Effects of Polyethylene Glycol-Induced Water Stress on the Physiological and Biochemical Responses of Different Sorghum Genotypes

Jeong-sung Jung
National Institute of Animal Science, South Korea

Zada Muhammad
National Institute of Animal Science, South Korea

Ki-won Lee
National Institute of Animal Science, South Korea

Jin-youg Mun
National Institute of Animal Science, South Korea

Hyung-soo Park
National Institute of Animal Science, South Korea

See next page for additional authors

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Jeong-sung Jung, Zada Muhammad, Ki-won Lee, Jin-youg Mun, Hyung-soo Park, Young-jin Kim, Won-ho Kim, Sang-hoon Lee, and Sang-hack Lee

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Effects of polyethylene glycol-induced water stress on the physiological and biochemical responses of different Sorghum genotypes

Jeong Sung Jung*, Zada Muhammad, Ki-Won Lee, Jin Youg Mun, Hyung Soo Park, Young Jin Kim, Won Ho Kim, Sang-Hoon Lee, Sang Hack Lee
National Institute of Animal Science, Rural Development Administration, Cheonan, Republic of Korea
*Corresponding author e-mail: jjs3873@korea.kr

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Introduction

Globally, abiotic stress is the primary cause of crop loss, reducing the average yields of most major crop plants by more than 50% (Bray *et. al*., 2000). Drought stress is one of the most widespread environmental stresses when the total area of arable land is classified according to the occurrence of various stress factors (Arora *et al*., 2002).
Drought and other abiotic stresses limit the photosynthetic activity of various crops, which in turn reduces the production of photosynthetic assimilates. Almost every developmental stage of the plant is affected by water stress. However, it has been observed that drought stress is more damaging to plants at the growth and germination stages, affecting seedling shoot length, flowering, and root length (Khayatnezhad, *et al*., 2010).

Significant work has been conducted investigating the growth of plants under drought stress conditions. First, the roots sense a water deficiency, and after an hour begin to synthesize abscisic acid (ABA). From within minutes to hours, ABA is transported via the xylem from the roots to the leaves; thus, root length is an important characteristic to consider when evaluating a plant's resistance to drought stress. Furthermore, seedling traits have also shown to exhibit moderate to high levels of heritability of genetic variance within environments (Rauf *et al*., 2008).

An alternative approach to drought stress-screening of the germplasm is to induce water stress through the application of polyethylene glycol (PEG) solutions. Polyethylene glycol has molecular mass of 6000 and is non-ionicand water-soluble polymers that do not rapidly penetrate into plant tissues. This solution interferes with the roots' ability to absorb water because of the associated reduction of osmotic potential (Dodd and Donovan, 1999).

In order to evaluate the physiological drought responses of different sorghum cultivars grown in Korea, polyethylene glycol (PEG) treatments of varying duration were applied to 4 different sorghum cultivars in order to imitate different levels of water stress. The effects of PEG-mediated drought stress on the CAT activity, APOD activity, GPOD activity, SOD activity, H_2O_2 content, MDA content, proline content, and chlorophyll content of sorghum seedlings were examined and compared to a control cultivar with a different degree of sensitivity to drought stress.

Materials and Methods

The four sorghum cultivars used in this study were SS405, SX-17, Jumbo, and Revolution. SS405 is a sorghum-sorghum forage hybrid (SSFH). SX-17 and Jumbo are sorghum-sudangrass hybrids (*Sorghum bicolor*-*S. bicolor* var. *sudanense*). Revolution is a hybrid of brown midrib (BMR) and sorghum. They were germinated under dark conditions, at 25 °C for 12 h, on moist cotton pads in petri dishes. The germinated seeds were raised to the seedling stage on one-fourth strength Hoagland nutrient medium containing different concentrations of SA (50, 500, and 100 μM). A set of plants growing in medium without SA was used as a control. The seedlings were grown in a plant growth chamber with an 8 h photoperiod at 25 ± 2 °C. The light intensity was approximately 200 μM $m^{-2}\cdot s^{-1}$. The primary leaves and roots of 7-day-old seedlings were used for the analysis

The shoot and root tissues of sorghum cultivars were removed after 20 days of growth, and their fresh weights (FW) were measured. The plant material was then oven-dried for 48 h at 70 °C, after which the plants were weighed to determine their dry weights (DW).

Polyethylene glycol (PEG) treatments of varying duration were applied to 4 different sorghum cultivars in order to imitate different levels of water stress. The effects of PEG-mediated drought stress on the CAT activity, APOD activity, GPOD activity, Superoxide dismutase (SOD) activity, H_2O_2 content, malondialdehyde (MDA) content, proline content, and chlorophyll content of sorghum seedlings were examined and compared to a control cultivar with a different degree of sensitivity to drought stress.

Experiments were performed with 3–5 replicates per analysis. The significance of the treatment effects was determined at a 5% probability level by one-way ANOVA, and the general linear model (GLM) function in the Minitab 15 software program.

Results and Discussion

Catalase (CAT) activity was shown to increase under drought stress, particularly in the Jumbo and Revolution cultivars under both treatments. Cultivars SX-17 and SS-405 exhibited differing results under different PEG treatments. Both SX-17 and SS-405 have shown high activity at PEG (30%) treatment for 72 h and low CAT activity PEG (30%) treatment for 24 hours (Fig. 1).

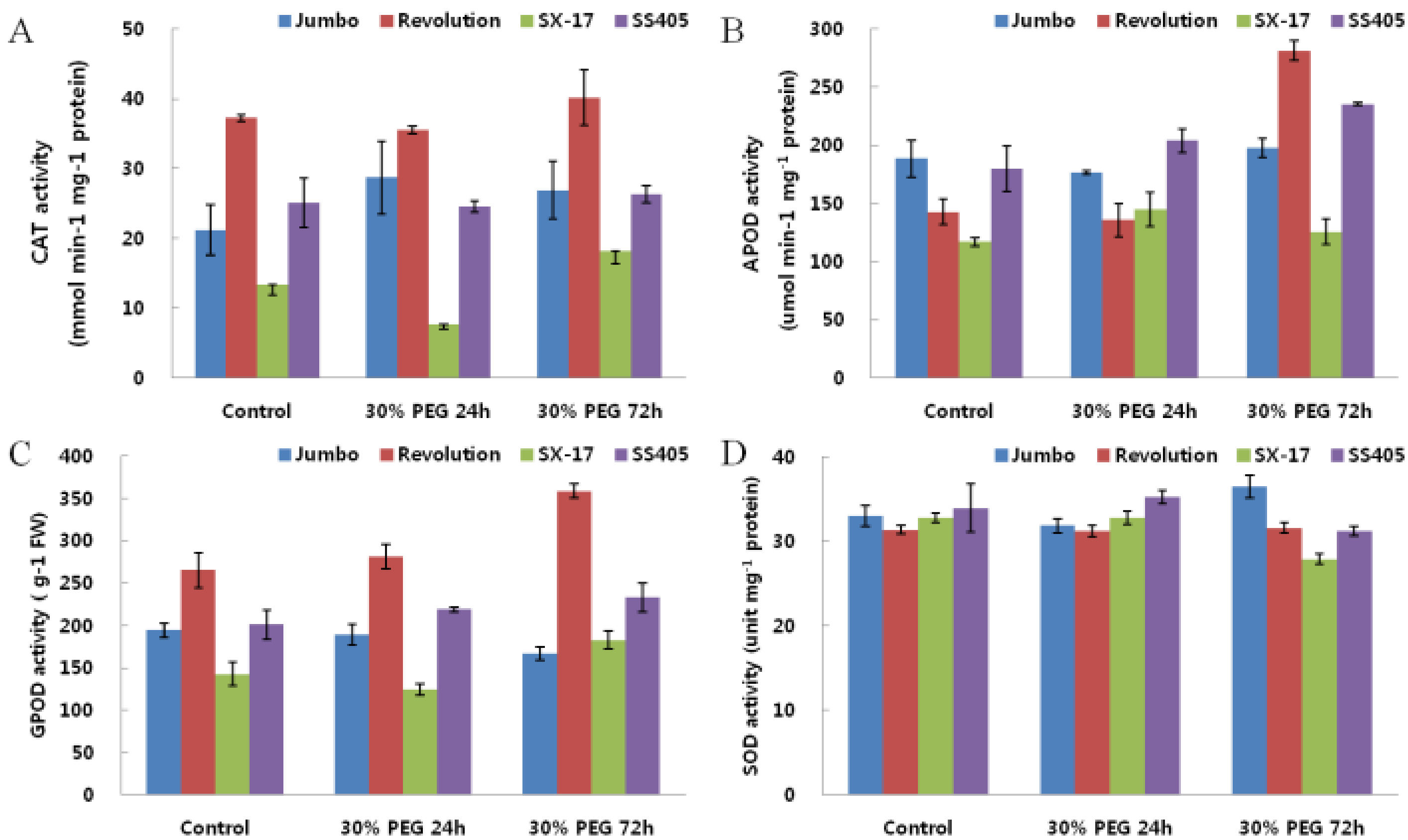

Fig. 1: Effects of PEG-mediated drought stress on the catalase (A), APOD (B), GPOD (C) and SOD (D) activity of seedling of different sorghum genotypes.

Ascorbate peroxidase (Fig. 1) showed high levels of activity under PEG stress, as compared to the control, particularly in cultivars Jumbo and Revolution. Guaiacol peroxidase (GPOD) showed high activity compared to the control. Guaiacol peroxidase GPOD activity might be involved in cell wall lignification, rather than in the protection of plant tissues against oxidative damage. Super oxide dismutase (SOD) (Fig. 1) exhibited elevated levels of activity under PEG stress.

SOD catalyzes the conversion of the superoxide anion to H_2O_2. Proline content was high in the sorghum seedling of different genotypes under PEG-mediated drought stress (Fig. 2). Significant proline accumulation appears to be an essential part of the drought protection mechanism of sorghum seedlings. With elevated proline content there was also a significant increase in the MDA content of the sorghum seedlings (Fig. 2). This can be explained by the assumption that the protective potential of proline was not sufficient to achieve the total removal of excess ROS. Chlorophyll content varied among treatments relative to the control. Enhanced chlorophyll content may increase the photosynthetic efficiency of plants.

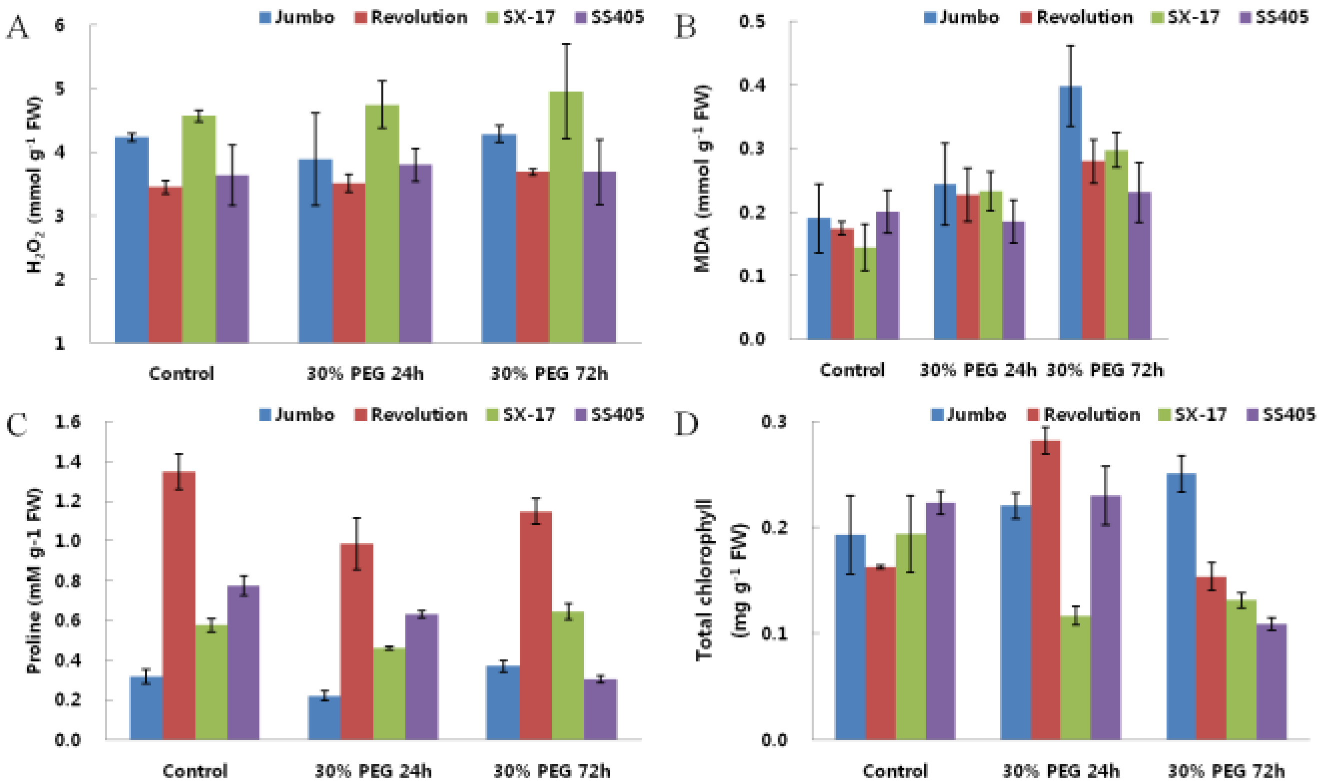

Fig. 2: Effect of PEG-mediated drought stress on the H_2O_2 (A), MDA (B), proline (C) and total chlorophyll (D) content of the seedlings of different sorghum genotypes.

Conclusion

Catalase activity increased in Jumbo, Revolution SX-17 and SS405 genotypes for 72 h treatment. It decreased in Revolution, SX-17 and SS405 at 24 h treatment. APOD activity increased in all sorghum genotypes under pEG-mediated drought stress. GPOD activity increased in all sorghum genotype except SX-17 for 24 h and Jumbo at 72 h treatment. SOD showed high activity in the seedling of sorghum genotype 'Jumbo,' 'Revolution,' and SX-17 but genotype SS-405 showed low activity. Under PEG-mediated drought stress H_2O_2 and Malondialdehyde (MDA) contents showed high amount in the seedling of all four sorghum genotype except Jumbo at 24 h treatment as compared to control condition. Content showed high contents in all sorghum genotypes with the exception of SS405 at 72 h. In PEG-mediated drought stress proline and chlorophyll contents showed different results in all four seedling of sorghum genotypes.

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