the susceptible crosses seem to keep their stomata open longer during drought periods. However, in the event of very severe moisture stress coupled with an increase in the atmospheric stress a rapid reduction in stomatal conductance leading to vegetative damage in addition to yield losses have been observed.

Leaf water potential(LWP)

The LWP in a plant is controlled by the availability of water from the soil, the demand for water imposed by the atmosphere and resistance to water movement within the plant. Under conditions of soil water deficit, the LWP show decrease depending on the degree of

stress. The plants under normal water supply maintain high LWP, whereas with the development of moisture stress in the field, the LWP show gradual reduction. Thus the ability of a plant to maintain a positive or even constant turgor potential as water potentials decrease is an important adaptation to drought. Under field conditions, the varieties show variations in LWP and those varieties, which record higher LWP under stress are considered as drought tolerant. In oil palm susceptible types recorded considerable reduction in leaf water content during dry period.

Epicuticular wax content(ECW)

The soluble cuticular lipids present on the surface of various plant organs impart resistance to water loss (transpiration rate). It is well established that when prolonged water deficits prevail, there is an increase in the epidermal waxes of leaves, which decreases cuticular transpiration. Genotypic differences in ECW were also reported in various crops. Thus, the estimation of ECW could be a useful method to screen the varieties for drought tolerance.

Root characteristics

In tree crops, it is difficult to undertake work on root growth and other parameters. However, the indirect method of studying the root activity is to determine the soil moisture content at different depths over a period of time. In coconut, the soil water deficit (SWD), expressed as the difference between the pre-stress and stress periods showed marked variations among the tolerant and susceptible genotypes. These indirectly reflect on the root development in terms of total mass and activity. Good root development favours drought resistance in oil palm by extracting more water

during stress situations. However an inverse relation has been observed between root development and yield. Selection of high root: shoot ratio at seedling stage may be useful in the selection of drought tolerant types in perennials.

Photosynthesis and water use efficiency

From the foregoing account of drought tolerant mechanisms, it is evident that stomatal control of transpiration is an important criteria for crop varieties to withstand moisture stress. Since stomatal pore also regulates the gaseous exchange, it is imperative to examine the influence of stress on photosynthesis. It appears that the drought tolerance to a great extent relates to stomatal diffusive resistance with high WUE or positive carbon balance and the extent to which the photosynthetic recovery takes place on rewatering.

Biochemical markers

The metabolic and biochemical adaptations to drought are understood to limited extent in plantation crops. Biochemical characterization is an important step in identifying the specific markers for drought tolerance. Besides the metabolism involving osmotic adjustments, the routinely studied biochemical aspects are the activities of enzymes like nitrate reductase, acid phosphatase, superoxide dismutase, peroxidase, catalase etc. in some of the plantation crops under stress conditions. In oil palm the mobilization of metabolites were rapid in tolerant than susceptible crosses.

Cell membrane stability

At the cellular level, the impact of stress is generally seen on the integrity of membranes and extent of solute leakage, which is regulated by the cell membrane stability. Normal cell functions are affected due to changes in

peroxidation of cell wall lipids during stress resulting in increased cell membrane permeability and solute leakage. In coconut susceptible varieties exhibited higher peroxidation of cell wall lipids coupled with lower activities of the stress sensitive scavenging enzymes like superoxide dismutase, peroxidase, catalase etc. In oil palm also a correlation between membrane sensitivity and the proportion of polyunsaturated fatty acids in total lipid has been observed.

Osmotic adjustment

In coconut accumulation of osmoticum like sugars, amino acids, proline etc are observed under severe stress conditions. This implies that osmotic adjustment plays an important role in drought tolerance in perennial crops also.

Anatomical features

The leaf anatomical features like leaf thickness, cuticle thickness, sunken stomata, epidermal cell size and parenchyma cell size are reported to paly important role in imparting tolerance to stress conditions as reported in coconut and other crops.

Screening for drought resistance/tolerance

From the foregoing account, it is evident that a set of desirable traits exists in crop varieties, which impart resistance/tolerance to moisture stress conditions. Thick leaves, thick cuticle, sunken stomata, parenchyma cell size and number, stomatal frequency, stomatal resistance, epicuticular wax content and water potential components are the essential anatomical and physiological indicators for assessing drought tolerance in palms. Similarly the metabolism of organic food products, peroxidation of cell wall lipids coupled with the activities of the enzymes are the biochemical traits.

Breeding for drought resistance/tolerance

The crop improvement programmes in areas with limited water supply or high frequency of soil water deficits should aim at identifying the varieties, which can withstand the adverse condition of soil and atmospheric droughts. The availability of a range of sensitive physiological and biochemical parameters were successfully employed as screening methods for drought tolerance in palms. The fact that varieties could be clearly identified for drought tolerance with desirable traits is a positive step towards selection for breeding strategies. Recovery potential of the cultivar after relief from stress also form a major factor for the selection of drought tolerant types under field conditions. The mechanism and strategies to be adopted in breeding and selection programmes will depend not only on their effect on productivity, but also on the type of drought likely to be encountered. In this connection the first step was to make crosses between identified drought tolerant / high yielding palms. Further, screening of selected crosses from the drought tolerant and susceptible cultivars along with the parents at the nursery based on the above physiological and biochemical traits will assist in the selection of promising drought tolerant types at the seedling stage.

Conclusions

In plantation crops, the scope for improvement under drought condition exists through the availability of relatively high tolerant varieties. The anatomical, physiological and biochemical basis of such tolerance mechanisms has been well established in coconut. The exploitation of the already identified varieties for drought tolerance involves meticulous planning of breeding strategies. The work on developing cross

combinations involving parents with not only drought tolerance but also the potential for high yield under limited water availability would be an important step for the overall improvement of crops under drought. The possibility for *in situ* conservation of drought tolerant types in farmers gardens also will help in conserving natural variability in the traits for drought tolerance which can be used for further breeding programmes.

Future thrust

1. Biotechnological approaches to stress tolerance. Identification of QTLs for tolerant traits in the varieties and genetic engineering for drought tolerance and high yield potential.
2. Evaluation of promising genotypes under water limited conditions for high WUE and yield.
3. *In situ* conservation of palms showing drought tolerant characteristics in farmers gardens
4. Production of seed material of identified genotypes for overall improvement under stress conditions.
5. Evolve management strategies for conserving available water sources to mitigate drought impact

Some selected references

- Chempakam, B., Kasturi Bai, K.V., and Rājagopal, V. 1993. Lipid peroxidation and associated enzyme activities in relation to screening for drought tolerance in coconut (*Cocos nucifera*, L.). *Plant Physiol. and Biochem.* **V. 20** : 5-10.
- Cornaire, B., Daniel, C., Zuily-Fodil, Y and Lamade, E. 1994. Oil palm performance under water stress. Background to the

NATIONAL SEMINAR ON RESEARCH & DEVELOPMENT OF OIL PALM IN INDIA-2005

problem, first results and research approaches. *Oleagineux*. 49(1): 1-12.

- Corley, R.H.V. 1983. Potential productivity of tropical perennial crops. *Exptl. Agril.* 19: 217-137.
- Dufrene, E. and B. Saugier. 1993. Gas exchange of oil palm in relation to light, vapour pressure deficit, temperature and leaf age. *Oleagineux* 48: 347-356.
- Foale, M.A. 1993. Physiological basis for yield in coconut. In *Advances in Coconut Research and Development* Eds. M.K. Nair, H.H. Khan, P. Gopalasundaram and E.V.V.B. Rao. Oxford and IBH Co. Pvt. Ltd. New Delhi. pp. 181-189.
- Kasturi Bai, K.V., Voleti, S.R., and Rajagopal, V. 1988. Water relations of coconut palms as influenced by environmental variables. *Agric. Forest. Meteorol.* V. 43: 193-199.
- Kasturi Bai, K.V., Rajagopal, V. 2000. Osmotic adjustment as a mechanism for drought tolerance in coconut (*Cocos nucifera* L). *Indian J. Plant Physiol* V . : 320-323.
- Naresh Kumar, S., Rajagopal, V. and Anitha Karun. 2000. Leaf let anatomical adaptations in coconut cultivars for drought tolerance. In *advances in Plantation Crops Research* (eds. N. Muralidharn and R. Raj Kumar). *Proceedings of Placrosym XIII*. Pp. 225-229.
- Naresh Kumar, S. Rajagopal, v., Situ, T. Thomas., Vinu, K. Cherman., Hanuman thappa, M., Anil Kumar., Srinivasulu, B and Nagvekar, D. ,2002. Identification and characterization of *in situ* drought tolerant palms in farmers fields in different agroclimatic zones. In *Proceedings of Placrosym XV*. (eds. K. Sreedharan., P. K. Vinod Kumar., Jayarama and Basavaraj M. Chulaki) 10-13, December 2002, Mysore. Pp. 335-339.
- Passioura, J.B. 1996. Drought and drought tolerance. *Plant Growth Regn.* 20:79-83.
- Phamthi, A.T., Vieira da Silva, J. and Mazliak, P. 1990. The role of membrane lipids in plant resistances to water stress. *Bulletin de la societe de Botanique Francaise*. 137: 99-114
- Rajagopal, V., Kasturi Bai, K.V. and Voleti, S.R. 1990. Screening of coconut genotypes for drought tolerance. *Oleagineux* V. 45 (5): 215-223.
- Rajagopal, V., Shivashankar, S. and Jacob Mathew. 1996. Impact of dry spells on the ontogeny of coconut fruits and its relation to yield. *Plantation research and development*. 3 (4):251-255
- Rajagopal, V., and Kasturi Bai, K.V. 2002. Drought tolerance mechanism in coconut. *Burotrop Bulletin* . V. 17. pp. 21-22.
- Repellin, A., C. Daniel, and Y. Zuily Fodil. 1994. Merits of physiological tests for characterizing the performance of different coconut varieties subjected to drought. *Oleagineux* 49: 155-167.