Performance of Some Olive Genotypes Grown Under Saline Stress Conditions

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ABSTRACT

This study was conducted during 2022 and 2023 seasons to evaluate six olive genotypes resulting from the genetic improvement project and divided into two groups: the first group (Coratina♀ × Frantoio♂) included genotypes: G10, G16, and G26, while, the second group (Frantoio♀ × Coratina♂) included genotypes: G4, G20, and G25. Eight years old trees were planted in a private farm with a spacing of 3 x 6 m in sandy loam soil under a saline drip irrigation system (5648 ppm), to evaluate vegetative, flowering characteristics, yield, and oil content percentage of these genotypes under saline irrigation, or using the resistant genotypes as rootstocks to graft commercially available salinity-sensitive cultivars. According to the data, genotype G25 had the maximum leaf surface area, canopy area, and volume, as well as the highest percentage of perfect flower and fruit set, yield, $Ca^{++,}$ and chlorophyll content, and the lowest proline concentration. G20 showed the lowest values for these parameters: trunk cross-section, leaf surface area, yield, and chlorophyll, $K^{+,}$ and Ca^{++} content in leaves. G16 had the highest levels of oil, chlorophyll, and K^+ content. G10 demonstrated the lowest oil percentage, K^+/Ca^{++}, and $K^+ + Ca^{++}/Na^+$ ratio. It can be recommended that genotype G16 is suitable for oil extraction in saline conditions, while genotype G26, which had the lowest oil content, can serve as a saline-tolerant rootstock for grafting salt-sensitive commercial olive cultivars. However, genotype G25 produces a moderate amount of oil and can be used for both oil extraction and as a saline-tolerant rootstock.

Keywords: Olive- Genotypes- Salinity- Yield- Oil content.

INTRODUCTION

Olive is widely regarded as the most important fruit tree in the Mediterranean (IOOC, 2003). In the Mediterranean basin, olive tree farming is expanding to irrigated land, where salinity is becoming a serious issue due to high evaporation and insufficient leaching (Calero et al., 2013). Furthermore, water shortage in the Mediterranean basin reduces the availability of fresh water for agricultural irrigation. To reduce water scarcity and manage rising water demand for agricultural expansion, the usage of salt water may become unavoidable. Olive is moderately responsive to salinity (Demiral, 2005), yet the sensitivity of plants to saline stress is a genotypic dependent trait. (Chartzoulakis et al., 2002, and Weissbein et al., 2008). Olive trees can adapt to saline stress by changing their morphology, anatomy, and physiology at the leaf level (Tattini et al., 1992). The ability of olives to maintain an important potassium $(K^+)/Na^+$ ratio and the salt exclusion mechanism at the root level, which stops sodium (Na^+) from accumulating up in leaf tissue, are primarily responsible for their resistance to NaCl (Chartzoulakis et al., 2002). In olive trees, salt stress limits photosynthesis, mostly due to stomatal closure (Loreto et al., 2003) and salt ion concentration (Melgar et al., 2008).

Drought and salinity are two of the biggest challenges to agricultural output. Saline land makes up almost 20% of the world's arable land (Zhu, 2001). Unsuitable and saline irrigation raises soil salinity, which has an impact on plants through salinity stress. Consequently, the area covered by salinized soil is growing annually. Utilizing cultivars that can thrive and perform well in these types of conditions is one of the greatest strategies to reduce the adverse effects of soil and water salinity on plants (Noori et al., 2015). One of the primary reasons of salinization in Egypt at the moment is the use of saline groundwater as the only source for irrigation (Karajeh et al., 2011). Olives may withstand salt to a moderate extent. By choosing cultivars that are resistant to drought and salt, olives, a common crop in semi-arid areas, could effectively acclimatize

to new climate change scenarios (Mousavi et al., 2019). The majority of published studies on olive plants have demonstrated that moderate to high saline levels (8, 12, and 20 dS) impair plant growth characteristics (stem height, leaf area, shoot, and root dry weight) (Chartzoulakis et al., 2002). Depending on the variety chosen for the study and the length of time exposed to saline, different characteristics of olive's vegetative growth are inhibited to varying degrees. Compared to total dry weight, leaf area seems to be more sensitive. The initial reaction of salt-tolerant plants is thought to be growth inhibition.

One of Egypt's most promising industries is the olive industry. Breeding programs are currently being conducted to obtain new olive cultivars with some of the preferred traits because of the increased local consumption of oil due to increased awareness of the importance of health and nutrients, as well as the failure of some fruit trees to thrive in the desert due to water salinity. In order to create new olive cultivars with some desirable characteristics of oil and table cultivars, the Horticulture Research Institute in Egypt has been conducting an olive breeding program since 1994. The goals of the breeding program were to enhance the qualities of these cultivars and create new genotypes with desirable traits such as early bearing, high oil content, productivity, pest and disease resistance, vigor, suitability for mechanical harvesting, and high-quality olive oil.

The objective of the present investigation is to evaluate six olive genotypes and identify the key traits of these genotypes that could enhance fruit quality and yield under saline irrigation, or using the resistant genotypes as rootstocks to graft commercially available salinity-sensitive cultivars.

MATERIALS AND METHODS

The Olive Genetic Improvement Project (1994) of the Horticultural Research Institute, Giza, Egypt, provided six olive genotypes aged 8 years from the olive oil cultivars "Coratina" and "Frantoio" for this study, which extended two growing seasons (2022 and 2023). Two cultivar groups were created:
(I) Coratina♀ X Frantoio♂, which had three genotypes (G10, G16 and G26).
(II) Frantoio♀ X Coratina♂, which had three genotypes (G4, G20 and G25).

Table (1) displays the genotype sources on the Olive Improvement Program Project map. F1 seeds were grown in sandy loam soil under a saline drip irrigation system (5648 ppm), at 3x6 m spacing in a private orchard located on the Cairo-Alexandria Desert Road (approximately 64 km from Cairo). All olive genotypes were grown under the same geographical conditions and received the same agricultural practices to characterize qualitative and quantitative traits and identify the most salinity-resistant genotype appropriate for cultivation in the newly reclaimed lands.

In the Soil, Water, and Environment Research Institute Laboratory, the physical and chemical characteristics of the soil as well as the chemical characteristics of the water were assessed using Jackson's methodology (1973). Tables provide a summary of the findings (1), (2), and (3). The average temperatures in 2022 and 2023 are summarized in **Figures (1 and 2).**

Table (1): The studied genotypes and their parents.

Genotype	Parents	
	♀	♂
G10 G16 G26	Coratina	Frantoio
G4 G20 G25	Frantoio	Coratina

Table (2). Physical and chemical properties of the experimental soil.

Texture	EC (dS m^{-1})	pH (1:2.5) susp.	Available macronutrients (mg kg^{-1})			Cations (meq/L)			
			N	P	K	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
			72.00	6.22	59.00	7.89	2.97	12.90	0.26
Sandy loam	2.68	7.2	Available micronutrients (mg kg^{-1})				Anions (Meq/L)		
			Cu	Fe	Mn	Zn	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{--}
			0.048	0.678	0.248	0.124	-	2.83	14.41	6.78

Table (3): The chemical analyses of the experimental ground water.

pH	8.30	Cations (meq/L)				Anions (meq/L)			SAR
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}	
E.C	7.06 dSm^{-1}	16.06	11.74	38.26	0.17	1.75	29.15	35.33	10.26
		Macro and micro nutrients (mg/L)							
	5648 ppm	$N(NH_4^{+})$	$N(NO_3^{-})$	P	Fe	Mn	Zn	Cu	B
		2.80	4.90	0.03	0.135	0.096	0.013	0.20	0.02

Measurements:

Vegetative, flowering, fruit set, yield, and fruit Characteristics:

The following characters were recorded according to the Methodology for primary characterization of olive varieties adopted by (IOOC, 1997 and Barranco et al., 2000).

Vegetative characteristics:

- **Qualitative measurements:**

- **Tree height (m):** It was classified according to methodology for primary characterization of olive genotypes (IOOC, 1997) to: very small (< 2.0m), small (2.0-3.0m), medium (3.0-4.0m), high (4.0-5.0m) and very high (> 5.0m).
- **Canopy volume (m^3):** It was measured by using the following equation: {0.5236 (D) ^{2} H}. Whereas: H = canopy height (m), D= average diameter of canopy = D1 + D2/2 (m). The rod was positioned at two locations perpendicular to each other. D1 is the widest canopy, and D2 is the narrowest. Canopy volume (m^3) was classified according to IOOC (1997) into: very small (<20), small (20-30); medium (30-40), large (40-50) and very large (>50).
- **Canopy surface area (m^2):** It was measured by using the following equation: CS (m^2) = 3.1416 x D. H. Where D is the average diameter of canopy = (D1 + D2)/2. The rod is placed perpendicularly at two points. Where D1 is the widest canopy and D2 is the narrowest, H = canopy height (m). Canopy surface area was classified according to IOOC (1997) to: very small (<20), small (20-35), medium (35-50), large (50-65), and very large (>65).

- **Quantitative measurements:**

- **Trunk cross-section (cm^2):** The diameter of the trunk (D) was measured at 10 cm above soil level according to Del Rio and Caballero (1994) by the following equation: 3.1416 (D/2)2. Which D = the diameter of the trunk.
- **Number of nodes per meter:** It was measured by the following equation: No. of nodes per meter = No. of nods x100/shoot length
- **Internodes length (cm):** Twenty shoots (one-year-old) were randomly selected around each tree canopy (replicate) and labeled in late March to record the internode length/shoot.
- **The leaf surface area(cm^2):** Samples of approximately 40 adult leaves taken from the middle section of one-year-old shoots to determine average leaf surface area (cm^2) according to Ahmed and Morsy (1999) by using the following equation: Leaf area =0.53 (length x width) +1.66.

Flowering, fruit set characteristics and yield:

- **Qualitative measurements:**

- **Number of flowers / inflorescences:** it was classified into low (<18 flowers); medium (18-25 flowers) and high (>25 flowers) according to (IOC, 2015).
- **Inflorescence length (cm)**: It was classified based on (IOC, 2015) into short (<2.5 cm), medium (2.5-3.5 cm), and long (>3.5 cm)**.**
- **Intensity of flowering**: it was classified according to Cimato and Attilio (2008) into: very low (<1-20 Inflorescence), low (20-40 Inflorescence), medium (40-60 Inflorescence), high (60-80 Inflorescence), and very high (80-100 Inflorescence)**.**

- **Quantitative measurements**

- **Percentage of perfect flower:** calculated according to Hegazi (2001) as the following equation:

$$\text{Perfect flower\%} = \frac{\text{No. of perfect flowers}}{\text{No. of total flowers}} \times 100$$

- **Percentage of fruit set:** was calculated after 60 days from full bloom according to Hegazi (2007).

Fruit set (%) = No. of fruits/ Total No. of flowers x 100.

- **Yield (Kg/tree):** Fruits were harvested during the ripe stage (olive with superficial pigmentation on more than 50% of the skin) and the average tree yield of each genotype was calculated (Dag et al., 2011).

Fruit characteristics:

To assess fruit and seed quality, thirty fresh olive fruits were hand-picked at random from among the examined genotypes according to the International Olive Council (IOC, 2015) standard method, as follows:

- **Qualitative measurements**

- Fruit weight was classified to: low (<2g), medium (2-4g), high (4-6g) and very high (>6g).
- Fruit shape: spherical (L/W <1.25), ovoid ((L/W 1.25-1.45) and elongated (L/W >1.45)
- Stone weight: low (<0.3g), medium (0.3-0.45g), and high (>0.45g)
- Stone shape: spherical (L/W <1.4), ovoid (L/W 1.4 - 1.8), elliptic (L/W 1.8-2.2) and elongated (L/W >2.2)

- **Quantitative measurements**

- Flesh weight (g), flesh/fruit weight (%), and percentage of olive fruit oil content (dry weight) were determined according to A.O.A.C. (2000).

Pigment concentration:

Samples of mature fresh leaves were homogenized with 85% acetone (V/V) in the presence of Na_2CO_3 and silica quartz, then filtered through a central glass funnel G4. The residue was washed several times with acetone until free of pigments. Each filtrate was diluted to 25 ml and measured spectrophotometrically at wavelengths of 662, 644 and 440.5 nm to determine chlorophyll a, b, and carotenoids, respectively (Brougham, 1960). The pigment concentration was calculated using the following equations.

$$\text{Chl. a (mg/gm)} = \frac{9.784 \times 662 - 0.99 \times 644}{A \times W \times l00} \times V$$

$$\text{Chl. b (mg/gm)} = \frac{21.428 \times 660 - 4.65 \times 662}{A \times W \times l00} \times V$$

Carotenoids (mg/gm) = 4.695 X 440.5 – 0.268 x (chl. a + chl. b)

Where:

V: is the volume in ml.

A: is the length of the light path in the cell

W: is the fresh weight in grams.

662, 644, and 440.5 are the absorbencies of chlorophyll a, b, and carotenoids

Proline percentage:

Mature fresh leaf samples (0.5 g) were homogenized in 10 ml of 3%-5% sulphosalicylic acid, then filtered through Whatman No. 1 filter paper. The filtrate (2 ml) was combined with 2ml of ninhydrin reagent and 2ml of glacial acetic acid, and boiled in a water bath for one hour. After boiling, the mixture was cooled in an ice bath. The reaction mixture was extracted with 4 ml of toluene, and absorbance was measured at 517nm, using toluene as a blank. Proline concentration was determined from a standard curve and calculated on a fresh weight basis (Bates et al., 1973).

Leaf mineral content:

The leaf samples were dried in an oven at 70°C for 48 hours until constant weight, then ground and used to prepare a wet digested solution (1:4 perchloric acid to sulfuric acid) as described by Piper (1950), which was analyzed for total macro elements. Potassium (%) was measured using a flame photometer (Brown and Lilleland 1946). Calcium and sodium (%) were determined by an atomic absorption spectrophotometer, Perkin Elmer-3300 (Chapman and Pratt 1961). Additionally, K^+/Na^+ leaf ratios and $(K^+ + Ca^{2+})/Na^+$ leaf ratios were calculated.

The summative evaluation (SE):

The summative evaluation of the investigated olive genotypes characteristics was calculated by using the average of 2022 and 2023 seasons basis of 100 units which were shared between the most important selected characteristics, within each of these parameters the genotype that recorded the uppermost values received all the units specified for it, relative values of all characteristics due to the other tested genotypes were calculated depending on the following equation:

$$\mathbf{SE = (B_1/A_1 \times 100/n) + (B_2/A_2 \times 100/n) + (B_3/A_3 \times 100/n) + (B_4/A_4 \times 100/n) + \ldots\ldots}$$

SE = Summative evaluation of each genotype.

$A_{(1-4)}$ = The highest values recorded for each studied characteristic among all genotypes.

$B_{(1-4)}$ = Values recorded for each specific characteristic for the other genotype to be evaluated.

n= number of the selected characteristics to be evaluated

In this investigation, four characteristics had been evaluated (yield/tree (kg), oil percentage %, proline (mg/100 g. f.w.), and $(K^+ + Ca^{++})/Na^+$ ratio). The ideas of summative evaluation had depended on those of El-Husseiny and Arafat (2020) and Mofeed et al. (2024), with the modification of adding the previous equation

Statistical analysis:

The experiment was conducted in a randomized complete blocks design, and the generated data were subjected to analysis of variance to evaluate significant differences between means under Snedecor and Cochran (1980). Furthermore, significant variations in means were identified using the Duncan multiple test range (Duncan, 1955).

RESULTS AND DISCUSSION

Vegetative characteristics:

- **Qualitative measurements:**

As indicated in **Table (4),** genotype traits were evaluated using a variety of metrics, such as tree vigor measured by tree height, canopy volume, and area, as well as the primary evaluation techniques for olive types described by the International Olive Oil Council. (IOC, 1997) as follows:

All genotypes recorded medium tree height (3-4 m), while the canopy volume was small for most of the genotypes (20-30 m^3) except G4 and G20, which were very small (<20). Whereas, the canopy area varied between the different genotypes, as it was medium (35-50 m^2) in each of G16, G26, and G25, while the rest of the genotypes achieved a small canopy area (20-35 m^2) in the average results of the studied seasons.

Table (4): Tree height, canopy volume, and canopy surface area of six olive genotypes during the 2022 and 2023 seasons.

Genotype	Tree height (m)					Canopy volume (m^3)					Canopy surface area (m^2)				
	Very small (<2)	Small (2-3)	Medium (3-4)	High (4-5)	Very high (>5)	Very small (<20)	Small (20-30)	Medium (30-40)	Large (40-50)	Very large (>50)	Very small (<20)	Small (20-35)	Medium (35-50)	Large (50-65)	Very large (>65)
G10			•				•					•			
G16			•				•						•		
G26			•				•						•		
G4			•			•						•			
G20			•			•						•			
G25			•				•						•		

All qualitative characteristics results were the average of the two quantitative seasons studied before converting to the qualitative form.

- **Quantitative measurements**

Regarding the quantitative traits presented in **Table (5),** it was found that trunk cross section showed its highest value with genotype G10 (140.1 and 162.1 cm^2) followed by G26 (127.2 and 131.4 cm^2) respectively in both seasons, while genotype G25 showed the highest value in the number of nodes/shoot (75.20 and 71.00) and leaf surface area (5.56 and 6.22 cm^2) respectively in 2022 and 2023 seasons, whereas the lowest values for these two traits (47.36 and 46.73 and 3.67 and4.40 cm^2) appeared in genotype G20 respectively, in both seasons,. As for the internode length, there was no clear trend, as genotypes G10, G26, and G20 in the first season and G10, G20 in the second season gave their highest values. Differences in vegetative growth characteristics among olive cultivars and genotypes are supported by findings of Aiachi et al. (2016), El-Husseiny and Arafat (2020) and Omran (2021).

Table (5): Trunk cross-section, number of nodes/meter, internode length, and leaf surface area of six olive genotypes during the 2022 and 2023 seasons.

Genotype	Trunk cross-section (cm^2)		No. of nods/meter		Internode length (cm)		Leaf surface area (cm^2)	
	2022	2023	2022	2023	2022	2023	2022	2023
G10	140.1A	162.1A	48.93E	52.94E	2.03A	2.13A	5.29C	5.64B
G16	103.1D	119.2C	60.00B	70.15B	1.66B	1.42C	4.47D	4.61C
G26	127.2B	131.4B	51.08D	54.05D	1.95A	1.85B	5.44B	5.63B
G4	97.41E	120.32C	58.11C	63.33C	1.57B	1.72B	4.23E	4.50D
G20	71.44F	89.90D	47.36F	46.73F	1.88A	2.11A	3.67F	4.40E
G25	114.9C	117.2D	75.20A	71.00A	1.32C	1.40C	5.56A	6.22A

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

Flowering, fruit set characteristics, and yield:

- **Qualitative measurements**

As the number of flowers/ inflorescences, and according to the IOC (2015) classification, **Table (6)** shows that all genotypes had a low number of flowers /inflorescence (<18 flowers) except genotypes G10 and G4, which had the greatest number of flowers/ inflorescences (Medium 18-25 flowers) in the average of the two studied seasons. The average Inflorescence length in the two studied seasons was medium (2.5-3.5 cm) in all genotypes except G4 generated from Frantoio x Coratina, had the shortest inflorescence (<2.5 cm).

Flowering intensity was high in all genotypes (60-80 inflorescences) except G10 and G4, which had the highest value (80 inflorescences). All the previous characteristics depend on several factors, including the variety, growing season, leaf-to-bud ratio, nutritional status, water stress during inflorescence development, and vegetative growth vigor. This result is generally consistent with the findings of Bellini et al. (2002), El-Sayed (2014) and Mikhail (2015). Similarly, in accordance with the primary olive genotype characterization approach of (IOC, 2015). However, Laaribi et al. (2014) and Barranco et al. (2000) found that some of the studied genotypes varied from short Inflorescence length (< 25mm) to long inflorescence (>35mm).

Table (6): Flowering qualitative measurements of six olive genotypes.

Genotype	Number of flowers/inflorescence			Inflorescence length (cm)			Intensity of Flowering				
	Low < 18	Medium 18-25	High > 25	Short < 2.5 cm	Medium 2.5-3.5 cm	Long > 3.5 cm	Very Low 1-20	Low 20-40	Medium 40-60	High 60-80	Very High80-100
G10		•			•						•
G16	•				•					•	
G26	•				•					•	
G4		•		•							•
G20	•				•					•	
G25	•				•					•	

All qualitative characteristics results were the average of the two quantitative seasons studied before converting to the qualitative form.

- **Quantitative measurements:**

Regarding to percentage of perfect flowers, fruit set%, and yield (kg/tree) during 2022 and 2023 seasons, **Table (7)** showed that genotype G25 statistically detected the highest percentage of perfect flowers (78.78 and 84.84%) and percentage of fruit set (8.66

and 9.09%), respectively during 2022 and 2023 seasons, followed by G16 and G26. Meanwhile, G4 achieved the lowest values of percentages of perfect flowers and fruit set. In the same trend, G25, G26, and G16 (in order) produced the highest values of yield /tree during the two studied seasons. However, the lowest ones were G4 and G20 (10 and 14kg/tree) respectively in the 2022 and 2023 seasons.

These findings are partially consistent with that reported by Cuevas and Rallo (1990), Ferri et al. (2006) and El-Badawy et al. (2019), who reported that differences in fruit set between olive cultivars, are due to varying degrees of self-fertility and cross-pollination requirements, as well as the percentage of perfect flowers, which affect the determination of fruit set percentage. Also, these findings are somewhat in line with those of Mikhail (2015), Yamen et al. (2017) and Dridi et al. (2019), who found that the yield of olive crops is largely independent of flower number and influenced by several variables, including biennial fruiting at varying levels based on the variety's genotype and environmental conditions.

Table (7): Perfect flower (%), fruit set (%) and yield (kg/tree) of six olive genotypes during the 2022 and 2023 seasons.

Genotype	Perfect flower (%)		Fruit set (%)		Yield (kg/tree)	
	2022	2023	2022	2023	2022	2023
G10	57.14D	62.50D	1.69CD	1.96D	17.00C	20.00D
G16	67.60B	79.45B	4.27B	4.77B	18.00B	22.00C
G26	59.47C	63.33C	1.92C	2.43C	19.67A	25.33B
G4	33.33F	34.78F	1.42D	1.50E	12.00D	14.00F
G20	50.34E	59.31E	1.42D	2.09D	10.00E	15.00E
G25	78.78A	84.84A	8.66A	9.09A	20.00A	26.00A

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

Fruit characteristics:

Fruit and stone qualitative measurements:

The resulting data in **Table (8)** make it abundantly evident that genotypes G16, G20 and G25 showed the lowest fruit weight (less than 2 g), meanwhile, G26 and G4 were of average weight, while G10 had the highest fruit weight. On the other hand, all genotypes had high-weight stones (above 0.45 g), except G25, which was of average weight. As for the fruit shape, which represents the ratio between the length and width of the fruit, most of the genotypes were elongated (L/W greater than 1.45), except G16 and G20 which tended to be ovoid fruit shape (L/W 1.25-1.45), whereas Stone shape varied from elongated shape (L/W>2.2) in G10, G26 and G4 to elliptic, ovoid and spherical in G25, G20 and G16, respectively. The qualitative and quantitative characteristics of the olive genotypes under study that show up in the morphology of the fruit and endocarps were significantly correlated. The International Olive Oil Council (IOOC, 1997) approved a simplified scheme that concentrates on the morphological traits of fruits and endocarps, which serves as the foundation for the majority of morphological investigations. Olive cultivars have been distinguished using these traits for descriptive. In accordance with the findings of Bellini *et al.*, (2002), Rallo (2014), Dridi et al. (2019) and El-Husseiny and Arafat (2020), who reported that those morphological characteristics allowed classification of different olive cultivars, the obtained results regarding qualitative fruit and stone characteristics allowed classification of the genotypes under study. Furthermore, El-Riachy et al. (2019), Nasr and Mohamed (2020), and Omran (2021) stated that morphological and biological traits are widely used to differentiate between olive cultivars.

Table (8): Fruit and stone qualitative measurements of six olive genotypes.

Genotype	Fruit weight (g)				Fruit shape			Stone weight (g)			Stone shape			
	Low (<2g)	Medium (2-4g)	High (4-6g)	V. high (>6g)	Spherical (L/W <1.25)	Ovoid ((L/W 1.25-1.45)	Elongated (L/W >1.45)	Low (<0.3g)	Medium (0.3-0.45g)	High (>0.45g)	Spherical (L/W <1.4)	Ovoid (L/W 1.4 - 1.8)	Elliptic (L/W 1.8-2.2)	Elongated (L/W >2.2)
G10			•				•			•				•
G16	•					•				•	•			
G26		•					•			•				•
G4		•					•			•				•
G20	•					•				•		•		
G25	•						•		•				•	

All qualitative characteristics results were the average of the two quantitative seasons studied before converting to the qualitative form.

Flesh weight, flesh/fruit weight% and oil content % (dry weight):

According to the results in **Table (9),** throughout the two seasons under study, genotype G10 had the highest flesh weight and flesh/fruit weight percentage (4.65 and 5.20 g) and (82.75 and 82.81%), respectively, whereas genotype G16 had the lowest ones. On the other hand, genotypes G16 and G4 recorded the highest oil content as a dry weight (33.77 and 34.66%) and (32.63 and 34.33%) in both seasons 2022 and 2023, respectively, while genotype G26 had the lowest oil content (19.96 and 20.40%) in the two studied seasons.

Many factors influence the amount of oil in olive genotype fruits, particularly the cultivar's genetic competence (genotype), soil type and climate, farming methods, and harvest date (Abdul-Sadeg, 2014). The total oil concentrations of the olive genotypes in our study generally mirrored the findings of earlier research on locally grown cultivars (El-Sayed 2014 and El-Badawy et al., 2019) as well as internationally imported cultivars (Yamen et al., 2017 and Dridi et al., 2019).

Table (9): Flesh weight, percentage of flesh/fruit weight, and percentage of oil content (dry weight) of six olive genotypes during the 2022 and 2023 seasons.

Genotype	Flesh weight (g)		Flesh/fruit weight (%)		Oil (%) (dry weight)	
	2022	2023	2022	2023	2022	2023
G10	4.65A	5.20A	82.75A	82.81A	20.40E	21.50D
G16	0.76F	0.90F	56.29E	57.14F	33.77A	34.66A
G26	1.83C	1.83C	73.98CD	73.20D	19.96E	20.40E
G4	2.04B	2.79B	77.36B	77.38B	32.63B	34.33A
G20	1.39D	1.43D	74.73C	71.35E	26.77C	28.34B
G25	1.14E	1.26E	73.84D	75.58C	25.48D	26.48C

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

Leaf pigments content (mg/100g): Chlorophyll a, b and carotenoids (mg/g F.W.):

Data in **Table (10)** revealed that among the six olive genotypes, genotypes G16, G26, G25, and G4 had the highest chlorophyll (a) content in their leaves, while genotype G20 exhibited the lowest amounts throughout the seasons under study. Regarding chlorophyll (b), genotypes G16 and G25 contained the most chlorophyll (b) content, whereas genotypes G10 recorded the lowest values. The highest values of carotenoid leaf content in the two studied seasons were observed by genotypes G26, G25, G4, and G16. Conversely, the lowest content of

carotenoids was noticed by genotype G20 during both seasons.

Salt stress affects olive trees by changing their photosynthetic pigment concentration (Jesus et al., 2015, Aparicio et al., 2014 and Ben Abdallah et al., 2018). Several olive cultivars have shown a reduction in leaf chlorophyll concentration as a result of salt stress (Cuevas et al., 2019, Jesus et al., 2015, Aparicio et al., 2014, Regni et al., 2019 and Shaheen et al., 2011). This decrease in chlorophyll concentration is a common response to increased oxidative stress (Yasar et al., 2008). Studies using several olive cultivars have demonstrated that a decrease in chlorophyll content and photosynthetic rate under salt stress coincides with increased catalytic activity of catalase and glutathione reductase in leaves (Regni et al., 2019 and Sevengor et al., 2011). The increase in salinity concentrations may have an effect on the amount of chlorophyll in all genotypes under study. This can be due to the inhibition of chlorophyll biosynthesis by activating chlorophyllase deterioration, which is the result of salinity-mediated chlorophyll degradation. (Gill and Tuteja, 2010 and Yasar et al., 2008). In the "Chétoui" and "Chemlali" cultivars, increased carotenoid content and carotenoid/ chlorophyll ratio were observed under salinity, which can be considered a protective response to prevent the photosynthetic apparatus from photo-oxidation (Ben Abdallah *et* al., 2018).

Leaf proline content (mg/100g):

Table (10) shows the leaf proline concentration throughout the 2022 and 2023 seasons. The G10 olive genotype had higher proline levels (61.59 and 62.18 mg/100 g f.w.) than other olive genotypes in both seasons. The G25 genotype produced the lowest values (39.16, 39.63 mg/100 g f.w.); the rest of the olive genotypes were between them. Proline, an essential amino acid, plays a role in several physiological processes in plants, especially olive trees, and significantly impacts their ability to tolerate salt exposure. Many studies have investigated the response of olive trees to saline conditions, revealing mainly the accumulation of proline as a result of its role in osmoregulation (Ayaz et al., 2021, Ben Rouina et al., 2006 and Trabelsi et al., 2024). The proline concentrations in olive leaves (Sigoise) were found to be positively correlated with soil salinity, suggesting a potential involvement of proline in the osmotic regulation of cytoplasmic pH or N storage for post-stress periods Demiral et al.(2011), Boualem et al. (2019) and Ayaz et al. (2021) reported a considerable rise in proline leaf content in three olive cultivars treated to various salt stress treatments. The proline content in olive leaves (Gemlik) increased significantly with increasing salt stress severity, indicating that olive trees use proline synthesis to mitigate salinity-induced osmotic stress. This study's findings are compatible with some of those of Hassan et al. (2020) and Shaheen et al. (2011). All of this confirms the hypothesis that proline accumulation correlates with the efficacy of salinity tolerance mechanisms in olive trees.

Proline may protect the photosynthetic activity of salt-stressed olive trees by controlling hydration and osmotic adjustment, thereby stimulating growth even in adverse conditions (Ben Rouina et al., 2006). Salt-stressed olive trees increased the content of proline in their cytoplasm in order to improve water absorption by tissues during active growth and preserve ionic equilibrium in vacuoles through osmotic adjustment effects (De Lacerda et al., 2003). Proline in the olive tree works as a protective osmolyte in the face of environmental concerns, particularly salty conditions, lowering toxicity and encouraging osmotic regulation.

Table (10): Leaf pigment and proline content of six olive genotypes during the 2022 and 2023 seasons.

Genotype	Chlorophyll a (mg/g. f.w.)		Chlorophyll b (mg/g. f.w.)		Carotenoids (mg/g. f.w.)		Proline (mg/100 g. f.w.)	
	2022	2023	2022	2023	2022	2023	2022	2023
G10	0.563B	0.572B	0.348D	0.354E	0.440B	0.451C	61.59A	62.18A
G16	0.638A	0.645A	0.422A	0.427A	0.495A	0.499AB	48.10C	48.71C
G26	0.626A	0.633A	0.374BC	0.381CD	0.476A	0.482B	42.41D	43.52D
G4	0.634A	0.643A	0.381B	0.395BC	0.485A	0.491AB	50.16B	50.71B
G20	0.486C	0.492C	0.358CD	0.363DE	0.409C	0.415D	49.78B	50.29B
G25	0.638A	0.647A	0.410A	0.417AB	0.490A	0.503A	39.16E	39.63E

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

Leaf mineral content:

Leaf mineral percentages of the studied olive cultivars are presented in **Table (11).** Regarding leaf potassium percentage, the highest values were acquired for genotype G26, followed by G16, and then G25. The lowest K leaf content was observed in G20. Other genotypes were in between. Similar results were observed with the percentage of Ca leaf content. The highest leaf calcium content was noticed by genotype G25, followed by G16, then G4. Contrarily, the lowest calcium content was recorded by G20. The opposite results were obtained with the percentage of Na leaf content. Whereas, the lowest values were realized by G26, then both genotypes 25 and 16. The highest percentage Na leaf content was illustrated with G10, then G20. **Table (11)** also represents the K^+/Na^+ and $K^+ + Ca^{++}/Na^+$ ratios of different olive genotypes in the 2022 and 2023 seasons. Genotype G26 significantly maintained the highest leaf ratios (2.236-2.380 and 4.316-4.550) for both ratios K^+ /Na^+ and $K^+ + Ca^{++}/Na^+$, respectively, in both seasons, followed by G16 and G25. The lowest values for those ratios were recorded by G10 in both seasons.

Olive trees, especially salt-sensitive varieties, exhibited a decrease in K^+ content when exposed to saline conditions (Tabatabaei, 2006). Likely, the presence of K^+ helps improve Na^+ exclusion by regulating channel selectivity. The cultivar's high K^+ concentration in leaves prevented osmotic Na^+ transfer from the roots to the aerial parts (Jacoby, 1999). Moreover, Tabatabae (2007) concluded that the ability of olive cultivars to store K^+ varies by genotype. Additionally, Kasirga and Demiral (2016) stated that K^+ content is recognized as an indicator of salinity adaptation in olive. Moreover, these findings align with those reported by Koubouris et al. (2015), who found that plant tissue analysis confirmed the antagonistic relationship between Na^+ and K^+. Tattini et al. (1992) discovered that K^+ content was consistently lower in Leccino (salt-sensitive) than in Frontoio (salt-tolerant). According to Zidan et al. (1991), the presence of K^+ and Ca^{++} ions reduces Na^+ entry into plant cells. Calcium helps keep cellular membranes intact and functioning properly. This ensures root selectivity for K^+ rather than Na (Vigo et al., 2005). Ca^{++} is thought to play a crucial role in sodium exclusion and retention mechanisms, contributing to survival under salt stress situations (Melgar et al., 2006). Jacoby (1999) and Fernandez-Escobar (2019) found that the presence of Ca^{++} improves Na^+ exclusion. This presence may boost tolerance to saltwater. Tattini et al. (1992) found that salt-sensitive Leccino had significantly lower Ca^{++} tissue concentration compared to salt-tolerant Frontoio. Leaf Ca^{++} content was considered a measure of olive adaptation to salinity, according to Kasirga and Demmiral (2016). It was determined that genotypes can be identified for salt tolerance based on their capacity to restrict salt entry to the shoot (Gucci and Tattini, 1997). According to research by Kasirga and Demiral (2016) and Larbi et al., (2020), the salt concentration level in olive plants' aerial portions was lower than that in their roots. The amount of sodium increased more in the leaves than in the roots of salt-sensitive cultivars (Demiral, 2005, Chartzoulakis, 2011 and Aparicio et al. (2014) who also found that the most salt-tolerant genotypes (Ocal and Picudo cvs.) had significant root

Na^+ accumulation and significant leaf Na^+ translocation inhibition.

Ion concentration in the xylem is controlled by ion exclusion and compartmentation at the root level, which keeps potentially hazardous ions from accumulating up in the aerial portions (Gucci et al., 1997). The findings above are consistent with Tabatabaei (2007) and Chartzoulakis (2014), who conclude that the genotypes of olive cultivars varied in how much Na^{++} they accumulate. Plant resistance to salt stress is mostly mediated by the decrease and accumulation of Na^{++} uptake (Zargar et al., 2019). Similar findings were made by Pandolfi et al. (2017) who observed that Leccino cv. (salt-sensitive) accumulated more sodium in all organs, particularly in leaves, than Frantoio cv. (salt-tolerant). Tattini (1994) concluded that the ability of salt-tolerant olive cultivars to keep an adequate K^+/Na^+ ratio in actively growing tissues is most likely linked to their resistance mechanism. Ranking of cultivars according to K^+/Na^+ ratio and Na^+ accumulation was more reliable than ranking according to shoot growth parameters (Gucci and Tattini, 1997 and Perica et al., 2008). Olives are remarkably tolerant of salinity because they can isolate Na^+ in vacuoles, limit its transport to shoots, and maintain a high K^+/Na^+ ratio to promote tissue metabolism (Connor and Fereres, 2005). The K^+/Na^+ ratio was found to be higher in leaves than in roots, according to Kasiga and Demiral (2016). Additionally, they stated that a larger K^+/Na^+ ratio in the plant leaves can be recognized as a crucial sign of the cultivar's degree of salt stress adaptation. The correct regulation of stomatal function, enzyme activation, protein synthesis, cell osmoregulation, turgor maintenance, photosynthesis, and oxidant metabolism all depend on a balanced K^+/Na^+ ratio. (Abbasi et al., 2016).

Compared to the salt-tolerant Frantoio cv., the salt-sensitive Leccino cv. displayed a reduced K^+/Na^+ selectivity ratio (Tattini, 1994 and Rossi et al., 2015). According to Tabatabaei (2006), the K^+/Na^+ ratio also showed variations in cultivar-specific K^+ selectivity. Leceino and Manzaillo obtained lower readings for NaCl. Aparicio et al. (2014) discovered that the most tolerant genotypes (Ocal and Picudo) had the least reduction in the K^+/Na^+ ratio. In both seasons under study, Picual's leaf K^+/Na^+ ratios were much greater than Kalamata's. Mousavi et al. (2019) showed that the capacity to keep leaves K^+ levels high and to avoid Na^+ buildup both contribute to salt tolerance. Salinity's effects on the plasma membrane's depolarization and selectivity are mitigated by raising the Ca^{++}: N^+ ratio in the external solution (Rinaldelli and Mancuso, 1996). Higher $K^+ + Ca^{++}/Na^+$ ratios in plant leaves can be regarded as a crucial indicator of the cultivar's degree of salt stress tolerance, according to Kasirga and Demiral (2016).

Table (11): Leaf content of K^+, Ca^{++}, Na^+ elements, K^+/Na^+ ratio and $(K^+ + Ca^{++})/Na^+$ ratio of six olive genotypes during the 2022 and 2023 seasons.

Genotype	K^+ (%)		Ca^{++} (%)		Na^+ (%)		K^+/Na^+ ratio		$(K^+ + Ca^{++})/Na^+$ ratio	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
G10	0.651D	0.662E	1.295C	1.315D	1.631A	1.589A	0.399F	0.417F	1.193F	1.244F
G16	1.345A	1.451B	1.326B	1.411B	0.688D	0.679D	1.955B	2.137B	3.882B	4.215B
G26	1.402A	1.509A	1.304C	1.376C	0.627E	0.634E	2.236A	2.380A	4.316A	4.550A
G4	0.736C	0.742D	1.329B	1.388C	0.962C	0.974C	0.765D	0.762D	2.147D	2.187D
G20	0.571E	0.578F	1.234D	1.269E	1.116B	1.134B	0.512E	0.510E	1.617E	1.629E
G25	1.058B	1.063C	1.543A	1.629A	0.698D	0.686D	1.516C	1.550C	3.726C	3.924C

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

Summative evaluation of six olive genotypes under Egyptian conditions:

The summative evaluation was calculated on the basis of 100 units, which were shared between yield (kg/tree), fruit oil% (dry weight basis), proline, and $(K^+ + Ca^{++})/Na^+$ ratio, which were specified. From the tabulated data in **Table (12) and Fig. (1)** obtained from this investigation, the best genotypes in terms of the investigated parameters (in order) were G16, then G25 and G26, recorded (89.26, 81.83, and 81.62 units) respectively. Meanwhile, genotype G20, which recorded (63.16 units), was the

least in total units of selected characteristics under the conditions of the study region. The previous summative evaluation was consistent with the same method which used by El-Husseiny and Arafat (2020) and Mofeed et al. (2024) when they evaluated some new genotypes in their similar studies.

Table (12): Summative evaluation of the six evaluated genotypes under Egyptian conditions.

Treatment	Yield	Oil %	Proline	$K^+ + Ca^{++}/Na^+$ ratio	Total (100 Units)
G10	20.11	15.31	25.00	6.92	67.35
G16	21.74	25.00	19.52	23.00	89.26
G26	24.46	14.75	17.62	25.00	81.83
G4	14.13	24.47	20.36	12.31	71.28
G20	13.59	20.14	20.20	9.22	63.16
G25	25.00	18.99	15.89	21.73	81.62

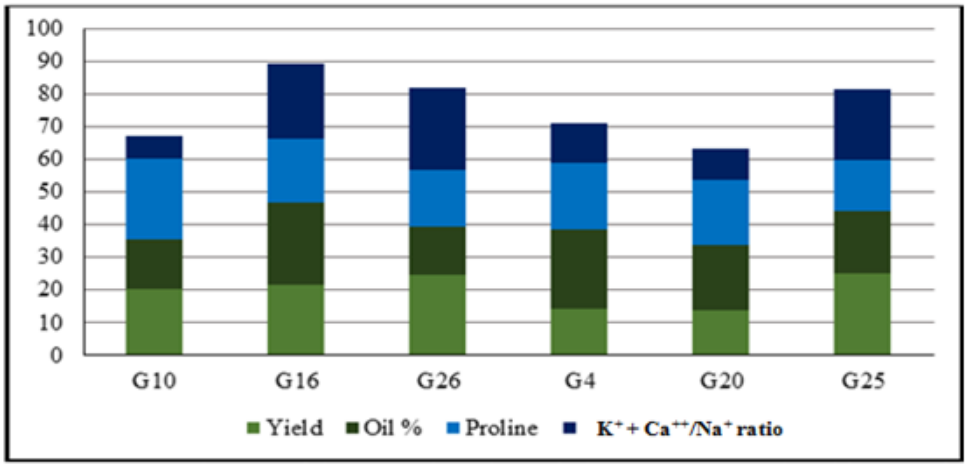

Fig. (1): Summative evaluation of the main phonological characteristics and yield/trees of six olive genotypes depending on the average of the 2022 and 2023 seasons.

CONCLUSION

The general summative evaluation table illustrated that the best olive genotypes in terms of the investigated characteristics (in order) were G16, G26, and G25 as oil purpose genotypes. Olive genotype G16 can be recommended for oil extraction under saline conditions, while genotype G26 had the lowest oil percentage, so it can be used as a saline-tolerant rootstock for grafting salt-sensitive commercial olive cultivars after conducting future studies to determine their compatibility with the selected rootstock. However, genotype G25 produces a medium oil percentage and can be used for both purposes, as an oil extraction or as a saline-tolerant rootstock.

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الملخص العربي

أداء بعض التراكيب الوراثية للزيتون النامية تحت ظروف الإجهاد الملحي

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أجريت هذه الدراسة على مدار موسمين (٢٠٢٢، ٢٠٢٣) لتقييم ستة تراكيب وراثية للزيتون ناتجة من التحسين الوراثي وقسمت إلى مجموعتين: المجموعة الأولى (كوراتينا♀ × فرانتويو♂) تضمنت الأنماط الوراثية: G10 وG16 وG26، بينما تضمنت المجموعة الثانية (فرانتويو♀ × كوراتينا♂) الأنماط الوراثية: G4 وG20 وG25، الاشجار (عمر ٨ سنوات) زرعت في مزرعة خاصة تقع على طريق القاهرة-الإسكندرية الصحراوي، على مسافات زراعة ٣ × ٦م في تربة رملية طينية تحت نظام الري بالتنقيط بمياه ملحية (٥٦٤٨ جزء فى المليون)، وتم تقييم هذه التراكيب الوراثية من خلال دراسة الصفات الخضرية والزهرية والمحصول ونسبة الزيت تحت ظروف الري الملحي، أو للتوصية باستخدام هذه التراكيب الوراثية المقاومة كأصول لتطعيم أصناف تجارية حساسة للملوحة. وفقًا للنتائج المتحصل عليها ، تميّز التركيب الوراثى G25 بأعلى مساحة سطح أوراق، ومساحة النمو الخضرى، وأعلى نسبة ازهار كاملة ونسبة عقد وكمية محصول للشجرة، بالإضافة إلى أعلى محتوى من الكالسيوم والكلوروفيل وأقل تركيز للبرولين. أما النمط الجيني G20، فقد أظهر أدنى قيم لقياسات المقطع العرضي للجذع، ومساحة سطح الأوراق وحجم النمو الخضرى ومحصول الشجرة ومحتوى الكلوروفيل والبوتاسيوم والكالسيوم. أما التركيب الوراثى G16، فقد تميّز بأعلى مستويات الزيت، والكلوروفيل، والبوتاسيوم. بينما أظهر النمط الجيني G10 أدنى نسبة زيت، ونسبة البوتاسيوم/الكالسيوم، والبوتاسيوم/الصوديوم. ويمكن التوصية بالتركيب الوراثى G16 مناسبًا لاستخلاص الزيت تحت ظروف الرى الملحى ، بينما يُمكن استخدام التركيب الوراثى G26 (الذي سجل أقل محتوى زيت) كأصل مقاوم للملوحة لتطعيم الأصناف التجارية الحساسة للملوحة عليه، أما التركيب الوراثى G25 فإنه ينتج كمية متوسطة من الزيت وعليه فيمكن التوصية به للغرضين كصنف زيت أو كأصل مقاوم للملوحة.