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Cassava and Abiotic Stresses

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Root and tuber crops, though often undervalued, are crucial sources of energy and nutrients, playing a vital role in nourishing populations across the globe. Cassava or tapioca (*Manihot esculenta* Crantz.) is one of the staple tuber crops across the tropical regions of the globe starting from South America to Southeast Asia through, Africa and India. Cassava is a new world crop whose origin is widely unknown. It is said to have originated in Brazil. Cassava is mainly grown for its starchy tubers of edible and commercial value. It produces more calories per unit area per unit time than any other crop. It is an important source of starch and a component of animal, fish and poultry feed. Moreover, it is also used in various industries including starch and starch-derived products such as sago, textile, alcohol and high fructose-glucose syrups. In cassava tubers, starch is present in pure form, free from proteins and lipids. Cassava starch is also being used in the manufacture of biodegradable plastic and processed products like baby food, vermicelli, chips and papads. Cassava is largely cultivated for human consumption in Kerala and for starch in Tamil Nadu. Besides, it is also grown in Andhra-Pradesh, Assam, Karnataka, Madhya-Pradesh, Pondicherry, Nagaland, Tripura, Mizoram and the Andaman-Nicobar islands.

Abiotic stresses

Under changing climatic conditions, abiotic stresses such as drought, floods, and salinity are becoming more common, significantly impacting the growth and yield of all crops. Cassava is no exception to this. It grows on marginal and eroded soil with minimal inputs, but the yields are significantly low under such conditions.

Drought

It is considered drought tolerant because of its survival instincts under moisture stress condition-ns. This drought tolerance of cassava is related to its ability to survive, often at the expense of tuber yield. Moisture stress in the soil, in the initial 3-4 months after planting, leads to the death of the plants. Hence, the critical period of irrigation is up to 4 months after planting and irrigation during this period is compulsory for proper establishment of the crop. A study on the sprouting of stem cuttings under moisture stress conditions found that the majority of cassava genotypes failed to sprout when irrigated only once every five days for the first three weeks after planting. Sprouting under moisture-stress conditions is also subjected to the viability and latex content of the stem.

Sparse sprouting in the field after 3 weeks of moisture stress

Leaf shedding is the most common resilience mechanism of cassava under drought conditions. This can be observed during mid-period moisture stress. Drooping of leaves in the upper portion of the stem is the first symptom associated with moisture stress in cassava. Leaf rolling and reduction in the size of the leaves are also observed.

Drooping of leaves under moisture stress conditions

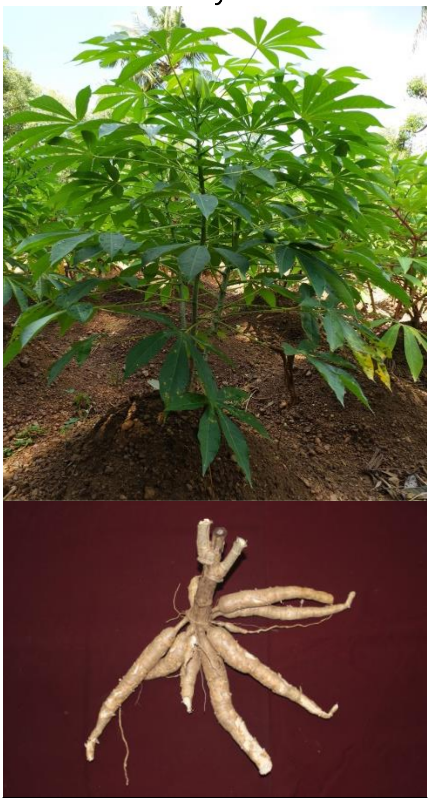
Proline is the amino acid that accumulates in the guard cells and induces stomata closure thereby preventing transpiration. ABA is the plant growth regulator responsible for the formation of an abscission layer between the petiole and stem. Leaves fall at this point, leaving leaf scars on the stem. Cassava is an efficient water saver under stress conditions. All these mechanisms work to minimize water loss through transpiration. Complete leaf fall is observed in some accessions of cassava under mid-period drought stress conditions. Stomata closure and a subsequent decrease in leaf area lead to reduced net photosynthesis and the translocation of nutrients from the leaves to the storage roots. This ultimately results in decreased yields under moisture-stress conditions. It also reduces the starch quality and the roots become fibrous making them unfit for consumption.

Leaf shedding under mid-period drought stress condition

High sprouting in H-226 under moisture stress conditions

Cassava is a long-duration crop which usually takes 10 months to harvest. In Kerala, cassava is grown as a rainfed crop. Cassava faces severe drought from December to March after the cessation of the monsoons. In this context, there is a growing emphasis on breeding short-duration and early varieties as a strategy to mitigate the impact of mid and late-period drought stress. *Sree Jaya* and *Sree Vijaya* are the two early maturing clones that were selected and released for cultivation by ICAR-CTCRI. These varieties come to harvest within a period of six to seven months thereby escaping the mid or late-period drought stress. However, these two varieties are highly susceptible to cassava mosaic disease.

H-226 is one of the most promising drought-tolerant cultivars of cassava selected from the cross between a local cultivar, Ethakkakaruppan and a Malaysian introduction M-4. It has a very high sprouting percentage (94.44%) under moisture stress conditions compared with other cultivars. It has high starch content and is a popular cultivar among the industrial areas of Tamil Nadu. However, it is not suitable for human consumption. *Sree Sahya* is another drought-tolerant cultivar released by ICAR-CTCRI. It is a multiple cross hybrid involving three parents namely a Madagascar introduction-Ac. No. 468, Ac. No. 82 and M-4 and is suitable for rainfed and hilly areas. Recently, a high-yielding mid-period drought-tolerant variety *Sree Kaveri* with cassava mosaic disease resistance has been released by ICAR-CTCRI.



Sree Kaveri plant (top) and tubers after 75 days of drought stress (bottom)

Waterlogging

Root rot is a common issue in cassava under waterlogged conditions or flooding. Given that cassava is predominantly cultivated in regions with dry climates worldwide, flooding has not historically been a significant concern for cassava production though, it might pose a challenge in Southeast Asian countries such as the Philippines and Indonesia, where natural disasters like floods and tsunamis occur frequently. Unfortunately, during the recent floods in Kerala, hundreds of hectares of cassava crops were lost due to waterlogging persisting for more than 10 days. Root respiration is the first physiological event to be inhibited under waterlogging conditions.

Cassava crop after receding of the flood (top) and rotten tuber (bottom) in the Panamaram block of Wayanad district of Kerala

The stagnation of water in the field deprives the roots of oxygen and creates asphyxia. Under anaerobic conditions, the roots begin to decompose, ultimately leading to the rotting of the roots/tubers. It begins from the tip of the roots and proceeds upward. Once the roots are dead, the absorption of water and nutrient from the soil stands hindered and leads to the death of the plant. After the flood water recedes, saprophytic fungi begin to feed on the dead root tissues. If waterlogging is brief, the plants will rejuvenate once the root respiration resumes.

However, prolonged water stagnation typically results in the complete death of the plants.

Salinity

Salinity is another important outgrowth of climate change following drought. Salinity poses challenges in marginal soils affected by topsoil erosion. Erratic rainfall and high evaporation losses from soil diminish the leaching of salts thereby increasing salt concentrations in the soil. Salinity is a common problem in coastal low-lying areas where seawater protrudes into the mainland such as backwaters. Cassava moderately tolerates salinity. However, at higher concentrations, a reduction in the yield of the tuber is observed. The presence of salt at higher concentrations in the soil affects the water and nutrient absorption through osmosis. Accumulation of salts in the leaf causes stomata closure which results in decreased CO_2 influx and net photosynthesis. It also inhibits the translocation of photosynthates from source to sink.

The tolerance of cassava to drought and salinity is merely related to its survival at the expense of tuber yield. Cassava exhibits a good amount of variation in the tolerance of various abiotic stresses. Selection of superior genotypes for abiotic stress tolerance is the common method of genetic improvement of cassava. The majority of the tolerant cultivars are high-starchy types used for industrial purposes. Drought-tolerant cultivars with excellent edible quality are essential for ensuring food security amidst changing climate conditions. Cassava is a vegetatively propagated crop and improvement in cassava through conventional breeding is difficult owing to its non-prolific and non-synchrony in flowering of male and female parents. Moreover, some clones don't produce flowers. Additionally, the highly heterozygous nature and inbreeding depression have limited breeding efforts in cassava. Hence, a combined effort of conventional and non-conventional methods like mutation and biotechnology, among others are to be formulated strategically to make cassava more resilient to climate change.

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