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Mini Review

Evaluation of Drought Tolerance of Cowpea (*Vigna unguiculata (L.)* Walp

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Abstract

Global climate changes are intensifying and may threaten agricultural production, especially in marginal tropical areas. Cowpea is a legume of great socioeconomic importance, grown worldwide, mainly under rainfed conditions. It is currently considered tolerant to water stress and presents diverse local varieties. However, water stress can negatively affect plants' various morphophysiological, biochemical, and molecular functions, especially in the pre-flowering stage, which is the most sensitive period to the effects of water deficit. Evaluating leaf protoplasmic tolerance may represent a promising approach for investigating drought tolerance, enabling discrimination between different genotypes.

Introduction

Lack of water is probably one of the abiotic stresses affecting agricultural productivity worldwide, reducing crop growth and productivity [1]. Worldwide, around 1.2 billion hectares are used for rainfed agricultural production, accounting for about 80% of all arable land, which suffers from prolonged droughts and rising temperatures [2]. The tropics are the regions that suffer most from the effects of drought on productivity, with variations in annual rainfall, high temperatures, and solar radiation. The exponential increase in population and climate change changes, especially in marginal zones, could jeopardize future generations' food and nutritional security. In this context, the Food and Agriculture Organization of the United Nations (FAO) identifies legumes as key crops for achieving world food security [3,4].

The cowpea *(Vigna unguiculata (L.) Walp.)*, in particular, is an annual legume native to Africa and cultivated worldwide. It is an excellent source of protein, carbohydrates, and vitamins, rich in antioxidants, fatty acids, and polyphenols [5]. In addition, an essential role in improving soil fertility and agricultural sustainability, especially for small farmers, due to atmospheric, is the biological nitrogen fixation via symbiosis with Rhizobium [6,7]. Although cowpeas are moderately tolerant to water stress [8], they can limit productivity, especially in arid and semi-arid regions, due to irregular rainfall and high temperatures, especially during severe drought [5].

In response to significant losses in productivity caused by water deficit, plants will develop morphological and physiological mechanisms over time to adapt and respond to this type of stress. However, some aspects of cowpea foliar metabolism under water restriction remain unclear, for example, the ability of some cowpea cultivars to recover from stress after rehydration. A plant's ability to recover is an important physiological characteristic for drought-tolerant genotypes, as it allows for a rapid supply of CO_2 during growth and after rehydration [9].

Adaptive responses to water stress

Under water stress conditions and high evapotranspiration rates, plants trigger some morphological, physiological, cellular, and biochemical responses, ensuring survival under natural conditions. Turner (1986) [10] proposed three adaptive responses to water stress: the escape mechanism, the tolerance mechanism under high water content, and the tolerance mechanism under low water content. On the other hand, Subbarao et al. [11] classified drought adaptation mechanisms into three types: escape, avoidance, and tolerance, which also include the abovementioned characteristics. Some of these characteristics allow plants to survive even in water-deficient environments, such as a shortened cycle, length of maturity, plant architecture, stomatal closure, relative water content, and maintenance of membrane integrity [6]. It is, therefore, necessary to identify the characteristics of the material under study that can confer survival in water-deficient environments and to ensure the selection of genotypes that can be used in low-tech systems, especially in tropical areas [10,12].

Cowpea Responses under Water Stress

Water deficit is probably a limiting factor for productivity, especially in arid and semi-arid regions. However, cowpeas show tolerance to water stress, achieving higher yields even in drought conditions, compared to other crops [7]. The phases most susceptible to water deficit are the pre-flowering and flowering stages due to the reduction in photosynthetic activity in the leaves, causing the embryo development in the seed to come to a standstill [13]. Under optimal growing conditions, cowpeas can yield more than 1000 kg of grain/ha. Still, drought reduces this potential to approximately 360 kg/ha, mainly when stress occurs during the pre-flowering stage [14].

The plant's ability to resist stress consists of several strategies, such as a tolerance mechanism under high water content and another based on the maintenance of tissues and physiological activity even under conditions of low water content, for example, protoplasmic tolerance [10]. Cell membranes are one of the first targets in plants under stress due to changes in cell compartmentalization linked to increased hydrolytic enzyme activities [15]. Under stress conditions, modifications can allow the plant to acclimate to the environment or lead to irreversible damage and cell death [16]. Cellular ion extrusion can assess leaf protoplasmic tolerance to drought in selected genotypes. Studies on four different genotypes of cowpea *(Vigna unguiculata)* (Table 1) showed that the integrity of each genotype's cell membrane was compromised under water stress conditions.

Table 1: Electrolyte release from leaf discs of four cowpea *(Vigna unguiculata)* genotypes during eight days of stress and two days of rehydration in a greenhouse.

Days of Stress	PAI*			
	EPACE 10	BRS Novaera	Paulistinha	BR 17 Gurgueia
0	0,92 a	0,90 a	0,90 a	0,86 b
2	0,89 a	0,87 a	0,88 a	0,84 b
4	0,86 a	0,82 b	0,88 a	0,82b
6	0,80 a	0,75 b	0,75 b	0,78 a
8	0,79 a	0,66 c	0,73 b	0,66 c
10**	0,80 b	0,84 b	0,90 a	0,82 b
Days of Stress	PRI*			
	EPACE 10	BRS Novaera	Paulistinha	BR 17 Gurgueia
0	91,90 a	90,70 a	90,72 a	86,78 b
2	89,48 a	86,77 a	87,99 a	84,03 b
4	85,77 a	81,88b	87,99 a	82,60 b
6	80,14 a	75,52 b	75,44b	78,81 a
8	78,97 a	66,49 c	73,61 b	66,37 c
10**	80,90 b	83,92 b	90,36 a	81,85 b
Days of Stress	PD*			
	EPACE 10	BRS Novaera	Paulistinha	BR 17 Gurgueia
0	8,09 b	9,30 b	9,27 b	13,22 a
2	10,52 b	13,22 b	12,0b	15,96 a
4	14,22 b	18,12 a	12,01 c	17,39 a
6	19,85 b	24,48 a	24,56 a	21,18 b
8	21,03 c	33,51 a	26,38 b	33,62 a
10**	19,08 a	16,07 b	9,63 c	18,14 a

*PAI (Percentage of Absolute Integrity: PA= 1- FE/ TE, where FE is the Free electrolyte leakage, and TE is the Total electrolyte leakage; PRI (Percentage of Relative Integrity: PRI= 9AI of stressed discs). 100); and PD (Percentage of Cell Damage: PD= 100-PRI). **The 10th day of water deficit was the day of rehydration and recovery. The means followed by the same letter within each line do not differ significantly by the Newman-Keuls test ($p<0.05$).

During water stress imposition, a more significant Percentage of Cell Damage (PD) was observed in the genotypes considered most sensitive to drought, BRS Novaera and BR 17 Gurgueia (Table 1). During water stress, EPACE 10 showed lower values of PD, but with rehydration, it had a high PD (Table 1) and can be considered the most water deficit tolerant. However, despite Paulistinha having a higher percentage of damage than the others on the sixth day, it had a greater capacity to recover when irrigation was resumed, with a low PD. This response is also a desired characteristic of this genotype under dehydration recovery, which can also be considered an adaptation mechanism, as for EPACE 10. The lower PD values are because the more adapted genotypes may have less effect on membrane integrity due to their lipid and protein composition [12]. The enzyme systems of the central metabolic pathways may only be inactivated. In contrast, in the more sensitive genotypes, these systems may be degraded through proteolysis, requiring synthesizing these systems again causing a low recovery [17,18]. Plants more tolerant to water stress have a lower mono-galactosyl-diacylglycerol (MGDG) content, which can increase susceptibility to drought-induced peroxidative or enzymatic degradation, causing low membrane fluidity. Therefore, leaf protoplasmic tolerance could be used for screening drought-tolerant genotypes [16].

Maintaining the integrity of the membrane seems to be a drought-tolerant characteristic at the cellular level, which is dependent on factors inherent to the membrane, such as its composition, hydrolytic and protective activities, antioxidant systems, and concentrations of defensive compounds such as amino acids, sugars, dehydrins, among others, at the cytoplasmic level [12]. Therefore, evaluating leaf protoplasmic tolerance could be used to screen new drought-tolerant genotypes to be cultivated in marginal areas for agriculture and improve cowpea yield in semi-arid regions.

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