Importance of Root System Architectural Traits Under Drought in Sorghum

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Introduction

Sorghum is a crucial dual-purpose crop as well as the greatest drought tolerant among the world's top five carbohydrate-rich crops along with its reputation as a model crop, whereas the cultivation of sorghum possesses a range from the equator (about 50° latitude) to altitudes of 2500 m (Rao *et al*., 2015). It is cultivated on marginal, fragile, and drought-prone environments in the semi-arid tropics. It is remarkably tolerant to low input levels which gave it an indispensable feature for the areas getting little rainfall. In the context of growing demand for limited freshwater source, growing usage of marginal farmland, and changing climatic patterns, sorghum thus can play a crucial character in nourishing the world's most helpless people. Such thought-provoking particulars about sorghum brand it an ideal plant species not only to explore evolutionary connections throughout other grass species but also to undertake various research from different perspectives under changing climate for ensuring food security.

Drought is defined as a prolonged period of insufficient plant-available water, primarily due to inadequate rainfall or precipitation. It can also result from exceptionally high temperatures and low humidity, which increase evapotranspiration in plants. Drought stress reduces carbon assimilation, stomatal conductance, and cell turgor, thus hindering normal crop growth and development and limiting yield. Globally, about 28% of the area cultivated with sorghum is permanently affected by drought, compared to 20% for wheat, 19% for barley, and 19% for maize (Wagaw, 2019). Rabi sorghum is typically grown under conditions of stored and receding soil moisture, with temperatures rising after flowering. Consequently, it faces both soil and atmospheric water deficits (drought). The limited availability of water causes moisture stress, which impacts various metabolic processes in the plant.

Root traits under drought stress

Roots are the primary plant organ affected by drought stress and other environmental stresses of the soil. Sorghum crown roots grow about 2 to 3 cm per day (Routley *et al*., 2003) and root growth is mainly affected by the amount of carbon partitioned to the roots, although it varies with environmental and genetic factors (Blum, 2005). Sorghum roots may grow to depths of 1 to 2 m by the booting stage, and can efficiently extract water to a lateral distance of 1.6 m from the plant (Routley *et al*., 2003). Root growth in sorghum terminates at flowering stage; however, it is more prominent in a senescent than in nonsenescent sorghum genotypes (Robertson *et al*., 1993).

In plants, one of the essential phenotypes for withstanding drought is having long and branched roots capable of penetrating deep into the soil to extract moisture from deeper layers (Fenta *et al*., 2014). Genotypes with the longest root length and smallest diameter capture more soil water compared to those with shorter root lengths and larger diameters. These findings suggest that drought tolerance in sorghum is primarily linked to root length rather than root diameter. Ekanayake *et al*. (1985) indicated that drought stress tolerance was found to be highly associated with root characteristics such as root thickness, root length density, number of thick roots, root volume, and root dry weight. It was also found that number of thick root, root thickness, and root length density were highly associated with leaf water potential. Habyarimana *et al*. (2004) found that the drought tolerance traits displayed by the genotypes were related to drought avoidance mechanisms. These, in turn, are associated with deep root system, which enables plants to exploit moisture from the deeper soil horizons. Nour *et al*. (1978) also reported root weight as the best and easiest attribute to determine drought tolerance in grain sorghum. During drought stress, plants often alter their root-to-shoot ratio, favoring root growth over shoot growth. This adaptation increases the plant's ability to capture water relative to its water loss through transpiration, helping maintain a favorable water balance. Root hairs increase the surface area for water absorption. In response to drought, some plants may develop more root hairs to enhance their ability to take up water from the soil, even when water is scarce. And Small diameter roots with greater specific root length enable plants to efficiently increase hydraulic conductance by increasing surface area in contact with soil water, increasing the volume of soil that can be explored for water. Matsuura *et al*. (1996) reported a positive correlation between drought tolerance and root length in sorghum and millet (*Pennisetum glaucum*). Root depth, root length density, root distribution was reported as drought tolerance contributing traits (Taiz and Zeiger, 2006). Drought is often associated with nutrient availability and the capacity of roots to absorb the available nutrients. Ludlow and Muchow (1990) indicated that greater root activity under intermittent drought should enhance crop stability by reducing the incidence of water deficits.

Many researchers (Girish *et al*., 2018; Pooja *et al*., 2021; Enyew *et al*., 2023) reported variation in root anatomy and morphology, among sorghum genotypes. Lavinsky *et al.* (2016) suggest a higher effort of plant in the development of the root system can represent an enhancing on water absorption, maintenance of the photosynthetic activity and plantation production. Tracing the behaviour of morphologic characteristics of the root systems in drought conditions represents an important bottleneck to understand the responses of different genotypes to this particular stress. In this context, the use of tools like Root scanner (Fig1) with "WinRhizo" software (Magalhães *et al*., 2016) to track morphometric characteristics of the root system will be an important strategy for genotypic evaluation (Lavinsky *et al*., 2016) with stronger root system. In nutshell, long prolific root system with narrow root angle, small diameter and considerable root length density, specific root length can be considered as an ideal ideotype of sorghum for root traits which perform better under drought condition.

Fig 1 Root scanner for root phenotyping

Conclusion

There is growing potential for breeding plants with specific root traits to improve productivity under water scarcity. While much knowledge exists about root traits and their functions, there is still a need for a deeper understanding of these traits in relation to plant growth strategies under water-limited conditions. Additionally, a clearer comprehension of the trade-offs involved with root traits is necessary to inform breeding initiatives. Overall, the root system's ability to efficiently capture and manage water is vital for plant survival under drought stress. Through structural and functional adaptations, roots help plants maintain hydration, sustain metabolic processes, and survive prolonged periods of limited water availability.

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