Scholars Academic Journal of Biosciences
Abbreviated Key Title: Sch Acad J Biosci
ISSN 2347-9515 (Print) | ISSN 2321-6883 (Online)
Journal homepage: https://saspublishers.com

OPEN ACCESS

Life Science

Progress on the Effect of Drought on Sorghum Growth and Its Response Mechanisms

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DOI: https://doi.org/10.36347/sajb.2024.v12i07.004 | **Received:** 19.07.2024 | **Accepted:** 25.08.2024 | **Published:** 27.08.2024

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Abstract **Review Article**

Drought is one of the key factors limiting the increase in crop yields in China and one of the main abiotic stresses affecting the growth and development of sorghum. With currence of global extreme climate become more frequent, the risk of sorghum suffering from drought stress is increasing. Although sorghum (*Sorghum bicolor* (L.)) is an important food crop, its growth and yield will be significantly affected under abiotic stresses (such as drought, salinity, high temperature and low temperature). Therefore, it is of great significance to study the response mechanism of sorghum drought stress. This study summarized the effects of drought stress on sorghum growth, including the effects of seed germination, leaves and roots. This study summarized the effects of drought stress on sorghum growth, including the effects of seed germination, leaves and roots. The response mechanisms of sorghum to drought stress was discussed from stomatal regulation, osmotic regulation and antioxidant system, and the ways to improve drought resistance of sorghum were prospected, so as to lay a foundation for further study on the morphology, physiological characteristics and molecular mechanism of drought resistance of sorghum and provide theoretical reference for workers engaged in sorghum production and related research.

Keywords: Sorghum, Drought Stress, Growth Effect, Response Mechanism

1. INTRODUCTION

Drought is one of the most prominent phenomena in global climate change and one of the key factors limiting China's crop production, which has had a serious impact on agricultural production. Drought is divided into arid region and semi-arid region. About two-thirds of the land in China belongs to arid area [1], which has the characteristics of wide occurrence range and long duration. Drought causes insufficient soil moisture, and plant roots cannot absorb enough water, affecting the normal growth [2], and metabolism of plants. At the same time, the decrease of photosynthesis, yield and quality of plants is caused by drought.

Sorghum (*Sorghum bicolor* (L.)) is a highly adaptable cereal crop with multiple resistances such as salt-alkali tolerance and drought resistance. It is mainly planted in the arid semi-arid areas of tropical, subtropical and temperate zones. In arid areas. It is the fifth largest cereal crop in the world [3], and one of the main grain crops in my country. However, with the change of global climate, the phenomenon of soil drought has obviously increased, which will cause great yield loss to sorghum. This study summarized the effects of drought stress on seed germination, leaves and roots of sorghum, discussed the response mechanisms of sorghum to drought stress from the aspect of physiological adaptation, and prospected the ways to improve drought resistance of sorghum, hoping to provide valuable reference for researchers in related fields and producers engaged in agriculture, promote further research on drought stress of sorghum, provide strong support for global food security and agricultural sustainable development, and reduce social and economic losses.

2. Effects of Drought Stress on Sorghum Growth

2.1 Effects of Drought Stress on Sorghum Seed Germination

The growth and development of plants are inhibited by drought stress. When drought stress reaches a certain value, it will limit the germination of seeds, thereby reducing crop yields. Under drought stress, the growth indexes of sorghum such as germination rate, germination index and vigor index all decreased [4]. Relevant studies have shown that when drought reaches a certain level, the bud length and bud dry weight of sorghum are significantly reduced compared with those under normal conditions. This indicates that drought stress is not conducive to sorghum seed germination.

2.2 Effects of Drought Stress on Sorghum Leaves

The most obvious effect of drought stress on plants is the yellowing of leaves, because drought leads to the decomposition of chlorophyll and exposes other pigments, such as carotenoids; at the same time, plants will also have the phenomena of leaf withering, leaf curling, slow growth of leaf area [5], changes in leaf thickness and structure. Under drought stress, the relative water content of sorghum leaves decreased significantly. This was caused by drought stress limiting the water absorption capacity of sorghum, causing water loss to exceed absorption. The chlorophyll content may be affected by drought stress, which affects the formation and degradation of chlorophyll, with most of the results showing a significant decrease or a small part showing no significant difference [6]. Mild drought stress can stimulate the increase of protective enzyme activity in sorghum leaves, and start the defense mechanism to clear up the excessive reactive oxygen species in sorghum. On the contrary, severe drought stress will reduce or inhibit the increase of protective enzyme activity [7].

2.3 Effects of Drought Stress on Sorghum Roots

As a bridge connecting soil and aboveground parts, plant roots are not only responsible for absorbing water and nutrients, but also participating in many functions such as plant fixation, signal transmission and material storage. Developed roots are an important guarantee for obtaining water and nutrients [8]. Under drought conditions, the difficulty of water absorption of plant roots is caused by the decrease of soil moisture, which further affects its growth rate and promotes adaptive changes in plant root morphology, such as increasing the number of root hairs and prolonging the length of root hairs. As a highly stress-resistant crop, sorghum has particularly obvious changes in root system morphology under drought stress. Under drought stress, the total root length, root surface area and root volume of green-holding sorghum all increased [9], and compared with ordinary sorghum varieties, the root number and root length increased more [10]. Root activity refers to the absorption capacity of crop roots, which can reflect the relationship between roots and soil under drought conditions [8]. There are obvious differences in root activity among different varieties. Studies have shown that the impact of drought stress on root activity during the irrigation period of sorghum is more obvious than during the seedling stage [11].

3. Mechanism of Sorghum Response to Drought Stress

3.1 Stomatal Regulation

Stomata is a tiny opening on a plant leaf, surrounded by two guard cells. Its main function is to allow the plant to exchange gases and plays a key role in photosynthesis, respiration and transpiration of the plant. Under drought stress, plants respond to the water-deficient environment by adjusting their stomata. The main function of stomata in sorghum life is to regulate the exchange of water and carbon dioxide, minimize the amount of water needed to fix a certain amount of carbon dioxide and maintain the heat balance of sorghum plants during the loss of water transpiration. It can also be used as part of the power to absorb and transport water and inorganic substances [12]. Under similar field conditions, stomatal closure is mainly regulated by swelling pressure, and the water potential required for stomatal closure of sorghum is the lowest among several crops [13]. The stomatal conductance of sorghum during the vegetative growth period is very sensitive to a small decrease in water potential, and the stomata are also open under low leaf water potential [14].

3.2 Osmoregulation

Under drought stress, plant osmoregulation is one of the important mechanisms for plants to cope with drought environments and maintain normal physiological functions. It is an important physiological adaptation mechanism. Osmoregulation refers to the process by which plants actively accumulate various organic or inorganic substances to increase cell fluid concentration and reduce osmotic potential under adverse conditions such as drought, thereby enhancing the water absorption or water retention capacity of cells to adapt to the drought environment. Osmoregulation substances can be divided into inorganic ions and organic solutes. Inorganic ions mainly include K^+, Na^+, Cl^-, etc. Organic solutes include a variety of small molecular organics and macromolecular polysaccharides. Common organic osmotic adjustment substances include proline, soluble sugar (such as sucrose and glucose) and betaine. The accumulation of these substances in the cells not only increases the osmotic pressure of the cell fluid, but also participates in the antioxidant reaction and energy metabolism of the cells.

Proline is one of the most effective osmotic adjustment substances with strong water solubility, and the increase of its content is beneficial to improve the water retention capacity of plant cells and tissues [15]. It can be combined with proteins to protect the stability of enzyme systems and cell structures, and can be used by plants as energy and other substances [16]. Related studies showed that proline content of different varieties of waxy sorghum seedlings increased significantly under drought stress [6]. In addition, the proline content of sorghum sugarcane increased significantly under drought stress, and the proline accumulation was higher than that of Silimei and Henong [16, 17]. These situations illustrate the important role of proline under adverse stress, and studies have found that exogenous spraying of proline can greatly improve the drought resistance of plants [18, 19].

3.3 Regulation of the Antioxidant System

Under drought stress, plants will activate their antioxidant system to cope with oxidative stress. This is because the lack of water caused by drought will lead to the accumulation of reactive oxygen species (ROS), which will cause damage to plant cells. As a signal molecule, low-concentration ROS participate in the regulation of abiotic stress reactions in plants [20]. The antioxidant system in plants is mainly composed of enzyme antioxidants and non-enzyme antioxidants, and the scavenging of active oxygen is mainly realized through these two parts. Enzyme antioxidants mainly include superoxide dismutase (SOD), catalase (CAT), peroxidase (POD), etc.

These enzymes play a crucial role in scavenging reactive oxygen species (ROS) produced in plants. Non-enzymatic antioxidants include small molecules such as vitamin C(Vc), glutathione, carotenoids and polyphenols. These antioxidants can react directly with ROS, thereby mitigating their damage to cells. Related research have shown that [21], the SOD activity of sorghum sugarcane first increased and then decreased with the increase of drought degree, and the change trend of POD activity was similar to that; The changes in CAT activity first increased and then decreased as the degree of drought increased. Under 15% drought, the CAT activity changed from an upward trend to a downward trend. This shows that sorghum resists damage by activating the oxidative system and increasing the activity of protective enzymes when it is subjected to drought stress. Mild drought stress can increase the antioxidant enzyme activity of sorghumcane.

4. Prospects and Ways to Improve Drought Resistance of Sorghum

4.1 Hardening for Drought Resistance

Hardening for drought resistance, also known as hardening treatment or drought tolerance exercise, is to pretreat plant seeds in germination or seedling stage by simulating drought conditions or adopting specific chemical and physical means to improve their survival rate and growth quality in arid environment. The methods of Hardening for drought resistance include seed treatment (chemical soaking, dry-wet circulation), seedling treatment (controlling watering, shifting roots and squatting seedlings) and chemical induction. Sorghum seeds or seedlings can be subjected to drought-resistant exercise methods such as dry-wet circulation to improve the survival rate, germination rate and growth quality of sorghum in arid environment. Relevant research shows that after farmers exercise corn seeds through dry-wet circulation, the survival probability of corn seedlings in dry environment increases, and the corn yield can be increased by 10% [22].

4.2 Reasonable Fertilization

Improve the resistance of plants to drought stress through scientific fertilization. K^+, Na^+, Ca^{2+}, Zn^{2+} and other ions are ions needed for plant growth, and external application of them can improve the drought resistance of plants; However, excessive application of nitrogen fertilizer may lead to excessive growth of plants, increase water transpiration and reduce drought resistance of plants. Therefore, it is necessary to properly fertilize plants to improve their drought resistance. To sum up, the ability of osmoregulation and Stomatal regulation of sorghum can be improved by reasonable fertilization, thus improving the drought resistance of sorghum. Relevant studies have shown that applying organic fertilizer to Haloxylon ammodendron under stress significantly increased the plant height, crown width and root length of Haloxylon ammodendron [23]. Rational application of potassium fertilizer can enhance the stress resistance of plants, such as drought and salt content [24].

4.3 Apply Growth Regulators or Antitranspirants

Growth regulators are a kind of chemicals that can regulate plant growth and development, and they play an important role in plant drought resistance. Growth regulators are divided into growth promoters, growth inhibitors and growth retardants. Commonly used plant growth regulators include gibberellin (GA), cytokinin (CTK), abscisic acid (ABA) and others. They can promote the growth of roots, enhance the water absorption capacity of plants, or change the growth direction of plants to make them more suitable for arid environments. ABA is particularly important in plant drought resistance, which can induce stomatal closure, reduce water transpiration and promote the synthesis of osmoregulation substances. Relevant studies have shown that the morphological characteristics and biomass pattern of Lespedeza root system are changed by ABA, which enhances the drought resistance of Lespedeza seedlings [25].

Plant antitranspirant is a kind of chemical substance that can reduce plant transpiration and keep water in plants. Antitranspirants can be divided into three categories, including reflective, thin-film and metabolic. Commonly used plant transpirants include diatomite, polyethylene glycol, methylated silicate and so on. These substances can be applied to plant leaves to form a protective film that reduce water loss. Studies have shown that spraying anti-transpiration agent evenly on maize at booting stage can make the leaf color dark green, increase the grain weight and increase the yield by 7.1% -14.8% per mu [26]. To sum up, the drought resistance of sorghum can be enhanced by applying plant growth regulators and plant antitranspiration agents, thus improving the quality and yield of sorghum.

5. CONCLUSIONS

This study summarized the effects of drought stress on sorghum growth, and analyzed the response mechanism of sorghum under drought stress. Through the existing research, the improvement of drought resistance of sorghum is prospected, hoping to provide ideas and ideas for reducing the impact of drought on agricultural production, and provide scientific and valuable reference for relevant personnel in the research field and agricultural producers. At the same time, the future of sorghum abiotic stress research is full of hope. By strengthening scientific research and technological innovation, more effective drought-resistant technologies and methods are explored to cope with the increasingly serious drought stress challenge.

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