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Effect of maltose and trehalose on growth, yield and some biochemical components of wheat plant under water stress

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KEYWORDS

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Abstract In the greenhouse experiment, wheat plants (Triticum aestivum L. cv. Giza 168) were treated with 10 mM of maltose and trehalose as foliar spray using Tween 20 as wetting agent at 15, 30 and 45 days post sowing with two times of irrigation at 10 and 20 days intervals. Two samples were taken after 45 and 120 days from planting. At the first sample date, plant height, shoot fresh and dry weights and leaf area were recorded. At harvesting time (the second sample) no. of spikes/plant, no. of spikelets/plant and weight of 1000 grains were taken. Chemical analyses were conducted in leaves at the first sample date for determination of phenolic compounds, flavonoids, amino acids, reducing sugars, total soluble sugars, protein, proline, PAL, POD, ascorbate peroxidase, catalase, PPO and MDA. The obtained results indicated that maltose and trehalose had significant and positive effect on most growth parameters. Opposite trend was found in plant height, no. of spike/plant and weight of 1000 grains by drought treatment. Maltose and trehalose treatments enhanced in the most biochemical components whereas they decreased PAL and catalase activity. Variable trends in amino acids and ascorbate peroxidase were observed by drought. However, the drought has more stimulative effect in most cases than the first time period of irrigation. The results concluded that foliar applications with maltose or trehalose induced water stress tolerance in wheat plants. Maltose treatment gave the best results in most morphological parameters, grains yield and biochemical components than trehalose treatment.

Introduction

During the last 100 years, the misused and uncontrolled use of the world's nature resources has greatly destroyed its vegetation and also led to accumulation of lots of industrial wastes, all of that upturns and changes the ecosystem balance and produces many environmental and climate difficulties as drought

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and soil salinization. Drought certainly is one of the most effective factors of the environmental problems that has a great bad effect on the agricultural production, and greatly affecting crop growth, yield quantity, the variety and the quality of the essential physiological and biochemical processes in plants (Hasanuzzaman et al., 2012). In arid and semi-arid regions, that have Mediterranean climate, wheat crop is usually facing and suffering from drought stress (Mohammadi et al., 2011). Modern evidence has proved that in plants, sugars such as glucose, sucrose, and fructose are not only playing the rule of plant growth but also it affects sugar sensing system that initiates changes in gene expression and then the plant growth (Koch 1996). For example, sugar depletion, upregulates genes for photosynthesis, carbon remobilization and export, and leads to increasing vegetative and shoot growth (Percival and Fraser, 2005). Maltose is the most common sugar in barley (Lindqvist and Asp, 2002). Trehalose is a non-reducing disaccharide of glucose that stabilizes biological structures and the macromolecules as protein and membrane lipids during water deficit (Luo et al., 2010). The increase in osmoregulators Trehalose production in genetically engineered model plants is proved to be better stress tolerance (Wang et al., 2005). Externally applied maltose and trehalose are rapidly accumulated and transported by leaves and root tissues and play important roles as osmoprotectants (Smith and Smith, 1973; Luo et al., 2010). Exposing plants to drought has an effect on the plant-water relations, and decreases the water content in the leaves and whole the plant leading to osmotic stress (Alam et al., 2013). It is usual that plants suffer from the environmental stress. Decrease in the water content conditions causes a reduction in the plant photosynthetic efficiency and stomatal conductance which inhibits Rubisco activity and breaks down energy balance and breaks down the distribution during photosynthesis (Demirevska et al., 2010). As a result, the reactive oxygen species (ROS), superoxide, O_2^-, hydrogen peroxide, and hydroxyl radical, highly accumulate in the plant (Hasanuzzaman et al., 2014). The ROS are major toxic radicals which may destroy biomolecules, including lipids, proteins and DNA (Vranova et al., 2002). In the presence of drought stress, plants improve and speed specific mechanisms to grasp, understand and fast respond to various environmental cues (Demirevska et al., 2010). Enhancing enzymatic and non-enzymatic protection system is a remarkable and significant strategy to proficiently removing ROS as phenolic compounds, flavonoids, amino acids, protein, proline, MDA concentrations and peroxidase (POX), polyphenyl oxidase (PPO), catalase (CAT) and ascorbate peroxidase (APX) activities (Gupta et al., 2009; Hasanuzzaman et al., 2012). Organic compatible solutes such as maltose and trehalose have a great effect on improving drought tolerance in wheat plants (Farooq et al., 2010; Nawaz and Ashraf, 2010).

Material and Methods

Pot experiments were carried out under field conditions at Agricultural Botany Department, Faculty of Agriculture, Ain Shams University. Grains of wheat (*Triticum aestivum* L.) cultivar Giza 168 were kindly obtained from the Crop Research Institute, ARC, Ministry of Agriculture, Egypt. Fifteen grains were directly sown on 15 November 2014, in plastic pots (40 cm in diameter) filled with clay/sand (2:1 v/v) soil. Germinated seeds were thinned to five uniform seedlings per pot after two weeks of sowing. Two interval periods of irrigation; 10 and 20 days, and 10 mM of maltose or trehalose were applied as foliar application, compared with control (untreated plants). The plants were sprayed 15, 30 and 45 days after sowing. Fertilization was performed according to the recommendation of Ministry of Agriculture, as follows: calcium super phosphate (13.5% P_2O_5) was added before sowing; ammonium nitrate (33.5% N) and potassium sulfate (48% K_2O) were added in two equal doses at first and third irrigation, at rates of 2 g/pot and 0.5 g/pot, respectively. Nitrogen, phosphorus and potassium fertilizes were added as per recommendation of Ministry of Agriculture.

Four replicates for each treatment were grown in a complete randomized design. Three plants were randomly taken from each treatment for the biochemical analysis after the third spray. Three plants were randomly selected after 45 days from planting for growth measurements, i.e. plant height (cm), shoot fresh weight (g), shoot dry weight (g), flag leaf area (cm^2). At grain maturation stage, number of spikes/plant, number of spikelets/plant and weight of 1000 grains (g) were measured.

Biochemical analyses

Free amino acids and total soluble sugars were extracted from fresh leaves according to Ackerson (1981) by using 80% ethanol at 70 °C. Free amino acids were determined colorimetrically by using ninhydrin solution according to Jayeraman (1985) using glycine as a standard. Reducing sugars were determined colorimetrically by using 3,5-dinitrosalicylic acid solution according to Miller (1959) using glucose as a standard. Total soluble sugars were determined in the previous extract by adding 5 ml HCl (2N) to 15 ml of sugar extract and heated in a water bath at 60 °C for 30 min. The solution was cooled, neutralized and made the total volume 50 ml with distilled water. Total soluble sugars were determined colorimetrically by using 3,5 dinitrosalicylic acid solution according to Miller (1959).

Proline concentration was determined using ninhydrin colorimetric methods of Bates et al. (1973). Phenolic compounds and total flavonoids were extracted by macerated 0.5 g of fresh leaves in 10 ml 80% ethanol for at least 24 h at 5 °C and repeated three times. The collected extracts were completed to 50 ml using 80% ethanol. Phenolic compounds were determined by the method of Folin-Ciocalteu as described by Shahidi and Naczk (1995) using gallic acid as a standard. Total flavonoids concentration was determined by the aluminum chloride colorimetric assay according to Marinova et al. (2005) using quercetin as a standard.

Soluble protein concentration was estimated to calculate specific activity of enzymes. Protein concentrations were quantified in the crude extract by the method of Bradford (1976) using bovine serum albumin as a standard. All determinations were expressed as mg/100 g fresh weight (f.wt.).

The level of lipid peroxidation was measured by determination of malondialdehyde (MDA) in plant tissues as described by Heath and Packer (1968). The MDA concentration was calculated using an extinction coefficient of 155 mM^{-1} cm^{-1}. MDA concentration was expressed as μmol MDA/g f.wt.

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