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Research article

Physiological and antioxidant responses of winter wheat cultivars to strigolactone and salicylic acid in drought

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ABSTRACT

Strigolactones are considered as important regulators of plant growth and development. Recently positive regulatory influence of strigolactones in plant in response to drought and salt stress has been revealed. Salicylic acid, a phytohormone, has reported to be involved in a number of stress responses such as pathogen infection, UV irradiation, salinity and drought. Considering the concealed role of strigolactones in agronomic crops drought tolerance and possible interaction among salicylic acid and strigolactone, we investigated the effects of exogenous application of GR24 and salicylic acid on two winter wheat cultivars under drought conditions. Foliar GR24 and salicylic acid were applied on drought sensitive and drought tolerant winter wheat cultivars at tillering and anthesis stages in 40% and 80% of field capacity moisture levels. Strigolactones and salicylic acid treated plants showed higher tolerance to drought stress with regard to lower electrolyte leakage and higher relative water content, leaf stomatal limitation, membrane stability index and antioxidant enzyme activities. Salicylic acid application dampened malondialdehyde content in wheat plants. Drought tolerance of wheat plants were intensified in most of the cases when theses phytohormones were used together, suggesting a possible interaction between salicylic acid and strigolactones in drought situations.

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the very first crops cultivated by our ancestors; it has been extensively planted all around the world owing to its adaptation to a various range of climates. A large proportion of the worlds' wheat growing areas including Iran suffers from water scarcity at some stages during the crop growth cycle. As the global temperature will increase, plants will find it harder to receive enough water to cover their demand and survive. Globally, wheat is the main vegetable protein source in human diet, having higher protein content than other major cereals like maize and rice. Wheat mainly is planted in arid and semi-arid parts of the world. According to statistics, drought is the most common abiotic stress affecting 60 million hectares of wheat cultivation in developed countries and at least 32% of 99 million hectares of wheat cultivation are located in developing countries (ajaram and International, 1999). Drought stress could dampen wheat grain yield with average yield loss of 17–70% (Nouri-Ganbalani et al., 2009). Drought reduces expansion of leaves and stomatal conductance rapidly and may eventually affect primary events in the photosynthetic process (Passioura, 1994). The number of spikes/m^2, weight of grains/spike, harvest index and biological yield are the most important yield variables that might be influenced by drought stress condition in wheat plants (Leilah and Al-Khateeb, 2005) Plants evolved sophisticated mechanisms to adapt themselves to biotic and abiotic stresses.

A various group of signaling molecules found in small amounts in cells that mediate these situations called phytohormone. Phytohormones are key effectors of the morphological and physiological plasticity of plants in response to unfavorable environmental situations. Role of phytohormones in promoting plant acclimatization to ever-changing environments by mediating growth, development, source/sink transitions, and nutrient allocation have been deeply engrained (Fahad et al., 2015). However, plant response to abiotic stresses depends on different elements.,

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Phytohormones are considered the most important endogenous substances for modulating physiological and molecular responses and a critical requirement for plant survival as sessile organisms (Wani et al., 2016). The most crucial occupation of modern agriculture is to supply food security for the growing population of the world in a sustainable manner.

Phytohormones include auxin (IAA), cytokinins (CKs), abscisic acid (ABA), ethylene (ET), gibberellins (GAs), salicylic acid (SA), brassinosteroids (BRs), and jasmonates (JAs). The strigolactones (SL) are relatively new phytohormones gained their name from parasite plant striga. The best studied hormones in the adaptive adjustments of plants to environmental stresses are Abscisic acid (ABA), Ethylene, Jasmonic acid and Salicylic acid (SA) (Xiong et al., 2002). To cope with environmental stresses, plants responses are regulated by a crosstalk among hormones and signal molecules (Bray, 2004; Peleg and Blumwald, 2011).

Previous researches illustrated that low concentrations of SA improve the antioxident capacity of plants, but high concentrations of SA leads to cell death or susceptibility to abiotic stresses (Jumali et al., 2011). SA activates various genes that encodes antioxidants, chaperones, and heat shock proteins. These genes are also involved in the biosynthesis of secondary metabolites such as cinnamyl alcohol dehydrogenase, cytochrome P450 and sinapyl alcohol dehydrogenase (Wani et al., 2016). Studies showed that to cope with water deficit, endogenous levels of SA increase in plants (Munne-Bosch and Penuelas, 2003; Bandurska, 2005). However, the detailed molecular mechanisms of SA's roles in abiotic stress positive responses remain largely unknown and more information are needed in this direction.

SA which participate in the regulation of physiological processes and has a key role in disease resistance is an endogenous growth regulator of phenolic nature (Hussain et al., 2008). Various researches demonstrated that SA act as beneficial element in plant responses to abiotic stresses such as ozone and ultraviolet (UV) light (Yalpani et al., 1994; Sharma et al., 1996), heat stress (Senaratna et al., 2000; Larkindale and Knight, 2002) chilling and drought (Senaratna et al., 2000), and salt and osmotic stresses (Borsani et al., 2001).

Strigolactones (SLs) a small class of carotenoid-derived compounds and rhizosphere signaling molecules classified as a new class of phytohormones that regulate several different process in plants (Ruyter-Spira et al., 2013). SL first characterized around 50 years ago as seeds germination stimulants in root parasitic plants such as *Striga Orobanche* and *Phelipanche* speices (Xie et al., 2010). Recently several roles of SL in plants and rhizosphere such as suppression of shoot branching by inhibiting the outgrowth of axillary buds (Gomez-Roldan et al., 2008; Umehara et al., 2008), enhancement of symbiosis between plants and arbuscular mycorrhizal fungi (AMF) (Akiyama et al., 2005) and development of root system architecture (Ruyter-Spira et al., 2011) has been revealed. In addition, clear relationship between P contents in shoot tissues and SL exudation of plants that grow under N deficiency was discovered. In several plants, N deficiency decreased P levels in shoots, which leads to enhancement of SL exudation (Yoneyama et al., 2012). Van Ha et al. (2014) provided evidences that in Arabidopsis, SL act as positive regulator of plant to abiotic stress tolerance such as salinity and drought stress (Van Ha et al., 2014). Under unfavorable conditions such as salinity, plants increase their SL production in order to promote symbiosis establishment and cope with salt stress (Aroca et al., 2013). There is not any published paper about the role of exogenous SL on agronomic crops yet. Unlike SA, there is not enough research about SL application in agriculture up to date.

Although various phytohormones such as SA are known to be involved in regulation of plant stress responses, the role of SL and its interaction with SA in this important process remains elusive. Since wheat is one of the most significant single crop in terms of human consumption and being threatened by climate change and drought, we decided to use this crop for our trials. With the hope that this research might turn on the bright candle in this inevitable climate change dark path.

With above background information, the work presented in this paper was designed to better understand the effects of exogenous application of phytohormones SA and SL on drought tolerant and drought sensitive wheat cultivars under normal and drought stress conditioned. We also assessed the results of using these phytohormones together and alone. With uncertainties in precipitation patterns and global climate change, food security may become more vulnerable than in the past. Results of the present study demonstrate the potential for use of genetic engineering to improve the stress tolerance of wheat crops by manipulating SL and SA biosynthesis or signaling as suggested by the improved drought tolerance observed in plants subjected to external application of SL and SA.

2. Material and methods

2.1. Plant material and chemicals

Seeds of winter wheat (*Triticum aestivum* L.) cv. Pishtaz and Sirvan were obtained from seed and plant improvement Institute, Karaj, Iran. The synthetic SL analogue GR24 was provided by Binne Zwanenburg (Department of Organic Chemistry, Radbourd University, Nijmegen, the Netherlands). The SA in the form of sulphosalicylic acid dehydrate was purchased from Merck Company.

2.2. Growth condition and irrigation regimes

This study was conducted at the greenhouse of the college of Agriculture, Shiraz University, Iran, using two wheat cultivars (Sirvan as a drought tolerant and Pishtaz as a drought sensitive cultivars). Plants were watered to maintain at field capacity level before starting irrigation treatments (until anthesis stage). From anthesis to ripening drought treatment was applied to maintain 40% of field capacity, while control pots were irrigated to 80% of field capacity. Soil water content in each plot was measured using a TRIME-FM TDR (Time Domain Reflectometry, IMKO Micromodultechnik, Ettlingen, Germany).

2.3. Experimental design and treatments

The experiment was factorial based on completely randomized design (CRD) with three replicates.

There were eight treatments for each wheat cultivar: no drought stress and no foliar application (wet,- SA,- Sl), no drought stress with SA application (wet,+ SA, -SL), no drought stress with SL application (wet, -SA, +SL), no drought stress with SA and SL application (wet, +SA,+ SL), drought stress without foliar application (dry, -SA,- Sl), drought stress with SA application (dry,+ SA,-SL), drought stress with SL application (dry, -SA, +SL) and drought stress with SA and SL application (dry,+ SA, +SL).

SA (0 and 1 mM) and synthetic form of SL, GR24 (0 and 10 μM) were applied with a hand sprayer until the solution began to drip off leaves at sunset. To assure SA and SL uptake by the leaves, they were applied on two consecutive days at tillering and anthesis stages. The pots not receiving SA or SL were treated similarly with equivalent amount of distilled water.