Salinity tolerance screening in Iranian and Afghan melons (Cucumis melon) based on several associated morphological and physiological traits

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Article

Keywords: Abiotic stress, Genetic diversity, Melon yield, Salinity, Tolerated cultivar, Total antioxidant activity

Posted Date: February 14th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2558976/v1

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Abstract

This study was carried out to investigate the effect of salinity on some physiological and morphological traits of native Iranian and Afghan melon cultivars using a split-plot experiment with a randomized complete block design and three replications. Two salinity levels (2 and 8 dSm\(^{-1}\) NaCl) and 39 cultivars from Iran and Afghanistan were utilized. This study was carried out to investigate the effect of salinity stress on growth and yield and recommend the tolerant genotype(s). PCA comparisons were done between biochemical and morphological parameters. The sensitive and tolerant cultivar was chosen based on proximity to high yield, morphological characteristics, and distance from stress indices. The biplot results showed a high correlation between vitamin C traits with soluble solids, proline, and relative water content and a negative correlation with Fv/Fm ratio. These indices are good indicators for identifying saline resistance cultivars. Salinity stress increased electrolyte leakage, proline concentration, total antioxidant activity, Na content, vitamin C, organic acid, and total soluble solids. In addition, salinity decreased the yield, mean fruit weight, firmness, fruit length, fruit width, internal cavity length, internal cavity width, flesh thickness and fruit peel thickness, Fv/Fm ratio, greenness index, relative water content, leaf K. The highest concentrations of Na and K were found in the G-SHI cultivar under salinity, while the highest concentrations of Na and K were found in the Tork cultivar under non-saline conditions. Based on the results, two types of Tork and Zank melon were recommended to plant in saline conditions.

Highlights

- Salt-tolerant cultivars have superior morphological characteristics and can produce higher-quality fruit under saline stress.
- Salinity stress increased electrolyte leakage, proline concentration, total antioxidant activity, Na content, vitamin C, organic acid, and total soluble solids.
- Between the 39 Afghan and Iranian plants tested in this experiment, Tork and Zank were advised to be grown in saline conditions.

1. Introduction

The melon (Cucumis melo L.) is one of the world's most significant horticulture crops, growing extensively in arid and semiarid regions (Akrami and Arzani 2018). Iran, the world's third-largest producer of melons, produces over 1.5 million tons per year, the majority of which is grown in saline zones (FAO 2016).

There is a salinity problem on 65% of the world's agricultural land (Erdinc et al. 2021). The process of evapotranspiration is intimately tied to the accumulation of salts in the soil (Pereira et al. 2020). Pereira et al. (2017) found that the susceptibility and tolerance of plants to salt may vary between species and cultivars of the same species, depending on regional climate variations, soil type, and irrigation management. Each plant species responds uniquely to adversity, resulting in a range of stress tolerance levels. Due to the use of excessive fertilizers and excessively saline water, saline environments are a
significant contributor to the rise in agricultural stress conditions (Dias et al. 2018). According to Pereira et al. (2020), salinity tolerance is primarily determined by the concentration and kind of salt in the irrigation water, the length of time the plant is exposed to salts, and how the salt comes into contact with the plant. The physical and chemical qualities of the soil are altered by salinity, which also diminishes the output of agricultural products. Then, half or all of the fertility of agricultural land is lost.

It has been found that salinity reduces vegetative growth in terms of growth rates, with dwarf structures and dark green, tiny leaves (Kusvuran 2012). Researchers have suggested that a reduction in leaf area under saline circumstances may be connected with a reduction in cellular swelling or a change in the transmission of hormonal signals from the base to the leaves (El-Hendawy 2004).

Under salt stress, osmotic potential due to limited water uptake from the soil and ion toxicity cause cell dysfunction and damage to physiological activities, such as photosynthesis and respiration, resulting in diminished plant growth and development at various growth stages (Deinlein et al. 2014). The plant has evolved many physiological and biochemical methods to alleviate the impacts of salinity stress, including osmotic adjustment, osmolyte accumulation enhancement, regulation of ion homeostasis, and antioxidant defense, all of which increase cell function as membrane integrity (Akrami and Arzani 2018).

The salinity tolerance threshold for melon is 2.2 dSm\(^{-1}\). Melon is a salt-sensitive crop (da Silva et al. 2020). The electric conductivity (EC) value of 3.31 dSm\(^{-1}\) has no significant effect on melon production, according to da Silva et al. (2020). In contrast, when the soil is irrigated with water with a high percentage of salt, a decrease in productivity is typically observed. Numerous researchers have studied the effects of salinity on melon cultivars throughout the entire crop cycle or at specific phenological stages and have determined that melons are sensitive to moderately sensitive plants and salinity (Erdinc et al. 2021). According to da Silva et al. (2021), to correct the osmotic potential within the cell, melon eliminates Na\(^+\) and Cl\(^-\) ions and synthesizes suitable solutes, such as proline and citrulline.

Pereira et al. (2017) investigated the impact of irrigation water salinity on melon cultivars and discovered that high water salinity decreases yield. Morais et al. (2018) demonstrated that increasing salinity in the nutrient solution lowered photosynthetic efficiency, transpiration rates, and stomatal conductance. Additionally, salinity increased intercellular CO\(_2\) concentrations in melon (Dias et al. 2018). According to Diniz Neto et al. (2014), the total number of fruits was altered by saline water management measures. The irrigation treatment of two days of nonsaline water followed by one day of saline water reduced the commercial production of watermelon by approximately 33 percent. According to Pereira et al. (2017), increasing irrigation water salinity lowers the growth, dry mass, and physiological attributes of melon cultivars. However, extensive research on the reaction of melons to salinity has revealed that melons’ tolerance is cultivar-dependent (Dias et al. 2018). Some melon cultivars are tolerant of salinity because they have more effective mechanisms for stress resistance, allowing them to be grown in salinized environments (Da Silva et al. 2021). Pereira et al. (2017) investigated five melon cultivars and discovered that Sancho was the most salinity-tolerant, followed by Mandacaru, Medellín, Sedna, and Néctar.
This study investigated the responses of Iranian and Afghan melon cultivars to salinity to determine: i) the effect of salinity stress on growth and yield; ii) the identification of some physiological markers of salinity tolerance, and iii) the selection of salinity-tolerant cultivars for future study and recommended to cultivate in the saline region.

2. Results

2.1. The result of the first experiment

PCA comparisons between biochemical and morphological parameters were presented in Figures. 2 and 3. The sensitive and tolerant cultivar was chosen based on proximity to high yield and improved morphological characteristics, and distance from stress indices in PCA analysis for biochemical parameters and stress indices. Additionally, we utilized ANOVA on all cultivars exposed to salinity in the supplementary file to select the most sensitive and tolerant cultivar. For the second experiment, tolerant (Tork and Zank) and sensitive (G-IVA and G-SHI) cultivars under salinity stress were separated between all cultivars (Iranian and Afghan cultivars) for a more in-depth investigation. The biplot results showed a high correlation between vitamin C traits with soluble solids, proline, and relative water content and a negative correlation with Fv/Fm ratio. Several cultivars, including Naki Johari, Hatchke Daroneh, Ghatori, Ghandak Tanabisefid, Hatchke Johari, Talebi Tanbalemax, and Zanki, due to the high produced concentration of proline, soluble solids, vitamin C, and relative leaf water content in salinity stress and due to the high correlation with the mentioned related traits with stress resistance are classified as cultivars tolerant to salinity stress.

The cluster analysis of the 18 melon cultivars based on biochemical traits produced two main clusters, including Naki Johari, Gezgi, Bandi Boyak, Hachkeh Drone, Kale Gorfi, Gorgab, Talebi Tanbalmax, Ghatori, Bargeney, Ghandake Tanabisefid, Hachkeh Johari, AbuJahl, Taki, Kaledorgi Droneh, Zanaki, and Chini, which were classified in the first group and as stress-tolerant cultivars. The cluster analysis of the 18 melon cultivars based on morphological traits also produced three groups: Kaleh Gorgi, Hachkeh Johari, Torkamani, Gorgi Shirdan Jorjeaval, and Gezgi cultivars are morphologically more prominent in their peel than other cultivars. There are Ghatori, Gorgi Ivan, Kadoei, and AbuJahl watermelons in the second group, which are better than other cultivars in terms of spots on the peel. The biplot diagram of these traits also confirms this issue.

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2.2. The result of the second experiment

Fruit hardness, length, flesh thickness, and seed hole length were enhanced in Tork and Zank, particularly under control and non-saline conditions. However, neither fruit width nor cavity width differed significantly between tolerant and sensitive cultivars (Fig. 3a-f). Fruit skin thickness, seed mass weight, yield per plant, and fruit weight followed the same pattern and were greatest in Tork, followed by Zank, when compared to salinity-sensitive cultivars (G-IVA and G-SHI). Seed length and diameter were similar between Tork and Zank. Seed length was substantially greater in tolerant cultivars compared to sensitive cultivars, although seed diameter was significantly the same (Fig. 4a-f).

Vitamin C and TSS rose in all cultivars due to salt. The Zank in salinity contained the highest levels of Vitamin C. The TA content of the tolerated cultivar increased in both salinity conditions. The cultivar with the greatest TSS was tolerant of salinity. Na increased, and K decreased by salinity. However, it was not statistically different by the nonsaline condition in each cultivar. The highest Na was in G-SHI salinity, and the highest K Conc. was in Tork at non-saline conditions (Fig. 5a-f).

Chlorophyll fluorescence was similar across all treatments and was unaffected by cultivar. The chlorophyll index increased in the tolerated cultivar in control and it was significantly the same in Tork and Zank and G-SHI cultivar in salinity. G-IVA had the lowest Chlorophyll index in both saline conditions. RWC was greater in tolerant cultivars (Tork and Zank) in both saline conditions, but it was lower in sensitive cultivars (G-IVA and G-SHI) under salt stress. EL decreased in tolerated cultivars (Tork and Zank) and increased in sensitive cultivars (G-IVA and G-SHI) in both saline conditions. All cultivars exhibited a rise in DPPH in response to salt, with G-IVA in non-saline conditions exhibiting the lowest DPPH (Fig. 6a-f).

3. Discussion
The effect of salinity on some morphological parameters in a tolerated and sensitive cultivar of studied melons

Due to a significant correlation with stress-related features such as proline and soluble solids, the relative water content of the leaf, and vitamin C, melon cultivars that are tolerant to salinity stress are ideal for field cultivation in saline soil. Torkamani and Zanki are the most suitable melon cultivars for field cultivation based on quantitative and qualitative fruit characteristics, including fruit length, fruit width, the internal length of the cavity, internal cavity width, fruit flesh thickness, yield, mean fruit weight, seed weight, vitamin C, soluble solids, organic acid, and fruit firmness.

The effect of salinity on yield and chlorophyll index, the water content of tolerated and sensitive cultivars of studied melons

According to Aslam et al. (2004), the reduction in leaf area and yield under saline conditions was a result of reduced growth due to decreased water intake, Na\(^+\), and Cl\(^-\) toxicity in the shoot cell, and reduced photosynthesis. They also indicated that a decrease in chlorophyll concentrations is possible due to the inhibitory effect of accumulated ions of various salts on the production of the various chlorophyll components. The effects of salinity stress on fruit yield, average fruit weight, fruit length, fruit breadth, fruit flesh thickness, length of internal fruit cavity, the width of internal fruit cavity, peel thickness, seed length, seed diameter, and seed mass weight were substantial. All characteristics reduced as salinity increased. Under salinity stress, a low fruit yield was caused by a decrease in fruit number and fruit weight, as these are the two most essential yield components. Multiple research demonstrated that increasing salinity has little effect on melons (Mendlinger and Pasternak 1992; Shannon and Francois 1978). According to Perez-Alfocea et al. (1994), the number of edible onions and tomatoes reduced as salinity increased. Akrami et al. (2018) demonstrated that fruit peel thickness was not affected by different salinity levels or salinization periods, whereas Da Silva et al. (2018) demonstrated that Fruit length and diameter, as well as peel and pulp thickness, decreased when subjected to EC values greater than 3.8 dSm\(^{-1}\).

Photosynthesis is the most critical physiological function of the plant, determining plant growth and yield to the greatest extent (Mobin and Khan 2007). The decrease in yield and fruit weight of sensitive cultivars is correlated with the expansion of the fruit's cavity and its pulp's reducing diameter. In the confirmation of these results, fruit length, fruit width, fresh weight of pulp, fresh weight of skin, fresh and dry seed weight, dry weight of 100 g pulp, and skin decreased significantly in the sensitive cultivar. As the number of epidermal cells increases, the stomata become narrower and retain cell moisture more effectively. According to Colla et al. (2006), the decrease in fruit yield is primarily attributable to the lower mean fruit weight in the salinity condition. Environmental stressors such as salt and temperature influence nearly every part of the physiology and biochemistry of plants and significantly reduce their...
Numerous researchers have documented a decline in fruit yield in response to salt stress (Zong et al. 2011; Hnilickova et al. 2019; Mohamed et al. 2020).

In conditions of mild stress, the chlorophyll content of a plant could increase by reducing leaf area. In other words, the rise in chlorophyll content under stress is the result of the reduction in leaf area and the thickening of cells, which causes the leaf cells to shrink. In contrast, high stress inhibits chlorophyll synthesis, corresponding with the findings of this experiment. The drop in SPAD value at salinity can be linked to the degradation of chloroplast structure, which reduces chlorophyll content. Pumpkins have also been reported to have chlorophyll concentration decreases due to salt, corresponding with our observations (Sevengor et al. 2011). Due to Na ion buildup in the leaves, chlorophyll concentration dropped (Molazem et al. 2010). Chlorophyll collects the light required for photosynthesis (Farooq et al. 2009). Maintaining chlorophyll and carotenoid levels, as well as preserving the photosynthetic machinery of Capsicum plants in optimal condition during drought stress, was attributed to the plant's resistance to stress, according to their findings in tolerated cultivars compared with sensitive ones (Olarewaju Okunlola et al. 2017).

Relative water content is a more accurate indicator of water status in plant tissues than cell water potential. In plant cells, the potential of intracellular solutions is determined by the volume of water and the concentration of soluble chemicals (Schonfeld et al. 1988). In the present experiment, the cultivar with the highest and lowest relative leaf water content was determined to be the cultivar with tolerance and sensitivity, respectively. The high relative water content in stress-tolerant cultivars may be attributable to processes that limit water loss by closing the stomata or increasing water uptake through root growth (Kaya et al. 2007). If stomatal conductance and photosynthesis are diminished, the plant will have less growth and a lower yield (Kumar and Sharma 2010). Salinity lowered stomatal conductance and the efficiency of photosynthetic electron transport (Sun et al. 2016; Hnilickoval et al. 2019).

The effect of salinity on Na, K, and TSS in a tolerated and sensitive cultivar of studied melons

The plant uses sodium for osmotic pressure and water uptake, but extremely excessive amounts are poisonous. By applying salinity stress, the amount of sodium in the shoot of melon increased, and the amount of sodium in the shoot was influenced. Due to a high Na+ concentration in the rhizosphere and the replacement of this ion by K+, the sodium content of the shoot rises during salinity stress. Under salinity stress, Na+ competes with K+ and decreases the absorption of other ions, particularly potassium (Parida et al. 2005). This study revealed that sensitive cultivars had the most sodium rise in response to salt stress compared to the tolerated cultivars. Increasing salinity increases Na absorption while decreasing K absorption. K is a vital plant element, and as its concentration decreases, stomata close and photosynthesis slows, resulting in a decline in plant development (Mirmohammadi Meybodi and Ghareh yazi 2002).

Potassium is one of the most important elements that play a key part in maintaining a low osmotic potential, the need for water balance within the plant, and the transfer of solutes owing to turbulence.
pressure in the wood vessel. Salinity treatment decreased the amount of potassium, according to the findings of the current study; Due to their chemical closeness, the concentration of sodium ions in the rhizosphere hinders the uptake of potassium ions under salinity conditions (Zhu et al. 2008). Potassium depletion under salt stress may be caused by sodium competition for binding sites on plasma membrane transporters or potassium loss as a result of plasma membrane instability (Fakhrfeshani et al. 2015). The conflict between sodium and potassium in root uptake is the reason for the decrease in root potassium at high doses of sodium chloride.

In the present study, a decrease in K content in salinity was detected in melons. According to Ou et al. (2011) and Polacik and Maricle (2013), the most probable explanation for this controversy involves root-to-shoot nutrient translocation, species features, and duration of stress. Salt creates a 'physiological drought' by decreasing stomatal conductivity (Ou et al. 2011; Polacik and Maricle 2013), so reducing the flow of nutrients to the shoot; may result in a drop in K concentration with extended salinity exposure (Jackson et al. 1996). Root growth is unaffected by the shock stress (Malik et al. 2002); this may result in a substantial uptake of K by the shoot (Wang and Wu 2013).

By increasing Na accumulation due to salinity, K$^+$ ion uptake is diminished due to increased competition (Akca and Samsunlu 2012). The interruption of K and Ca absorption caused by Na increased salt tolerance. Tolerant melons utilized this plant defense mechanism against Na stress (Shi et al. 2003; Lecerda et al. 2005).

Total soluble solids (TSS) rose as salinity increased, particularly in tolerant cultivars.

Since the accumulation of soluble chemicals in various plant parts reflects the plant's adaptability to osmotic regulation, it can be deduced that osmotic regulation is greater in these melons. By applying stress during the key phase of sugar accumulation in the fruit, it is likely to increase the fruit's soluble solids by increasing photosynthesis and the distribution of assimilates from the source leaves to the fruit (Long et al. 2006).

The salinity stress treatment decreased fruit firmness relative to the control treatment. Changes in fruit tissue stiffness caused by salt stress are directly connected to cell wall composition (Sato et al. 2006). Due to salt stress, calcium absorption is diminished, and calcium's involvement in cell wall strength causes fruit tissue to soften. Botia et al. (2005) observed that irrigation with salt water throughout the growing season decreased the yield of melon fruit. In this treatment, fruit quality increased in both cultivars, including total soluble solids and ripening coefficient. It has been observed that saline water improves the quality of melon fruit. Increasing salt per unit from 3 dS/m lowered tomato fruit yield by 9 to 10% of decreased fruit weight and fruit number (Cuartero and Fernandez-Munoz 1998).

It was discovered that the soluble solids content of melons increased as salinity rose, whereas fruit size decreased (Shannon and Francois 1978). Identical outcomes were seen in this experiment. The greatest soluble solid is found in cultivars with tolerance. The existence of a higher TSS in the salinity-tolerant cultivar may aid in maintaining osmotic control in fruits, hence preserving photosynthesis under stress,
preventing a decrease in assimilate production in leaves and preventing a decrease in fruit weight. The results of this experiment prove their validity. In sensitive cultivars, salinity lowered fruit quality in terms of firmness and acidity. Melons irrigated with saline water exhibited improved fruit quality, as evidenced by a rise in TSS and a decrease in pH (Botia et al. 2005).

The effect of salinity on some stress indices of tolerated and sensitive cultivars of studied melons

The Fv/Fm ratio can indicate the plant's resistance to environmental pressures and the extent of its damage. Salinity stress increases variable fluorescence (Fv), maximum fluorescence (Fm), and beginning fluorescence (Fo) while decreasing photosystem II's maximal quantum performance under dark conditions (Fv/Fm) (Kao et al. 2007, Zhao et al. 2007).

Proline was increased in tolerated melon more than in sensitive cultivars. Proline accumulates in all plant organs; however, it accumulates more rapidly and in greater quantities in the leaves. Proline accumulation in tissues is the result of proline synthesis under stress conditions and its protection from oxidation, as demonstrated by multiple studies (Misra and Gupta 2005). Increasing proline concentration under salt conditions may be the result of biosynthesis or a decrease in proline's oxidation to glutamate conversion protein to proline (Flowers et al. 1977). Salinity raises the concentration of proline, which functions as osmoregulation, membrane stabilization, and reactive oxygen species (ROS) scavenger (Kushwaha et al. 2020). The proline act as osmoregulation in salinity and retains the RWC in better condition but does not act as a membrane stabilizer because the results for EL and proline did not reflect the same trend.

Proline concentration increased simultaneously with the decrease in leaf water content and the severity of salt stress. Given the importance of proline amino acids in moderating the harmful effects of environmental stressors, particularly salinity and osmotic control, this rise seems justifiable (Nasir Khan et al. 2007). The accumulation of proline in a plant increases its tolerance to salt. The greater the proline content in plant tissues, the greater the plant's resistance to stress (Kishor et al. 2005). During times of stress, proline increases in all plant organs.

However, it accumulates more rapidly and in greater quantities in the leaves than in other organs. Proline is one of the osmotically regulating chemicals, and its increase in plant tissue is one of the most salinity-induced alterations in plants. Under salinity circumstances, osmotic regulators enhance the osmotic pressure of the cell cytoplasm and stabilize proteins and membranes (Perez-Alfocea et al. 1994). Multiple reports of proline synthesis under stress and avoidance of oxidation indicate that proline accumulation in stressed tissues results from proline production (Mansour 2000; Misra and Gupta 2005). The rise in proline concentration under salinity stress may be the result of biosynthesis, decreased proline oxidation to glutamate, or protein conversion to proline. Additionally, proline supplies the energy required to deposit ions in the vacuole (Flowers et al. 1977).

DPPH% increased in all melons under salinity but is greater increase was seen in tolerated cultivars. Similar to other abiotic stresses, salinity exposure induces oxidative damage via reactive oxygen species. Oxidative stress caused by salinity leads to peroxidation of membrane lipid and loss of selectivity,
resulting in increased permeability of cell membranes to ions and electrolytes; thus, salinity indirectly reduces membrane cohesion and increases the percentage of ion electrolyte leakage from leaves (Wu et al. 1998). Abraham et al. (2004) reported that cell membrane stability decreases under stress and the cell wall is destroyed, and cell fluid enters.

The atmosphere is compromised, and electrolyte loss increases. By measuring the radical activity of DPPH, the activity of non-enzymatic antioxidants is determined (Kang and Saltveit 2002). Antibody activity can be measured by preventing the generation of free radicals or removing them in a radical-generating system. According to our findings, salt stress increased the antioxidant activity of many melon cultivars. In this investigation, the salinity treatment of 8 dSm⁻¹ resulted in the maximum amount of tolerance. Utilizing antioxidant enzymes, \( \text{H}_2\text{O}_2 \) is decontaminated. The activity of oxidative enzymes also reduces the accumulation of reactive oxygen species, which causes damage to plant tissue and disrupts the function of vital enzymes in the plant’s metabolic cycles, thereby enhancing the growth of these cultivars. It has been reported that salinity stress increases antioxidant activity by increasing the accumulation of phenolic compounds.

Significant increases in electrolyte leakage produced by free radical generation in a chain reaction beginning with photosynthesis were triggered by salinity (Ghoulam et al. 2002).

In addition, ion imbalance with salinity, particularly Na in salinity, increases phenol content and antioxidant activity above EL %. However, a substantial correlation between Na accumulation and EL increase was seen in the biplot test.

Tolerant cultivars have the highest phenol content and antioxidant activity. Increasing phenol and antioxidants appear to be another resistance mechanism that helps melons maintain development in saline. Rezazadeh et al. (2012) examined the effect of salinity stress on the phenolic compounds and antioxidant activity of artichoke leaves and found that salinity increased phenolic compounds. Some researchers have identified an association between antioxidant activity and phenolic chemicals, whereas others have documented a poor link or no correlation between antioxidant activity and phenolic compounds in the leaf (Keutgen and Pawelzik 2007).

All cultivars accumulated proline in their leaves during stress.

4. Conclusion

Conclusively tolerant cultivar by enhancing osmolytes such as proline, TSS, and K, antioxidant activity, vitamin C as a radical scavenger, and TA to achieve commercial yield and quality. It appears that melons, through osmoregulation with proline, TSS, and K, attempt to reduce the negative effects of saline stress, however further physiological studies are required for confirmation. So between the 39 Afghan and Iranian plants tested in this experiment, Tork and Zank were advised to be grown in saline conditions. In future studies, this tolerant cultivar can be used for breeding objectives. Consider the fact that salt-
tolerant cultivars have superior morphological characteristics and can produce higher-quality fruit under saline stress.

5. Materials And Methods

First experiment

Field experiments: Assessment of salinity tolerance in melon cultivars

Treatments consisted of thirty-nine Iranian and Afghan melons cultivars irrigated with $S_1 = 2$ and $S_2 = 8$ dSm$^{-1}$ of NaCl as control and salinity levels. The experimental design was performed as split-plot randomized blocks, with two irrigation levels, 39 melon genotypes, and three replications with three plants in each replicate. We compiled all the relevant institutional, national, and international guidelines and legislation for the cultivation of plants were followed. This investigation was conducted at the Isfahan University of Technology Lavark Research Farm Station, located in Najaf Abad (32°32′N, 51°23′E, 1630 m above mean sea level, mean annual temperature 14.5°C, and 140 mm mean annual precipitation), Iran. Based on the Koppan grouping system, it has a semi-arid climate with hot and dry summers. The soil texture was clay loam, thermic Typic, Haploargids with a bulk density of 1.4 g cm$^{-3}$ and an average pH of 7.5. Based on an initial soil investigation, plowing, animal manure, and chemical fertilizers were applied. Thirty-nine varieties of Iranian and Afghan melons 14 from the central part of Iran and 26 cultivars from the southwest of Afghanistan described in Table 1 (Fig. 7), were collected were planted in fourteen rows (seven rows as control treatments and seven rows as salinity treatments) with a 2 m row spacing and a 36 m row length.
Table 1
Studied samples and their collection places.

<table>
<thead>
<tr>
<th>Accession number</th>
<th>Native name</th>
<th>Species</th>
<th>Place of collection</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Naki</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
<td>35°63 N</td>
</tr>
<tr>
<td>2</td>
<td>Ghatori</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
<td>35°63 N</td>
</tr>
<tr>
<td>3</td>
<td>Potk-e Ablagh</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
<td>35°63 N</td>
</tr>
<tr>
<td>4</td>
<td>Barg-e Ney</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
<td>35°63 N</td>
</tr>
<tr>
<td>5</td>
<td>Ghandak-e Zard</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
<td>35°63 N</td>
</tr>
<tr>
<td>6</td>
<td>Murchaghi</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
<td>35°63 N</td>
</tr>
<tr>
<td>7</td>
<td>Saderati</td>
<td>Cucumis melo L.</td>
<td>Iran-Isfahan</td>
<td>32°51 N</td>
</tr>
<tr>
<td>8</td>
<td>Bandi Pirzali</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
<td>35°63 N</td>
</tr>
<tr>
<td>9</td>
<td>Zanki</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
<td>35°63 N</td>
</tr>
<tr>
<td>10</td>
<td>Kale gorgi doroneh</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
<td>35°63 N</td>
</tr>
<tr>
<td>11</td>
<td>Habibabadi Cantaloupe</td>
<td>Cucumis melo L.</td>
<td>Iran-Isfahan</td>
<td>32°51 N</td>
</tr>
<tr>
<td>12</td>
<td>Zardak</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
<td>35°63 N</td>
</tr>
<tr>
<td>13</td>
<td>Gorgi from Shirdan</td>
<td>Cucumis melo L.</td>
<td>Iran-Isfahan</td>
<td>32°51 N</td>
</tr>
<tr>
<td>14</td>
<td>Isfahan melon</td>
<td>Cucumis melo L.</td>
<td>Iran-Isfahan</td>
<td>32°51 N</td>
</tr>
<tr>
<td>15</td>
<td>Nazokch-e Nasvari</td>
<td>Cucumis melo L.</td>
<td>Afghanistan-Badghis</td>
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The plants were spaced apart by 50 cm. At the four-leaf stage of the melon seedling, two water salinity of 2 as a control according to the well EC of the region and 8 dSm$^{-1}$ were applied. The plant was irrigated (once every 4–6 days) utilizing drip irrigation systems with a dripper distance of 50 cm, based on its water requirements. This experiment was conducted using a split-plot, randomized complete block, three-replication design. After harvesting the fruit, the following morphological and physiological characteristics were investigated. The leaves were collected twice, 70, and 75 days after planting.

Evaluation of physiological and morphological characteristics

The responses of native Iranian and Afghan melon cultivars to salinity stress were examined by assessing the changes in biochemical characteristics of leaf samples collected at the visible flag leaf stage (41 days after sowing). 22 Morpho-physiological characteristics were evaluated and described according to descriptor (ECPGR 2008). leaf length and width, fruit ripening time, fruit length and width, inside fruit length and width, fruit weight, fruit skin thickness, flesh fruit thickness, tail length and thickness, flesh thickness, fruit tissue firmness, groove width, length and width of seed cavity, 1000-seed weight, fruit color before and after ripening, fruit shape, fruit tail changes after ripening, skin pattern surface of the fruit, total soluble solids (TSS) of fruit, juice pH, taste quality.

The relative water content (RWC)

The relative leaf water content (RWC) was determined using the method of Filella et al. (1998). To accomplish this, 0.5 g of fresh leaves from the youngest mature leaves (FW) were extracted from each sample and replication and placed in distilled water for 24 hours. The samples were then cleaned for surface moisture and weighed once more (TW). The leaf samples were dried for 48 hours at 75°C, and their dry weight (DW) was determined. The relative water content of the leaves was determined by the following formula:

$$RWC = (FW - DW) / (FW - DW) \times 100 \quad (1)$$
SPAD index

Using a chlorophyll meter (CLO1), the SPAD index of the youngest completely grown leaves was determined at the conclusion of the experiment (Hansateach instruments LTD, UK). In order to accomplish this, three readings of each sample were taken in each treatment replication, and their mean was then calculated (Franco et al. 1993).

Leaf proline concentration

Bates et al. (1973) developed a method for determining the proline concentration in leaves. First, 0.5 g of each experimental unit's fully expanded leaves were weighed. After freezing the samples in liquid nitrogen and pouring them into test tubes, 10 mL of 3 percent Sulfosalicylic acid was added to each tube, and the tubes were centrifuged at 30,000 revolutions per minute for 30 minutes. Each Falcon tube received 2 mL of the produced extract, followed by 2 mL of Ninhydrin and 2 mL of pure acetic acid. Closed tubes were placed in a 100°C hot water bath for one hour. They were immediately transferred from the hot water bath to the ice water bath to cease the reactions. After cooling, 4 mL of toluene was added to each tube, which was then vortexed for 20 seconds to create two distinct layers. Using a toluene-control spectrophotometer, the upper-colored portion's absorption rate was determined at 520 nm (UV-600A model).

Electrolyte evaporation

The proportion of electrolyte leakage was determined using the method of Lutts et al. (1996). From the plant leaves, three one-centimeter-diameter discs were made. The samples were cleaned three times with distilled water and once with deionized water before being placed in tubes containing 10 mL of deionized water and shaken.

Using a conductometer, the initial electrical conductivity \( (EC_1) \) of the solution was measured after 24 hours (CC-50). The tubes were then placed in an autoclave for 20 minutes at a temperature of 120°C. After removing the test tubes from the autoclave and bringing them to room temperature, the final electrical conductivity \( (EC_2) \) of the solutions was determined. Following this, the proportion of leaf electrolyte loss was calculated:

\[
\text{Electrolyte leakage (\%)} = \left( \frac{EC_1}{EC_2} \right) \times 100
\]

Na and K concentration

Leaves extract is made with diluted nitric acid and potassium concentrations determined using a flame photometer (Model PFP7, Jenway, England). Using a Shimadzo UV 2401 PC spectrophotometer, Na concentrations were determined colorimetrically (Masoumi et al. 2021).

Fruit firmness
The firmness of the fruit was measured with a penetrometer (model 10576-OSK-I). To determine the firmness of the fruit, a conical head 11 mm deep was driven into the fruit's center. The pressure of the device in kilograms was read from the screen of the device. Then firmness was reported as Newton (N) based on the equation $N = m \cdot g$ (Pongener et al. 2011).

Total soluble solids (TSS)

Total soluble solids were measured by a refractometer (model k-0032 from Japan). The gadget was initially calibrated. With the juicer, a drop of extracted melon flesh was obtained, filtered, and placed on the prism of the refractometer; the number of solids was read, and the degree of brix of the extract was recorded. The device was calibrated with distilled water to measure each repetition to minimize error.

Acidity that can be titrated (TA)

Utilizing the titration method and monitoring the pH of the juice, organic acids were determined. In this procedure, titratable acidity (TA) was evaluated by titrating 10 mL of fruit juice with 0.1 N NaOH solution to a pH of 8.2 and recording the volume of NaOH used. The percentage of malic acid was used to calculate the amount of titratable organic acid.

Productivity and fruit weight

After harvesting, each fruit was individually tallied and weighed. The average quantity and weight of fruits were determined. The yield per plant per square meter was estimated using the average plant weights.

Quantitative features of fruit

A ruler and caliper were used to determine the length, width, flesh thickness, peel thickness, length and width of the fruit's internal cavity, and length and diameter of its seeds. In addition, the weight of the seeds was determined using a digital balance (g).

Statistical analysis

Analysis of variance and mean's comparison were performed based on LSD tests at 1 and 5% probability levels using Statistix 8 (Tallahassee FL, USA) and the tables presented in the supplementary file. Cluster (shown in supplementary file) and biplot analysis were also done using Statgraph 18 software.

Second experiment

Two tolerant (Tork: Torkamani, Zank: Zanki) and sensitive (G-IVA: Gorgi Ivan, G-SHI: Gorgi Shirdan Jorgeaval) cultivars were selected and cultivated based on the results of the first experiment, specifically yield cluster analysis, and principal component analysis. The experimental design was a split-plot randomized complete block design with three replications, 2 m row spacing, and 36 m length. The plants were spaced apart by 50 cm. At the four-leaf stage of the watermelon seedling, two salinity of 2 and 8
were applied. The plant was irrigated (once every 4–6 days) utilizing drip irrigation systems with a dripper distance of 50 cm, based on its water requirements. The growth period lasted approximately 90 days, and the above-mentioned parameters were measured exactly. Data were analyzed using Statistix 8 (Tallahassee FL, USA). All data were analyzed using two-way ANOVA, and significance was determined by comparing the means at $P \leq 0.05$ using the least significant difference (LSD) test.

**Declarations**

**Acknowledgments**

The authors would like to thank the Isfahan University of Technology for its support of this study. In addition, we are grateful to our colleagues in the language center at the Isfahan University of Technology for rereading and editing the work in terms of language use and style, including grammar, punctuation, and spelling.

**Author contributions**

M.H., and H.E. designed the research study and obtained the funding for the field research. The analysis was developed by H.H. The data collection strategy was developed by M.H., H.H., H.E., and G.B. Data collection was conducted by H.H., and H.H. conducted data analysis under the guidance of M.H., and H.E. G.B. prepared the initial draft, figures, tables, and Supplementary Materials, with edits provided by M.H. and H.E. All authors have read, contributed to, and approved the final version of the manuscript.

**Competing interests**

The author(s) declare no competing interests.

**Data availability**

Raw data used in this study are available from the corresponding author upon reasonable request.

**References**


**Figures**
Figure 2

Figure 3

The effect of some morphological changes between tolerate (Tork and Zank) and sensitive (G-IVA and G-SHI) cultivare under salinity stress. G-IVA: Gorgi Ivan, G-SHI: Gorgi Shirdan Jorgeaval, Tork: Torkamani, Zank: Zanki
Figure 4

The effect of some morphological and yield parameter between tolerate (Tork and Zank) and sensitive (G-IVA and G-SHI) cultivare under salinity stress. G-IVA: Gorgi Ivan, G-SHI: Gorgi Shirdan Jorgeaval, Tork: Torkamani, Zank: Zanki
Figure 5

The effect of some stress indices changes between tolerate (Tork and Zank) and sensitive (G-IVA and G-SHI) cultivars under salinity stress. G-IVA: Gorgi Ivan, G-SHI: Gorgi Shirdan Jorgeaval, Tork: Torkamani, Zank: Zanki
Figure 7

Geographical distribution of studied melon cultivars.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- suppli29.5.401.doc.docx