Abstract

Morpho-physiological and biochemical analyses were carried out in eight diverse indigenous muskmelon (Cucumis melo L.) genotypes exposed to different degrees of water deficit (WD). The ability of genotypes MM-7, and especially MM-6, to counteract better the negative effect of WD was associated with maintaining higher relative water content (RWC), photosynthetic rate, efficiency of PSII, and photosynthetic pigments compare to other genotypes. Furthermore, MM-6 showed a better ability to maintain cellular homeostasis than the others. It was indicated by a stimulated antioxidative defense system, i.e., higher activities of antioxidant enzymes, accumulation of nonenzymatic antioxidants together with lower concentration of reactive oxygen species and malondialdehyde. However, the genotypes MM-2 and MM-5 suffered greatly due to WD and showed reduced RWC, photosynthetic rates, pigment content, and exhibited higher oxidative stress observed as lower antioxidant enzyme activities.

Additional key words: antioxidant enzyme; muskmelon; photosynthesis; proline; reactive oxygen species.

Introduction

Muskmelon (Cucumis melo L.) is an important vegetable that is frequently cultivated in arid and semiarid regions, where water availability is a major limitation (Cabello et al. 2009, Ibrahim 2012). Despite being water a scarce resource in (semi)arid regions, increasing demands of industrial as well as domestic sectors, particularly in developing countries like India, are forcing a decline in water availability for agriculture. Further, the foreseen consequences of change in global climate may worsen the situation in future. This highlights the urgency for developing a new strategy to identify potential genetic resources with specific traits and technological developments that can improve productivity of vegetables under declining natural resources and increasing environmental stresses (Pandey et al. 2016). Drought or water stress represents the most significant environmental constraint, limiting growth and yield efficiency of plants worldwide (Chaves et al. 2002, Adibah and Ainuddin 2011). Plants show either susceptible or tolerant response to water stress that is ascertained by interactive effects of physiological, biochemical, and morphological determinants (Penella et al. 2014).

Plants exposed to WD conditions show reductions in shoot and root biomass, leaf chlorosis and necrosis, while under mild WD, these symptoms are less apparent, but various cellular processes may be altered (Dhillon et al. 2011, Kusvuran 2012). Water stress induces in plants WD and loss of cell turgor, which in turn results in stomatal closure, and ultimately retarded photosynthesis and finally also plant growth (Lawlor 2002). Besides, at the cellular level, WD results in enhanced generation of reactive oxygen species (ROS), such as superoxide radicals (O$_2^-$),...
hydrogen peroxide (H$_2$O$_2$), and hydroxyl radicals (OH$^-$), which can directly affect membrane lipids and inactivate metabolic enzymes, as well as cause damage to nucleic acids, leading to cell death. The half-life of H$_2$O$_2$ is comparatively longer than that of other ROS, and the enhanced H$_2$O$_2$ in plant cells may lead to oxidative stress (Deeba et al. 2012). However, in order to cope with such disorders, plants employ various mechanisms. A complex antioxidant defense system exists against ROS to protect the plant cells (Gill and Tuteja 2010). It includes antioxidant enzymes, such as superoxide dismutase (SOD), catalase (CAT) ascorbate peroxidase (APX), and peroxidase (POD), as well as nonenzymatic antioxidants, such as reduced glutathione, ascorbic acid, α-tocopherol, and carotenoids (Kumar et al. 2015a). During the enzymatic detoxifying process, the first enzyme, SOD, dismutates O$_2^-$ to H$_2$O$_2$, then CAT and peroxidases scavenge the accumulated H$_2$O$_2$ to render it to nontoxic concentrations by conversion to H$_2$O and O$_2$ (Colla et al. 2013). In addition, the accumulation of compatible solutes (e.g., sugars, proline, glycinebetaine, or potassium) is an important strategy that plants adopt to protect against cellular dehydration by maintaining the osmotic strength of the cytoplasm and thus sustaining plant physiological processes and growth (Lee et al. 2009, Kravić et al. 2013, Penella et al. 2014). Plant responses to WD can be determined by comprehensive analyses of their physiological, biochemical, and molecular traits. Therefore, plant's capacity to withstand WD is of great significance in an ever-changing climate. Once a genotype with high water-use efficiency (WUE) and better yield has been identified, it can be utilized for future breeding programs to develop more efficient varieties (Pandey et al. 2013).

The reactions, as well as a potential to withstand drought environments, depend on the species and genotype, duration and level of water loss, age and stage of development, organ, cell type, and type of subcellular compartment (Jaleel et al. 2008). Hence, many reports demonstrate differential responses of species or genotypes to drought stress (Dhillon et al. 2011, Pandey et al. 2013). Although, a number of drought-tolerant genotypes have been identified in many crops (Fleury et al. 2010), limited information is available for muskmelon (Cabello et al. 2009, Kusvuran 2012). In fact, the Indian muskmelon varieties were developed under best agronomic practices, including irrigation, but they have been hardly tested for yield efficiency under drought conditions (Pandey et al. 2008). Like many other vegetables, muskmelon plant is sensitive to water stress probably due to its larger leaf surface which evokes more transpiration, as reported in pepper by Penella et al. (2014). In general, muskmelon growth and productivity are greatly affected by drought stress. For example, the total production of melon in Gansu province (China) declined by 50% as a result of severe drought (Feng and Wu 2007). Therefore, in the area with decreased water availability, an improvement in crop yield is the main scientific and economic challenge (Penella et al. 2014). The potential of indigenous genetic materials for Indian muskmelon has been revealed in earlier studies for a range of traits (Pandey et al. 2008, 2013, 2016; Ansari et al. 2017). However, detailed study of genotypes required based on various physiological and biochemical parameters to explore the intrinsic potential of selected materials against the specific environmental constraints. In view of this, the present study aimed to elucidate the differential responses of diverse indigenous genotypes of muskmelon by assessing their intrinsic potential at different physiological and biochemical processes under varying degree of WD.

Materials and methods

Plant materials, experimental conditions and water-stress treatments: Eight diverse indigenous muskmelon genotypes: Arka Jeet (MM-1), IIHR-663 (MM-2), Dharwad Selection 1 (MM-3), Hara Madhu (MM-4), IIHR-595 (MM-5), MJ-7 (MM-6), BS-25 (MM-7), and IIHR-659 (MM-8), were selected for the present study. Genotypes were identified according to preliminary field screening (Pandey et al. 2013). The experiment was conducted at the experimental field of ICAR – Indian Institute of Vegetable Research, Varanasi (25.10°N, 82.52°E and 76.1 m above mean sea level in the Eastern Indo-Gangetic Plain of India). Plants were grown in 10-L pots (22 cm in diameter and 23.8 cm in height) and the experiment consisted of four sets [i.e., 0 (for control well irrigated), 7, 14, and 21 d of water deficit, DWD]. Each set was replicated thrice and each genotype included five pots in each set. The soil in the pots was a mixture of sand, loamy clay, and farmyard manure (1:2:1, v/v) with a bulk density of 1.34 g cm$^{-3}$ and pH 6.8. The soil had 0.39% (w/w) organic carbon content, 0.30% (w/w) total nitrogen content, and 0.51 mgAvailable phosphorus) g$^{-1}$, and 0.35 mg(potassium) g$^{-2}$. During the experiment, mean temperature and relative humidity ranged from 21.4 to 38.2°C and 59–89%, respectively. Water (2 L) was applied at 3-d intervals to each pot until imposition of WD treatment (i.e., 30 d after seed germination). WD was imposed by withholding water for 0, 7, 14, and 21 d (DWD). The arrangement of experimental pots were random and periodically rotated to minimize the effects of environmental heterogeneity. Plants of muskmelon genotypes were grown under greenhouse conditions and natural light/dark cycle.

Soil moisture was measured according to the formula: soil water content [%] = [(FM – DM)/DM] × 100, where FM is the fresh mass of the soil portion taken from the pot and DM is the dry mass of the soil portion after drying in a hot air oven at 85°C for 4 d (Cha-um et al. 2013). The fully expanded 6–7th leaf from the tip was harvested on