

Evaluation and selection of potato varieties (*Solanum tuberosum* L.) in vitro and study of their tolerance to osmotic stress

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Abstract

The experiments were conducted in the tissue culture laboratory of the National Commission for Biotechnology (NCBT) in Damascus, and at the Faculty of Science - University of Damascus with the aim of evaluating the response of nine introduced potato varieties resulting from *in vitro* tissue culture (Montereal, Salvador, Synergy, Yalas, Agria, Arizona, Everest, Evora, Hind) to artificial osmotic stress using sorbitol. This was based on some growth indicators and certain biochemical parameters (chlorophyll a and b, total carotenoids, and proline), to determine the cultivars most adapted to osmotic stress. The plants were treated by adding different concentrations of sorbitol (0, 100, 200, 300, 400 mM) to the growth medium.

The experiment was designed according to a completely randomized block design, and significant differences were estimated at a 99% confidence level. The nine varieties varied in their response to osmotic stress, with an increase in the level of osmotic stress (sorbitol concentration) in the growth medium causing a significant decline in all growth parameters (plant length, root length, number of leaves and roots) compared to the control, as well as some biochemical traits (chlorophyll molecules types a and b, and carotenoids), and an increase in some biochemical parameters (proline), compared to the control. Cluster analysis based on the total relative values of growth parameters and biochemical parameters showed the distribution of the studied varieties into three groups depending on their tolerance to osmotic stress. The results indicated that the varieties (Yalas and Salvador) are among the tolerant varieties, while the varieties (Arizona, Hind, Synergy) are moderately tolerant, and the varieties (Agria, Everest, Montereal, Evora) are considered sensitive to osmotic stress. The results indicate the possibility of evaluation and selection in the laboratory as a rapid and effective method to explore the genetic variation for osmotic stress tolerance in potatoes.

Introduction

The potato (*Solanum tuberosum* L.) is one of the most important vegetable crops in the world. It belongs to the genus *Solanum* and the family *Solanaceae*. Potatoes are grown in about 150 countries ¹, and they are the most important non-cereal food crop globally ^{2,3}. They are cultivated on all continents in vast areas and are a staple food in Europe, the Americas, and developing countries. FAO statistics show that potatoes are grown on an area of more than 20.7 million hectares, with global production estimated at about 437 million tons, and they are consumed by billions of people as a staple food. China is one of the world's largest potato producers ⁴.

Potatoes are a rich source of carbohydrates, proteins, and dietary fiber, and have numerous industrial uses. Starch is extracted from potatoes and used in the manufacture of paper, textiles, and adhesives. Potatoes are also used in fermentation and the extraction of alcohols such as ethanol and butanol, as well as acids like citric and lactic acid ⁵. Land occupies approximately one-quarter of the Earth's surface, and nearly half of its arable land suffers from water scarcity, sometimes reaching the point of drought. This has led to a 25% decrease in arable land ⁶.

Therefore, water stress is considered one of the most important factors threatening food security globally ⁷. Stress tolerance is defined as the ability to grow, flower, and provide a good economic return under unfavorable environmental conditions. Stress-tolerant plants are defined as plants that adapt to survive under stress conditions by inducing morphological, physiological, chemical, and molecular responses ⁸. Water stress is the main factor limiting the yield of all agricultural crops, including potatoes. Plants are exposed to periods of water deficit due to a decrease in the amount of water absorbed by the roots, which is insufficient to compensate for the water lost through transpiration, leading to the cessation of plant growth ⁹.

Potato breeding and genetic improvement programs have helped develop new varieties that meet market demands in terms of stress resistance, improved quality and yield. However, genetic progress in osmotic stress tolerance remains slow due to complex quantitative traits and the lack of complete understanding of the genetic basis of drought tolerance, especially under field conditions, due to the significant interaction between environmental and genetic factors. Therefore, many scientific studies have highlighted the importance of screening to reveal genetic variation among drought tolerance genotypes. Consequently, tissue culture technology has emerged as an alternative and effective method for developing stress-tolerant plants in recent years, as it can be achieved under controlled conditions in less time and space¹⁰. The effect of osmotic stress on plant growth using tissue culture technology is similar to its effect under field conditions; therefore, *in vitro*-grown plants can be used as an alternative to stressful and costly field trials ⁸.

Drought is a major abiotic stress that negatively impacts the performance and productivity of various plants by inhibiting photosynthesis. Drought causes stomata to close, reducing water loss through transpiration and maintaining the hydration of plant cells. However, this is usually accompanied by a decrease in the diffusion rate of carbon dioxide (CO₂), which is the precursor to sugar synthesis in the Calvin cycle ¹¹. Potatoes adapt to stress conditions by enhancing their enzymatic and non-enzymatic antioxidant activities. They synthesize protective substances, such as proline and polyols, to counteract the damaging effects of drought ¹². These substances contribute to changes in cellular osmotic pressure and ensure membrane integrity ¹³. Chlorophyll pigments are also important for plants because they harvest light energy necessary for the synthesis of energy-rich compounds during photochemical reactions (NADPH, ATP). Both chlorophyll a and chlorophyll b molecules are significantly damaged when plants are exposed to drought, as the ratio of chlorophyll a to chlorophyll b changes ¹⁴. Manoj et al. (2011) ¹⁵, proved that tissue culture is a practical technique for producing stress-tolerant plants, both biotic and abiotic, by applying selection agents such as NaCl (for salinity tolerance) and PEG, mannitol, or sorbitol (for osmotic stress tolerance) to the culture medium. Only plants capable of surviving in such media are selected.

In a study conducted by Sobh (2020)¹⁶ to determine the effect of varying levels of sorbitol-induced osmotic stress on certain morphological traits in eleven potato varieties, using plant tissue culture techniques, increasing the osmotic stress level (sorbitol concentration) in the growth medium resulted in

a significant decline in all morphological traits compared to the stress-free control, This included a decrease in the concentration of chlorophyll a and b molecules and total carotenoids, and an increase in proline and oxygenated water. Mehmandar et al. (2023)¹⁷, also demonstrated that *in vitro* assessment can be a precise, rapid, and reliable method for evaluating and identifying drought-tolerant genotypes.

Results and discussion

Growth parameters under the influence of osmotic stress in vitro:

Plant height (cm):

The results of the statistical analysis showed significant differences in the average plant height among the varieties and different levels of sorbitol. The average plant height decreased with increasing sorbitol concentration for each variety. The highest plant length was observed in the control treatment (13.01 cm), with a significant difference compared to the other treatments in all studied varieties. The lowest significant value was at the concentration of 400 mM (1.71 cm). The longest plant height was recorded for the Evora variety (8.67 cm), while the shortest was for the Everest variety (4.52 cm), (Figs. 1–2).

Number of leaves:

The results of the statistical analysis showed significant differences in the average number of leaves between the different varieties and levels of sorbitol. The average number of leaves per plant decreased directly and significantly with increasing sorbitol concentration in the growth medium. The highest number of leaves was observed in the control treatment (11.5 leaves/plant) with a significant difference compared to the other treatments, while the lowest number of leaves was observed in the sorbitol 400 mM treatment (1.82 leaves/plant). The highest number of leaves was observed in the Evora variety (8.87 leaves/plant), and the lowest in the Everest variety (4.30 leaves/plant). (Fig. 1–2).

Root Length:

Statistical analysis revealed significant differences in average root length between different varieties and sorbitol levels. Average root length decreased proportionally and significantly with increasing sorbitol concentration in the growth medium. The control treatment exhibited a significantly higher average root length (5.85 cm) compared to the other treatments, while the shortest root length was observed in the 400 mM treatment (0.57 cm). The highest average root length was observed in the Salvador variety (4.52 cm), and the shortest in the Arizona variety (2.29 cm), (Fig. 1–2).

Number of Roots:

Statistical analysis revealed significant differences in the average number of roots between different varieties and sorbitol levels. The average number of roots per plant decreased proportionally and significantly with increasing sorbitol concentration in the growth medium. The highest average number of roots was observed in the control treatment (8.39 roots/plant), significantly higher than the other treatments, while the lowest was in the 400 mM treatment (0.6 roots/plant). The highest average number of roots was observed in the Hind and Evora varieties (6.03 and 5.9 roots/plant, respectively), while the lowest was observed in the Arizona variety (2.69 roots/plant), (Fig. 1–2).

Figure (1) Effect of osmotic stress coefficients on growth parameters of the studied potato varieties

Figure (2) The effect of osmotic stress on growth indicators in nine studied potato varieties

Figure (3). The effect of different concentrations of sorbitol on growth indicators in the studied potato varieties: A- Salvador, B- Yalas, C- Arizona, D- Hind, E- Everest, F- Evora, G- Montereal, H- Agria, I- Synergy.

Biochemical Indicators:

Leaf Chlorophyll a content (mg. g⁻¹ wet weight):

Statistical analysis revealed significant differences ($P \leq 0.01$) in the mean leaf chlorophyll a content. The average leaf content of chlorophyll a was significantly higher in the control (0.76 mg. g⁻¹ wet weight) and it decreased proportionally with increasing sorbitol concentration in the growth medium. The leaf content of chlorophyll a was significantly lower at the highest osmotic concentration of 400 mM (0.19 mg. g⁻¹ wet weight) Figure (4). The highest average leaf content of chlorophyll a was found in the Salvador variety (0.67 mg. g⁻¹ wet weight) while it was significantly lowest in the Everest variety (0.24 mg. g⁻¹ wet weight) Figure (5).

Leaf Chlorophyll b Content (mg. g wet weight):

Statistical analysis revealed significant differences ($P \leq 0.01$) in the average leaf content of chlorophyll b. The average leaf content of chlorophyll b was significantly higher in the control treatment (0.62 mg. g⁻¹ wet weight) and it decreased proportionally with the increase in sorbitol concentration in the growth medium. The leaf content of chlorophyll b was significantly lower at the highest osmotic concentration of 400 mM (0.21 mg. g⁻¹ wet weight). The highest average leaf content of chlorophyll b was found in the Salvador variety (0.53 mg. g⁻¹ wet weight) while the lowest was in the Synergy variety (0.27 mg. g⁻¹ wet weight) (Fig. 4–5).

Leaf Carotenoid Content (mg. g⁻¹ wet weight):

Statistical analysis revealed significant differences ($P \leq 0.01$) in the average leaf content of carotenoids. The average leaf content of carotenoids was significantly higher in the control treatment (0.24 mg. g⁻¹ wet weight) and it decreased proportionally with increasing sorbitol concentration in the growth medium. The leaf content of carotenoids was significantly lower at the highest osmotic concentration of 400 mM (0.13 mg. g⁻¹ wet weight). The highest average leaf content of carotenoids was significantly higher in the Arizona variety (0.25 mg. g⁻¹ wet weight), while the lowest was in the Salvador variety (0.13 mg. g⁻¹ wet weight), (Fig. 4–5).

Leaf proline content (µg. g⁻¹ green matter):

Statistical analysis revealed significant differences ($P \leq 0.01$) in the mean leaf proline content. The mean leaf proline content was significantly highest at the highest osmotic concentration of 400 mM (58.67 µg. g⁻¹ green matter), while the mean leaf proline content was significantly lowest in the control treatment (34.11 µg. g⁻¹ green matter). The highest mean leaf proline content was found in the Arizona cultivar (53.93 µg. g⁻¹ green matter), and the lowest in the Everest cultivar (34.82 µg. g⁻¹ green matter), (Fig. 4–5).

Figure (4) Effect of osmotic stress coefficients on biochemical indicators in the studied potato varieties

Figure (5) Effect of osmotic stress on biochemical indicators in nine studied potato varieties

Osmotic Stress Levels and Morphological Changes:

Osmotic stress levels showed significant changes in some morphological plant growth indicators, significantly reducing plant height, number of leaves, and root length and number. This reduction was directly proportional to increasing sorbitol concentration. Some studies have attributed the decrease in these indicators to osmotic stress, which inhibits root elongation and number due to high osmotic stress in the growing medium. This leads to a decrease in water potential (becoming more negative), thus reducing the amount of free water available to the plant. Consequently, the rate of water uptake by the root system is negatively affected, and the amount of water absorbed becomes insufficient to compensate for the water lost through transpiration by the aerial parts. As a result, plant elongation and cell division are inhibited, affecting plant diameter and reducing the number of nodes and leaves formed on the stem. This results from a decrease in the filling potential within leaf cells, which inhibits leaf cell elongation and growth, leading to water deficit in plant cells due to reduced water content ¹⁸.

These results are consistent with those of Wishart et al. (2014)¹⁹ and Bundig et al. (2016)²⁰, who found genetic variation in response to drought conditions, Potato varieties depend on some morphological characteristics, such as root length and aerial parts. Similarly, the study by Sajid (2022)²¹ showed a decrease in most growth indicators when treated with sorbitol and mannitol as osmotic stress factors for two potato varieties.

Biochemical Indicators:

The variation in the leaf content of chlorophyll a and chlorophyll b molecules among the studied varieties is attributed to the genetic factors responsible for the stability of chlorophyll molecules. All the genetic varieties in which the leaf content of chlorophyll a molecule was significantly higher also had a significantly higher leaf content of chlorophyll b the leaf content of chlorophyll b. Similarly, varieties that had significantly lower chlorophyll a also had lower chlorophyll b content. Osmotic stress affected the biochemical processes of potato varieties, leading to a decrease in the chlorophyll and carotenoids content of the leaves. Osmotic stress contributes to a decline in the level of gene expression of genes responsible for proteins associated with chlorophyll molecules (Chlorophyll a-b), and increases the activity of the enzyme Chlorophyllase, which breaks down chlorophyll molecules. This leads to a decrease in the chlorophyll content of the leaves and also affects the basic enzymes in the photosynthesis process and the enzymes responsible for sucrose synthesis. Dehydration increases the level of gene expression of the enzymes responsible for breaking down sucrose ²².

Our results are consistent with those of Mehmandar et al. (2023)¹⁷, where the addition of sorbitol reduced the chlorophyll content while increasing the proline and malondialdehyde content. The addition of sorbitol to MS medium mimics dehydration stress better than polyethylene glycol.

The decrease in carotenoids under stress conditions is attributed to the breakdown of beta-carotene and the formation of zeaxanthins, which play a role in protecting against photoinhibition. These findings align with those of Farooq et al. (2009)¹⁴, who indicated that carotenoids (orange pigments) regulate the uptake of light energy by chlorophyll molecules to prevent photoinhibition when light utilization efficiency is reduced in stressful environments.

Additionally, crops produce proline under drought stress conditions, which protects drought-sensitive cell enclosures from damage ²³. These substances play a key role in stress tolerance ²⁴. These findings are consistent with those of Wellpott et al. (2024)²⁵, where potato genotypes showed genetic variation in the rate of synthesis and accumulation of compatible organic solutes, which explains the genetic variation in drought tolerance.

Al-Hadid et al. (2023) ²⁶, showed that proline concentration increased with increasing salt stress compared to the control for both C3 and C4 plants.

Proline accumulation under abiotic stress conditions in many plant species is associated with enhanced stress tolerance. Its concentrations are typically higher in stress-tolerant plants than in sensitive ones. However, stress-sensitive genotypes can sometimes synthesize larger quantities of proline, in which case proline accumulation is related to the extent of damage rather than the level of tolerance ²⁷. Thus, we observe that sorbitol led to a decrease in leaf chlorophyll and carotenoid content and an increase in proline content with increasing osmotic stress.

Results of Agglomerative Hierarchical Clustering (AHC):

The cluster analysis, based on the sum of the relative values of the studied parameters (growth indicators and biochemical parameters), led to the division of the studied potato varieties, according to their tolerance to the sum of osmotic stress levels, into three groups, (Fig. 6):

-Group 1 (G1): Plants tolerant to osmotic stress, including the cultivars Yalas and Salvador.

-Group 2 (G2): Plants with moderate tolerance to osmotic stress, including the cultivars Arizona, Hind, and Synergy.

-Group 3 (G3): Plants intolerant to osmotic stress, including the cultivars Agria, Everest, Monteral, and Evora.

Since tolerance to abiotic stresses is a complex quantitative trait ²⁸, and there is a significant interaction between the environment and specific genetic factors associated with economic yield, many studies have focused on studying genetic diversity in potatoes and determining the extent of tolerance to abiotic stresses. These studies often use cluster analysis, which relies on various indicators such as morphological and physiological traits ^{29,30}

Figure (6) Cluster analysis of nine potato varieties according to their tolerance to osmotic stress, based on the sum of the relative values of all the studied indicators (growth indicators, chemical parameters).

Conclusion

Many scientific studies indicate the importance of tissue culture technology as an alternative and effective method for developing stress-tolerant plants. This technology can be implemented under controlled conditions in less time and space. Furthermore, the effect of osmotic stress on plant growth using tissue culture technology is similar to its effect under field conditions. Therefore, this research aimed to investigate the effect of osmotic stress on certain morphological characteristics and chemical parameters, and to select varieties tolerant to osmotic stress.

This research is significant in its screening and evaluation of the tolerance of potato (*Solanum tuberosum* L.) varieties to osmotic stress *in vitro*. The results showed a decrease in most growth indicators and some biochemical properties (chlorophyll molecules of both types (a,b), and carotenoids), and an increase in some biochemical properties (proline) compared to the control when treated with sorbitol as an osmotic stress-causing agent. The nine varieties also varied in their response to osmotic stress, as cluster analysis showed the distribution of the studied varieties into three groups based on their tolerance to osmotic stress. The results showed that the two varieties Yalas, Salvador are considered tolerant varieties, while the varieties Arizona, Hind, Synergy are considered moderately tolerant varieties, and the varieties Agria, Everest Monteral, Evora are considered sensitive varieties to osmotic stress.

Materials and Methods

Place and Time of Research

This research was carried out in the laboratories of the Faculty of Science, Damascus University and the laboratories of the National Commission for Biotechnology in Damascus, during the period (2024–2025).

Plant material: Nine varieties of commercial starchy potatoes, preferred by farmers were used in this research: (Montereal, Salvador, Synergy, Yalas, Agria, Arizona, Everest, Evora, Hind), These varieties were recently approved in Syria and were obtained from the Seed Multiplication Foundation in Damascus.

Primary Culture and Propagation

Rosettes taken from tubers were cultured in plastic pots containing sterile peat moss. After 45 days, the resulting shoots were collected and cut into 2–3 cm single cuttings, each containing one lateral bud. These cuttings were soaked in a 3% sodium hypochlorite solution for 10 minutes as recommended by previous studies ³¹, and then washed three times consecutively with sterile distilled water for 5 minutes each time. After disinfection, the cuttings were cultured in test tubes containing 18 ml of MS medium ³², as shown in table 1, supplemented with 30 g. L⁻¹ sucrose and 7 g. L⁻¹ agar at pH 5.8. The cultured tubes were incubated in a growth chamber at 22 ± 2C°, with a light cycle of 16 hours light /8 hours of darkness, and a light intensity of 3000 lux ³³. Following this, the plant propagation stage began. This stage aims to obtain the largest possible number of well-developed vegetative growths. The propagation process was repeated several times consecutively to obtain the sufficient quantity of plant material for the research.

Table (1) Composition of the nutrient medium for Murashige and Skoog (MS).

Concentration (mg.l⁻¹)	Chemical Composition	Compound
1650	NH ₄ NO ₃	Ammonium Nitrate
1900	KNO ₃	Potassium Nitrate
440	CaCl ₂ .2H ₂ O	Calcium Chloride Hydrate
370	MgSO ₄ .7H ₂ O	Magnesium Sulfate Hydrate
170	KH ₂ PO ₄	Potassium Phosphate
27.85	FeSO ₄ .7H ₂ O	Iron Sulfate Hydrate
37.25	Na ₂ EDTA	Sodium Chelate
22.3	MnSO ₄ .7H ₂ O	Manganese Sulfate Hydrate
8.6	ZnSO ₄ .7H ₂ O	Zinc Sulfate
6.2	H ₃ BO ₃	Boric Acid
6.6	KI	Potassium Iodide
0.83	Na ₂ MoO ₄ .2H ₂ O	Ammonium Molybdate Hydrate
0.025	CuSO ₄ .2H ₂ O	Cupressus Sulfate Hydrate
0.025	CoCl ₂ .6H ₂ O	Cobalt Chloride Hydrate
1	B1	Thiamin
100		Myo-inositol
30000		Sucrose
7000		Agar
5.8		pH

Stress treatments

Plant samples from the propagation stage were divided into small cuttings containing a lateral bud, and drought stress was applied using different concentrations of sorbitol (0, 100, 200, 300, and 400 mM) added to the growth medium. Each treatment consisted of three replicates, with an average of four plants per replicate, compared to the control (sorbitol-free medium).

The studied indicators

The results were recorded after 45 days of applying different stress treatments to laboratory plants. The following indicators were estimated

Growth Parameters

- Stem length (cm): The stem length was measured using a measuring tape, from the base of the stem to the apical bud.
- Number of leaves (leaves/plant).
- Root length (cm): Measured using a measuring tape, from the base of the root to the tip of the longest root.
- Number of roots (roots/plant) ³⁴.

Biochemical indicators:

Estimation of leaf content of chlorophyll and total carotenoids:

Pigments were extracted by grinding 1 g of frozen plant leaves treated with sorbitol, in the presence of 4 ml of 80% acetone. The extract was then separated using a centrifuge at 10,000 rpm for 10 minutes. The supernatant phase was transferred to new test tubes, and the absorbance was measured using a spectrophotometer at wavelengths of 645 and 662 nm to estimate the amounts of chlorophyll a and b, respectively, and at a wavelength of 470 nm to estimate the total carotenoids ³⁵.

Estimation of the leaf proline content:

Proline was extracted by crushing 0.5 g of plant leaves after 45 days of exposure to osmotic stress in the presence of 2 ml of a 3% aqueous solution of sulfosalicylic acid. The extract was then separated by centrifugation at 10,000 rpm for 10 minutes, and its volume was adjusted to 5 ml using 3% sulfosalicylic acid. To estimate the proline content of the extract, 2 ml were taken and 2 ml of ninhydrin solution were added to activate the reaction, along with 2 ml of glacial acetic acid. The tubes were placed in a boiling water bath for 1 hour, then removed and rapidly cooled, 4 ml of toluene was added to each tube, and the tubes were shaken and allowed to separate into two phases. The upper phase was taken, and its optical absorption was measured at a wavelength of 520 nm, according to the concentration of proline in the plant sample compared to a standard curve of known concentrations of commercial proline³⁶.

Experimental design and statistical analysis:

The experiment was designed using a completely randomized block design, with measurements taken after 30–45 days of applying the stress treatments. Each treatment including the control, had three replicates, with each replicate consisting of 4 plants in test tubes. The results were analyzed using the

statistical program XLSTAT to compare the means and calculate the least significant difference (LSD) at a significance level of 1%, along with the coefficient of variation (CV%).

The Agglomerative Hierarchical Clustering (AHC) method, which classifies variable data into several subgroups such that they are homogeneous within one group (cluster) and different with respect to other clusters, was used to determine the tolerance of varieties to osmotic stress.

The cluster analysis followed the equation of Vreugdenhil et al. (2007)³⁷, and Al-Biski (2018)²⁹ based on the sum of the relative values of the studied parameters, the control and stress coefficients were determined as follows:

$$RV_{\text{plant status}} = \sum \frac{(Sp1 \rightarrow p8 * 100)}{Cp1 \rightarrow p8}$$

Where $RV_{\text{plant status}}$: is the sum of the relative values specific to the variety, $Sp1 \rightarrow p8$ is the value of the studied indicator in the stressed plant, $Cp1 \rightarrow p8$ is the value of the indicator in the control plant.

Data availability

The datasets used and analysed during the current study available from the corresponding author on reasonable request.

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Abbreviations

NCBT- National Commission for Biotechnology; MS- Murashige and Skoog medium;AHC- Agglomerative Hierarchical Clustering; NaCl- Sodium hypo Chloride;PEG- Poly Ethylene glycol.

Declarations

Competing interests

L. laila, S. Zaid, F. Al-Biski & S. Jabal declare that they have no competing interests.

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Author Contribution

L. Iaila, PhD in Plant Biology. Department of plant Biology, Faculty of Sciences , Damascus University, Syria , was carried out this research in the field and at the laboratory of plant biotechnology and the wrote of this scientific research was done by the help of supervisors Dr. S. Zaid, Dr. F. Al-Biski & Dr. S. Jabal . In addition, designed the experiment, analyzed the data, drafted and improved the manuscript were carried out by all of us.

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Data Availability

The datasets used and analysed during the current study available from the corresponding author on reasonable request.

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Figures

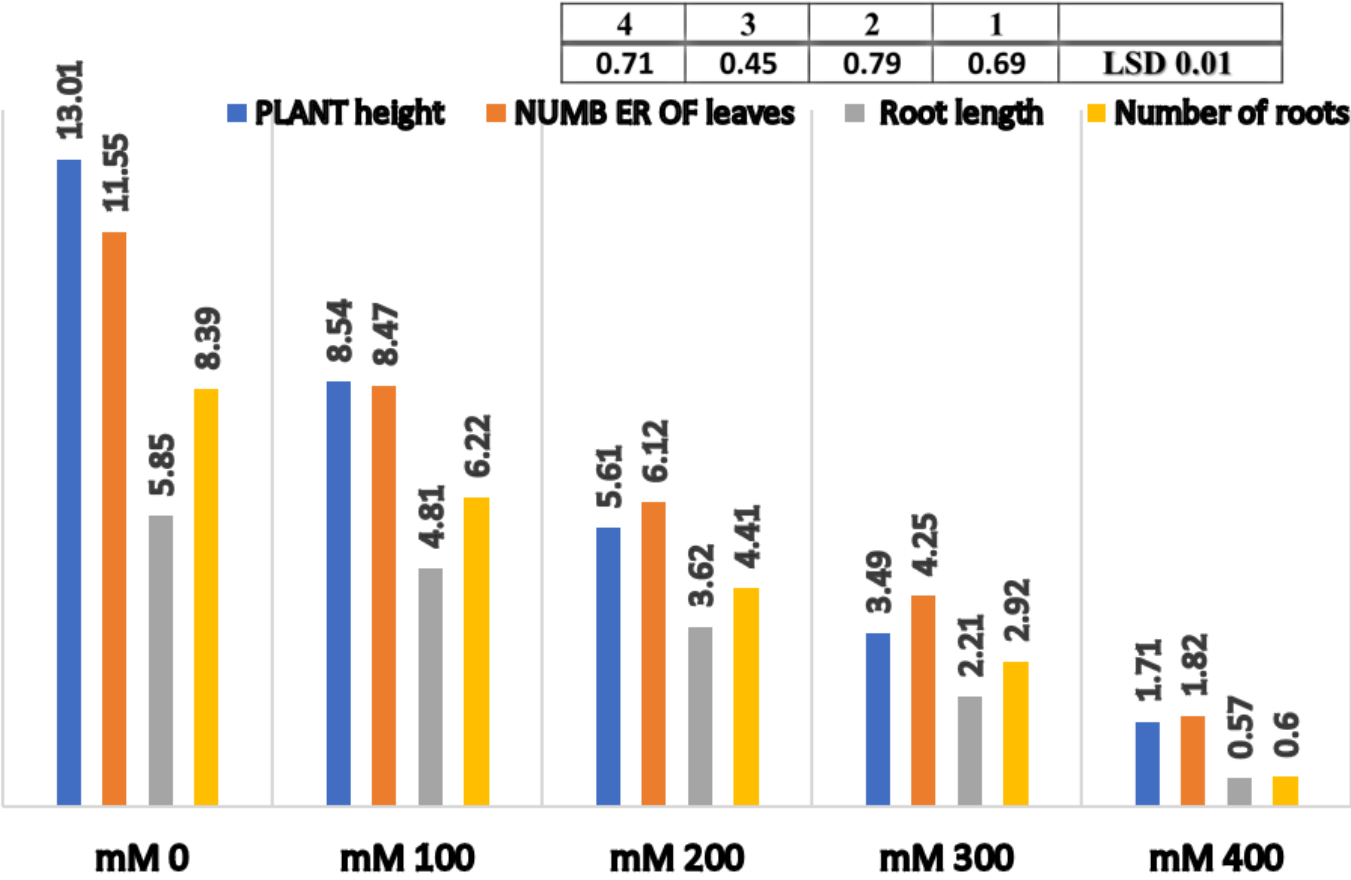


Figure 1

Effect of osmotic stress coefficients on growth parameters of the studied potato varieties

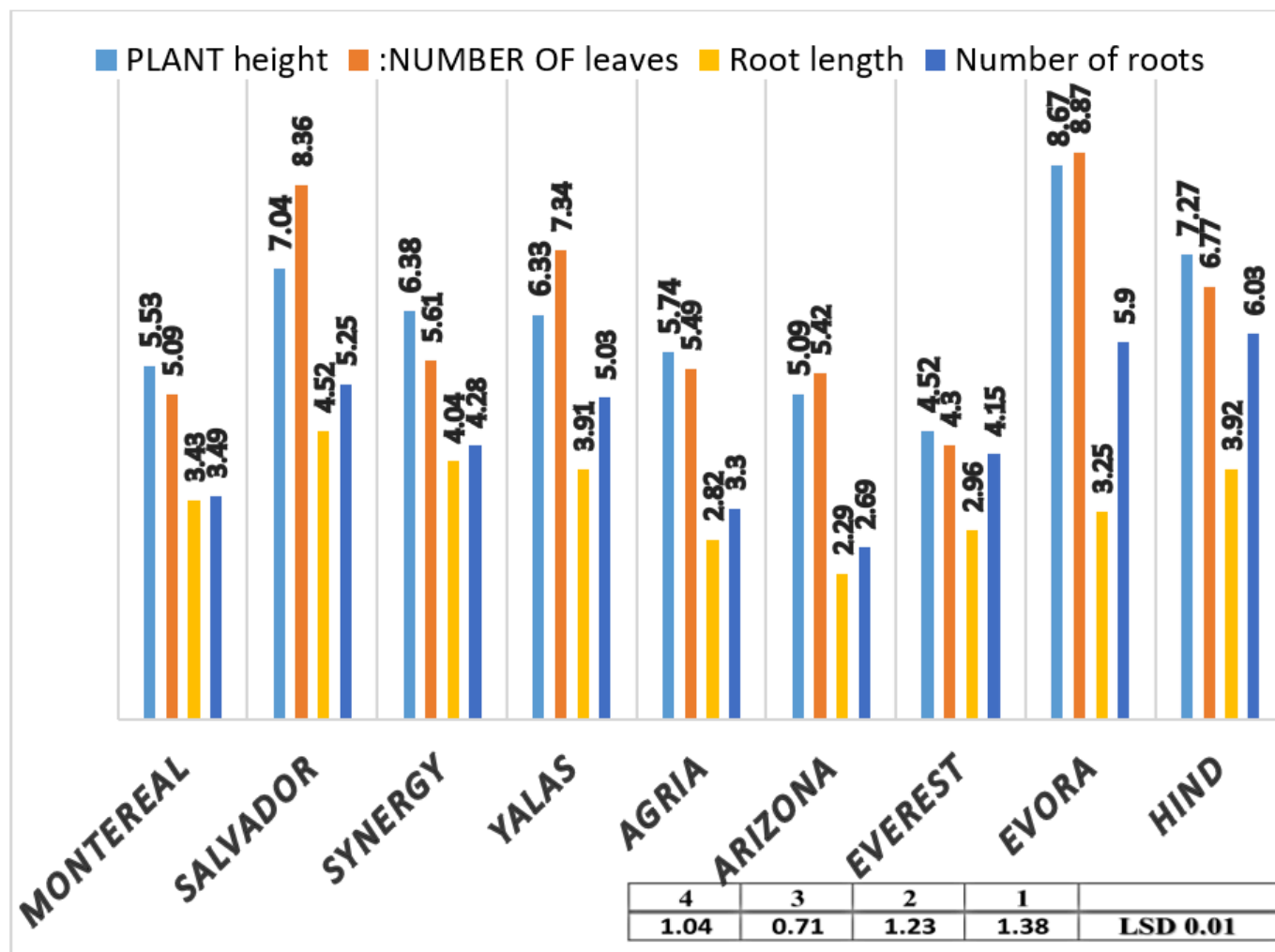


Figure 2

The effect of osmotic stress on growth indicators in nine studied potato varieties

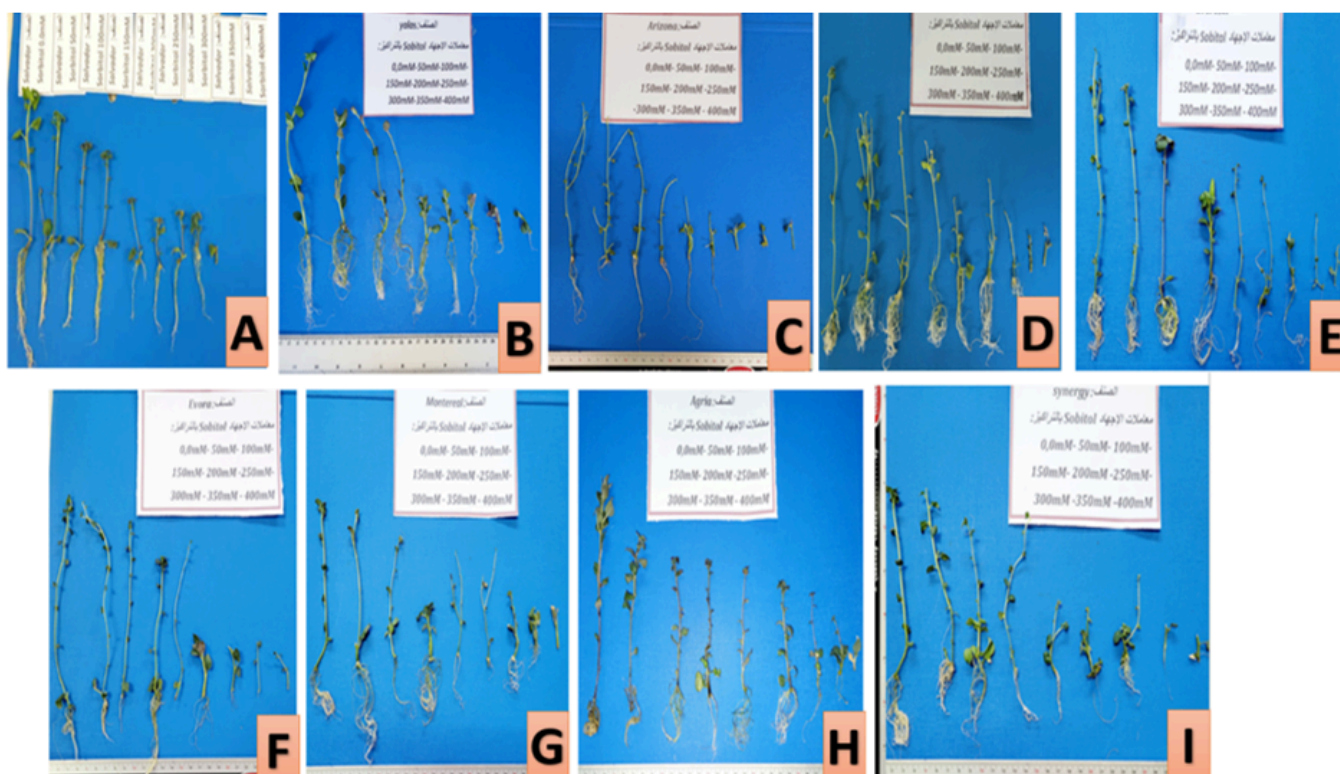


Figure 3

The effect of different concentrations of sorbitol on growth indicators in the studied potato varieties: A- Salvador, B- Yalas, C- Arizona, D- Hind, E- Everest, F- Evora, G- Montreal, H- Agria, I- Synergy.

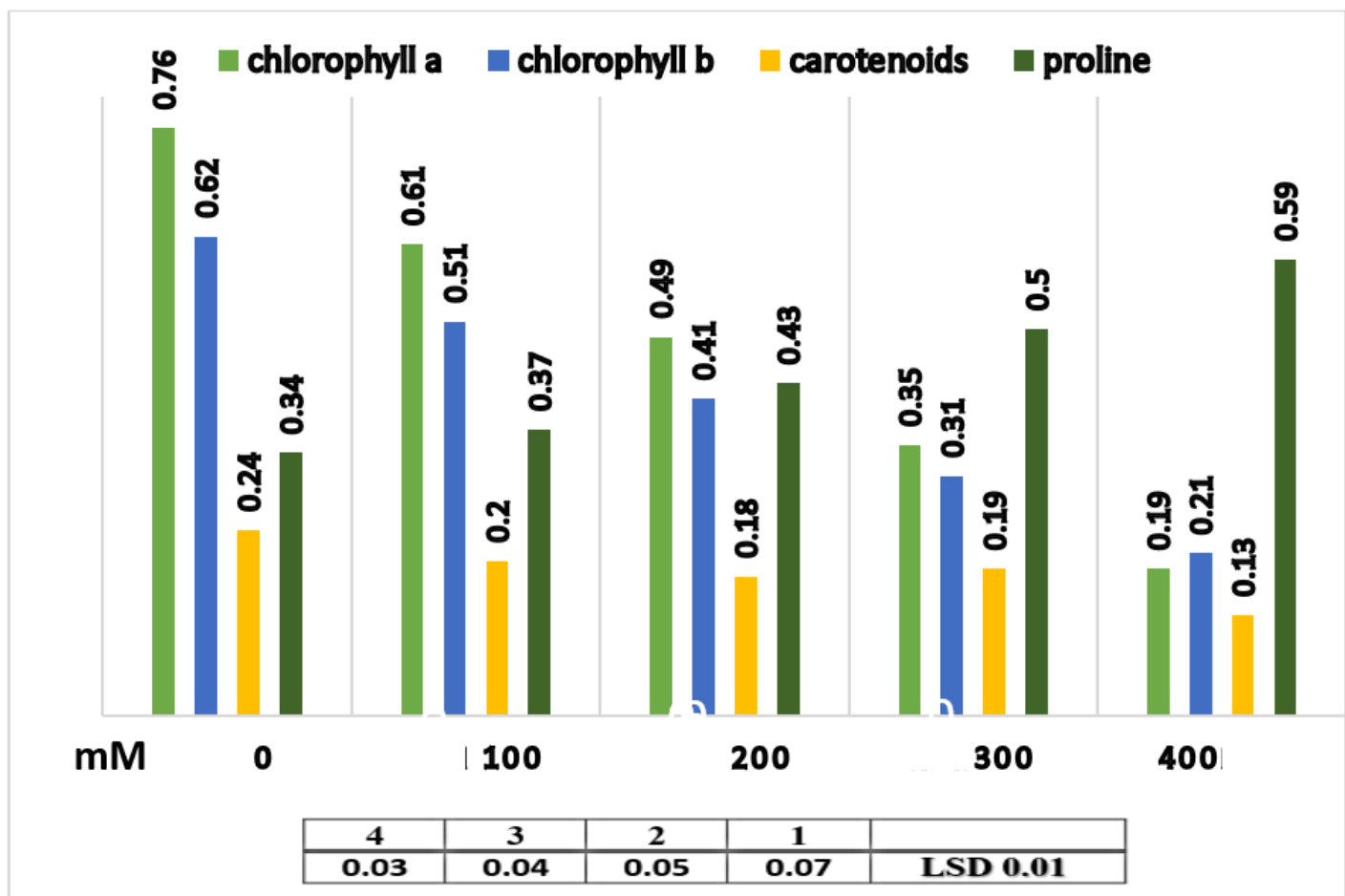


Figure 4

Effect of osmotic stress coefficients on biochemical indicators in the studied potato varieties

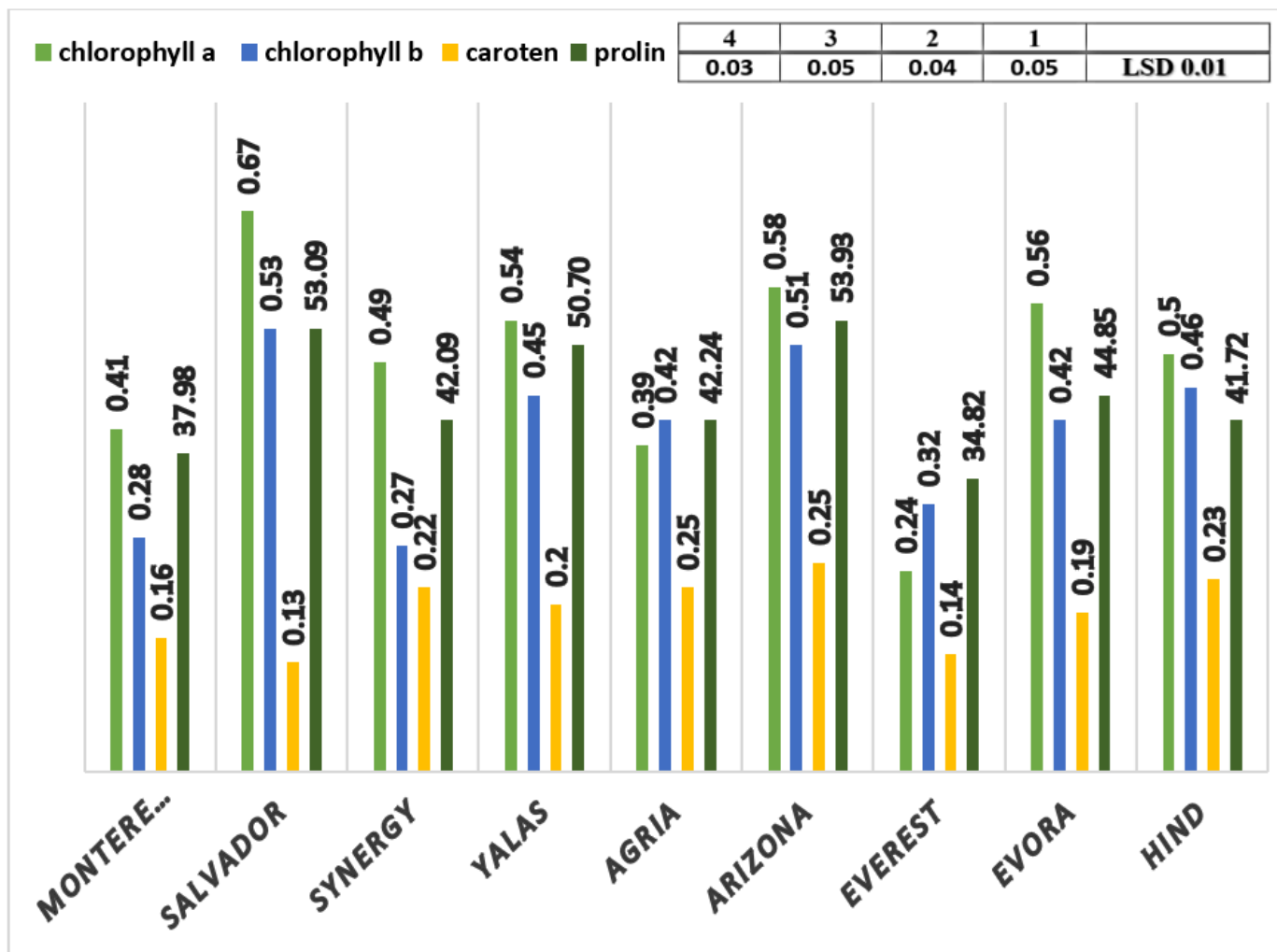


Figure 5

Effect of osmotic stress on biochemical indicators in nine studied potato varieties

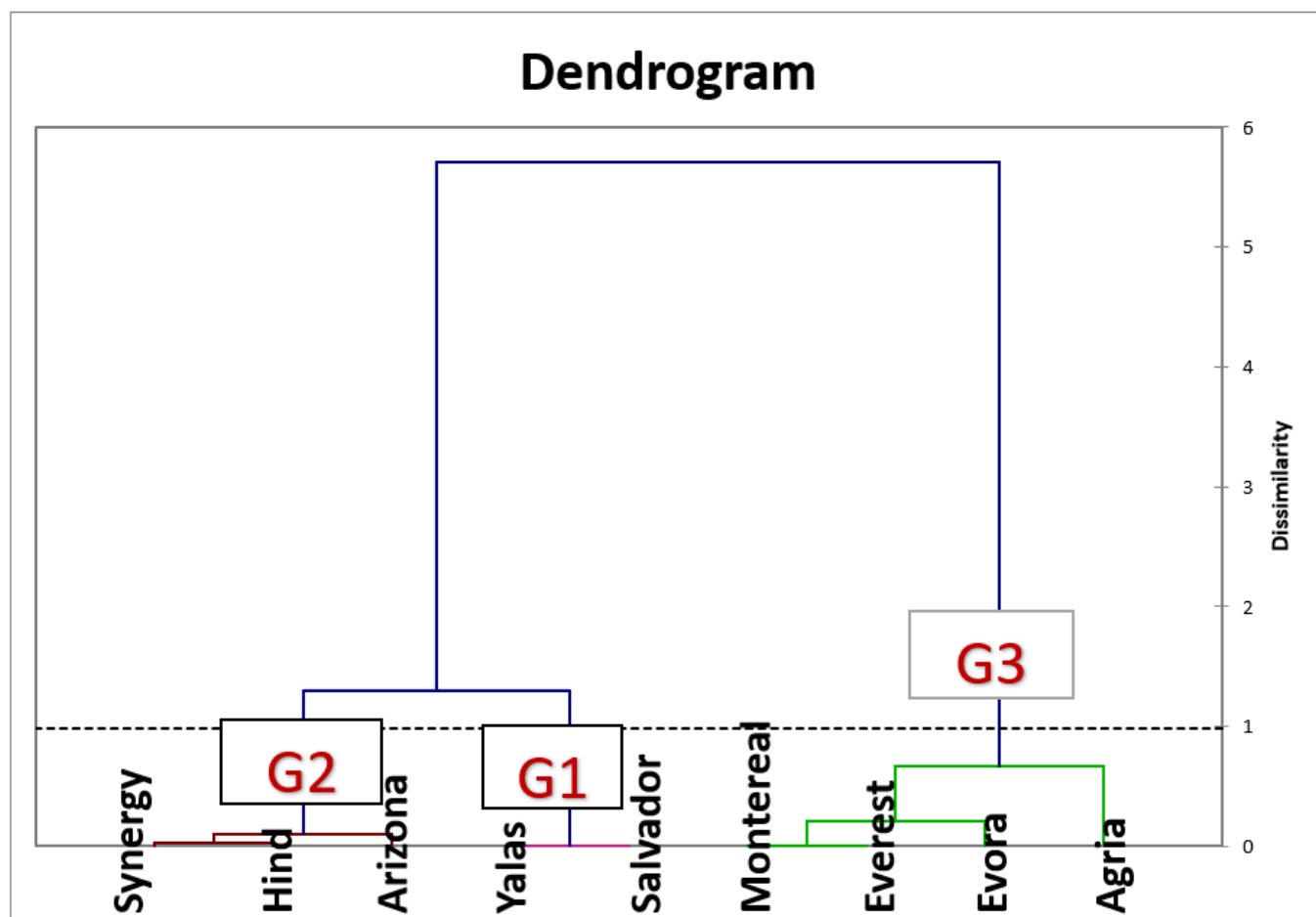


Figure 6

Cluster analysis of nine potato varieties according to their tolerance to osmotic stress, based on the sum of the relative values of all the studied indicators (growth indicators, chemical parameters).