International Journal of Advanced Research and Review

www.ijarr.in

PIVOTAL FUNCTION OF EPICUTICULAR WAX UNDER DROUGHT STRESS CONDITIONS: A REVIEW ARTICLE

Wubishet Tamirat*

Jimma Agricultural Research Center, Ethiopian Institute of Agricultural Research, Jimma, Ethiopia. Email: wubishettamirat3@gmail.com

ABSTRACT

Drought stress impacts plants at various levels, causing damage and adaptive responses. Plant species have developed various mechanisms, including morphological, physiological, biochemical, cellular, and molecular responses, to adapt to drought conditions, enabling them to overcome stress.Plant species develop mechanisms like the cuticle layer, composed of cutin and wax. The cuticle plays a crucial role in plant life, regulating water loss, gas exchange, and nutrient absorption, and its wax acts as a tolerant mechanism. The aim of this paper is to review the role of Epicuticular wax on coffee under drought conditions.Plant epicuticular waxes represent the outermost boundary layer of the majority of land plants. Epicuticular wax (ECW), a protective substance, forms crystalline projections on plants' surfaces, enhancing water repellent properties, reducing radiation load, improving transpiration efficiency and their crucial influence on surface wet ability and particle adhesion. It acts as a natural barrier, enhancing plant resistance against diseases, and protecting against harmful organisms. Therefore, Epicuticular wax is a trait utilized for drought-tolerant mechanisms on coffee under drought stress conditions.

Keywords: Biochemical Trait, Self balancing, Stress, UV light, Water loss regulation

1. INTRODUCTION

Drought stress impacts plants at the cellular, tissue, and organ levels, leading to both specific and nonspecific reactions, damage, and adaptive responses [1]. Plant species have developed a range of mechanisms at the morphological, physiological, biochemical, cellular, and molecular levels to effectively cope with such challenging conditions. In order to survive under drought conditions, plants exhibit various morphological, physiological and biochemical physiological responses, thereby adapting and overcoming the stress [2, 3].

The plant cuticle serves as the external layer that envelops all primary plant organs, excluding the roots. It is a naturally occurring composite comprised of two hydrophobic elements: the biopolymer cutin and a variety of lipophilic compounds commonly referred to as waxes [2]. The plant cuticle layer, primarily composed of cutin and wax, is a hydrophobic substance that covers plant organs and tissues. Cutin serves as the foundation, while intra-cuticularwax partially coats it. Epicuticular wax, the outermost layer, envelops the cuticle, encompassing most land plants. Plant cuticle regulates water loss, gas exchange, nutrient loss, radiation shielding, cooling, wind, physical abrasion, pathogenic microorganisms, and herbivorous insects, while epicuticular wax (ECW) enhances water repellent properties[4, 5]. Changes in leaf cuticular wax compositions are observed in drought conditions [6]. ECW is crucial for drought tolerance in coffee cultivars.Therefore the objective is to review the role of Epicuticular wax on coffee under drought conditions.

2. CHEMICAL COMPOSITION

Cutin is insoluble polyester, can be embedded as intra-cuticular waxes or deposited on the outer surface as an epicuticular film. This diverse range of functional groups allows for the inclusion of fatty acids, primary alcohols, and aldehydes. Cuticular wax, derived from very-long-chain fatty acids, is produced through several stages [7, 8].

The cuticle is a complex layer of lipids, cutin, and intra-cuticular wax, with epicuticular wax on the surface, containing diverse chemical compounds. It is composed of hydrophobic organic compounds, primarily straight-chain aliphatic hydrocarbons. Waxes, chemically diverse, include long-chain fatty acids, hydrocarbons, alkanes, alcohols, ketones, esters, sterols, triterpenes, and flavonoids. Epicuticular waxes, found in intricate composite microstructures, cover outer plant coverage. Epicuticular waxes in plants are primarily composed of long-chain n-alkanoic acids [7-9].

3. ROLE OF ECW

The cuticle in plants regulates water loss, gas exchange, foliar leaching, nutrient and ion loss, radiation shielding, cooling, wind, physical abrasion, pathogenic microorganisms, and herbivorous insects [10- 12]. Epicuticular wax, a protective substance found in plants, forms crystalline projections on their surface, enhancing their water repellent properties and protecting them from both biotic and abiotic stresses [13].

3.1.It serves as a tolerant mechanism to abiotic stresses

Abiotic stresses like drought, salinity, high light, and nutrient deficiency significantly impact crop production and food quality [14-16]. Waxes protect aerial plant parts from abiotic stresses like radiation, cold, and drought. ECW reduces radiation load and enhances transpiration efficiency. Low abiotic stress tolerance is associated with ECW, but its composition varies between tender and mature leaves. The study found that wax biosynthesis genes expression varies based on leaf developmental stages and drought stress intensity. Multiple traits, including water relations and cellular tolerance, regulate drought tolerance in crop plants. Drought stress increases wax depositions on leaves, suggesting regulation of cuticular wax as a desirable trait [14, 17].

Plant cuticles' barrier properties are due to intracuticular waxes, which control water loss and volatile compound absorption. These hydrophobic, three-dimensional waxes contribute to the water-repellent nature of many plant species [18]. The permeability of cuticle water is influenced by the thickness of the wax layer or cuticle itself, but experiments show a negative relationship between wax amount and transpiration rate. The thickness and wax coverage on leaves also affect water loss. The plant's defense system's efficiency relies on water regulation, with the cuticle reducing non-stomatal water loss and cuticular wax being crucial for water conservation under drought stress [17, 19].

Drought conditions cause changes in leaf cuticular wax quantity and composition in crops like cotton, wheat, and sesame, as well as coffee. The cuticle, a complex layer, contains various chemicals, with epicuticular waxes forming complex microstructures. ECW is a measure of drought tolerance in coffee cultivars. Chandragiri coffee has higher ECW accumulation under water stress and stress alleviation in Figure1 [20]. Studies show ECW increases in all graft combinations and pure line seedlings under water stress. The Sln.9 rootstock positively influences the S.795 and S.4202 scion [21].

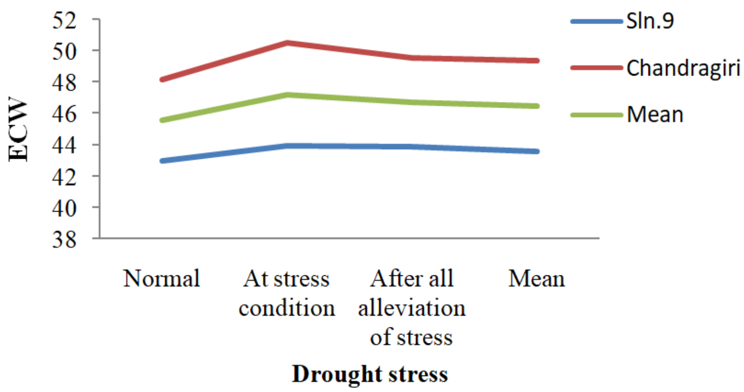

Figure 1. The amount of epicuticular wax (μg/cm^2) in coffee varieties under drought stress conditions. ECW is epicuticular wax.

Cuticle and waxes affect light reflectance and absorption in visible and infrared spectra, with Dudleya brittonii Johansen reflecting 83% of UV radiation, while most epicuticular waxes are ineffective. Epicuticular wax, like the white, chalky wax coating of Dudleya brittonii, has the highest UV reflectivity [2, 22]. The presence of epicuticular wax can reduce light absorption during photosynthesis, with an increase in UCT resulting in decreased IQY and AQY. The heterogeneous cutin matrix in the leaf cuticle impacts light focusing, allowing actinic light to penetrate deeper into mesophyll [23, 24].

3.2.It serves as a tolerant mechanism to biotic stresses

The cuticle, a lipid protective layer, protects plants by keeping leaf surfaces dry and hindering spore germination. The cuticle protects plants by shielding surfaces from pathogens, while epicuticular waxes enhance water retention and prevent fungal invasion. Epicuticular wax, formed on the cuticle, acts as a natural barrier, enhancing plant resistance against diseases, and protecting against harmful organisms [4, 5, 10-12].

Superhydrophobicity on plant surfaces is achieved through sculptured epidermal cell morphology and fine wax projections, causing water droplets to form due to surface tension and wax crystals, effectively removing dirt particles and microorganisms. Self-cleaning surfaces prevent inorganic contaminants and pathogen colonization on plants by effectively removing spores from leaves during rainfall and preventing their establishment [2, 25].

4. FACTORS THAT AFFECTS EW

Pollution causes changes in epicuticular wax morphology, including erosion, crystal modifications, and decreased wax content. The cumulative effects of pollutants on leaf surface exacerbate these issues, reducing water retention capacity and causing water stress in plants [26, 27].

Previous research findings showed that fungicides on rust-resistant coffee plants (Obatã) and susceptible ones (Catuaí Vermelho) affect the composition and structure of epicuticular wax. Applying fungicides decreases wax content and alters morphology, making plants more vulnerable to diseases. Variations in wax content may be linked to rust resistance. The sprays resulted in a gradual decrease in wax content in both cultivars, attributed to the cumulative effect of the product on leaves in Table 1 [28]. Fungicide may affect epicuticular leaf wax synthesis, as control plants show gradual increase in wax content due to leaves' ability to absorb substances. The findings showed that the content and composition of epicuticular wax chemistry directly influence both species' resistance to pathogens and their tolerance to certain chemical pesticides [29].

Table 1. Median and mean values of epicuticular leaf wax content (μg cm^2) of the adaxial (AD) and abaxial (AB) leaf surfaces of coffee 'Catuaí Vermelho' and 'Obatã' from control treatments and with the fungicide Cuprozeb.

Sample	Control						Cuprozeb					
	Median		Mean		Dp		Median		Mean		Dp	
	AD	AB	AD	AB	AD	AB	AD	AB	AD	AB	AD	AB
	Catuaí Vermelho											
1	6674aA	6498cA	6802	6671	138*	102*	6422aA	56049dA	6799	5631	257*	107*
2	6544aA	6387cA	6739	6511	201*	193*	5727bB	4527dB	5519	4753	112*	148*
3	7958aB	7128cB	7801	7005	180**	224*	3960dc	3260dc	3791	3174	103**	112*
4	7737aB	6983cB	7814	6895	157**	113*	2713bD	2471dD	2519	2185	109**	157*
	Obatã											
1	6610aA	6537cA	6729	6652	193*	117*	5681bA	6147dA	5572	6163	092*	106*
2	6597aA	7029cB	6631	6971	095*	070*	4924bB	5507dB	4813	5326	112*	038*
3	7827aB	8415cC	7701	8239	107*	027*	3160bC	4383dc	2911	4013	029*	147*
4	83369aC	9201cD	8247	9062	085*	118*	2218bD	3065dD	1950	3292	177*	069*

Medians followed by different letters, lowercase in the same line (Mann-Whitney test) and uppercase in the same column (Kruskal-Wallys test), present statistical differences; DP: standard deviation. * and ** Significant and highly significant at 5 and 1% probability, respectively.

5. SUMMARY AND CONCLUSION

The cuticle in plants regulates water loss, gas exchange, foliar leaching, nutrient and ion loss, radiation shielding, cooling, wind, physical abrasion, pathogenic microorganisms, and herbivorous insects and its wax acts as a tolerant mechanism. Epicuticular wax, a protective substance found in plants, forms crystalline projections on their surface, enhancing their water repellent properties and protecting them from both abiotic and biotic stresses. The plant's defense system's efficiency relies on water regulation, with the cuticle reducing non-stomatal water loss and cuticular wax being crucial for water conservation under drought stress. Expicuticular wax is one of important parameter for drought tolerance mechanisms. Therefore research interventions should be needed.

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