The Evaluation of Grafting with Some Different Rootstocks on The Yield, Berry Characteristics and Bioactive Compounds in “Starlight” Grape Cultivar

Hitham M.A. Mohamed and Abdelgawad S.S. Ahmed

Viticulture Research Department, Horticulture Research Institute, Agriculture Research Center, Giza, Egypt.

ABSTRACT

In the current study, we endeavored to assess the impact of grafting with three grape rootstocks namely (Freedom, Richter 110R and SO4) on yield, quality and accumulation of bioactive compounds in "Starlight “grape cultivar. We conducted the experiment over the course of the principal growing seasons in 2024 and 2025. Four treatments as follow (Control (un-grafted), grafted on Freedom rootstock, grafted on Richter 110R rootstock, and grafted on SO4 rootstock) were applied on 7-year-old vines, located at a private farm in Menia Governorate. Our findings indicated that grafting 'Starlight' grapevine cultivars onto various rootstocks generally enhanced their growth, fruit yield, quality and accumulation of bioactive compounds (Proline, Total phenolics and Tannins). Specifically, results have shown that vines grafted onto Freedom rootstock can lead to higher yields and larger vine vigor. Besides, it significantly boosts shoot growth and leaf area, improve berry size and weight, surpassing other rootstocks and those grown from their own roots. In contrast to the minimal growth observed with SO4 rootstock. Chemically, 'Starlight' vines grafted onto Freedom rootstock showcased the highest levels of Total Soluble Solids (TSS%) and TSS/acid ratio, whereas, it was the lowest in acidity percentage in the juice of berries, contributing to sweeter grapes with better coloration and anthocyanin content. Additionally, Richter 110R rootstock led to a higher accumulation of bioactive compounds compared to SO_4 and Freedom, with SO_4 outperforming Freedom in Proline and Tannins.

Keywords: Starlight grape- Bioactive compounds- Rootstocks- Freedom- Richter 110R and SO4.

INTRODUCTION

"Starlight" grape variety:

The Starlight grapevine (*Vitis vinifera* L.) is a promising red seedless table grape variety that has recently gained attention for its early ripening, market appeal, and adaptability to warm climates. Originating as a pink mutation of the Prime Seedless variety, Starlight was developed through breeding efforts aimed at enhancing earliness and fruit quality. It is characterized by medium-sized, round to slightly elongated berries with a light red to pink skin, crisp texture, and a sweet, neutral flavor, making it highly desirable for fresh consumption (KDB Fruit Farm, n.d., 2025).

As an early-season cultivar, Starlight matures significantly earlier than other red seedless varieties such as Flame Seedless, providing growers with an opportunity to target high-value early markets. Recent evaluations under Egyptian conditions have confirmed its adaptability, good vegetative growth, and satisfactory yield, aligning well with the country's agro-climatic profile. Its complete seedless, attractive berry appearance, and favorable consumer traits further enhance its commercial potential. As such, Starlight represents a valuable addition to Egypt’s expanding portfolio of table grape cultivars, with potential for both domestic and export markets (El-Hady, A., Tanta University and Agricultural Research Center, 2023).

Moreover, according to Hoekstra Fruit Farms & Volcani Institute (n.d.) and Matroosberg Grapes (n.d.) (2025), Starlight is seedless, early-season, and produces pink to red oval to broadly ellipsoid berries. The "Starlight" grape variety is known for its seedless nature, with the seeds being underdeveloped and not fully mature. This early-season type is distinguished by its

large, oval to broadly ellipsoid berries that exhibit a pink to red hue.

As for its growing timeline, it reaches maturity around the early days of June, providing an aesthetic value to those who cultivate it. Although its berries might be large, their storage potential is considered moderate. The flesh is not overly juicy, but it delights the palate with a subtle Muscat flavor. Its notable medium to large cluster size, unique leaf appearance, and pleasantly mild taste make the "Starlight" variety a remarkable choice for grape cultivation (Gaser et al., 2023).

Rootstocks:

The use of rootstocks has become a compulsory practice in commercial grapevine plantations, mainly because it provides resistance to root pests, adaptation to different soil types, and an increase in vine productivity and grape quality (Ibacache et al., 2016).

Rootstocks can also affect vine vigor, as it is the root system that provides the plant with the uptake of water and minerals necessary for growth and holds most of the nutrient reserves that are stored over winter (Klimek et al., 2022).

Some rootstocks support the physiological development of the vine and can ensure optimal ripening of the grafted variety (Reynolds and Wardle, 2001 and Klimek et al., 2022). Studies have shown that there is a significant interaction between grapevine cultivars and rootstocks with respect to yields, sugar accumulation in berries, berry chemistry, and flavors (Ollat et al., 2003).

Moreover, cluster weight, berry size and soluble solids content yield and fruit quality were also affected by rootstocks (Zhiyuan, 2003 and Gaser, 2007). Rootstocks are employed in grape cultivation to overcome several biotic and abiotic stresses, in addition to controlling vegetative growth and fruit quality. Numerous studies have shown that rootstocks can affect the parameters of the vine growth, flower development, yield and fruit quality through the interactions between the environmental factors, the physiology of scions and rootstock cultivars employed (Turker and Ak, 2010).

Freedom rootstock: It is hybrid between (1613 Couderc x V. champini); moderate to high vigor, highly resistant to nematodes and phylloxera and moderate drought tolerant (Hifny et al., 2016). It is valued for its strong vegetative growth, particularly its ability to produce thick basal shoots, which improves its suitability for grafting and nursery propagation. It is especially renowned for its resistance to nematodes, including root-knot and dagger nematodes, making it a preferred choice in soils with high nematode pressure. Although Freedom performs well under moderate water stress, it is less drought-tolerant than some other rootstocks like 110R. Its vigor can lead to enhanced canopy growth, which may require careful management to maintain balance between vegetative and reproductive growth. This rootstock is commonly used in table grape production due to its positive effects on vine vigor and overall vine health (Abd El-Wahab et al., 2015).

Richter 110R rootstock: It is hybrid between (Berlandieri x Rupestris); has moderate vigor, Phylloxera and Nematode resistance, salt and drought tolerance and soil adaptability tolerant to calcareous (chalky) soils and a deep root system, making it suitable for lighter, shallower soils (Howell, 2005). It is one of the most drought-tolerant rootstocks available and is widely used in arid and semi-arid viticulture regions. It promotes moderate to high vine vigor and is known for its deep rooting system, which allows it to access water and nutrients from deeper soil layers. This deep-rooting trait not only improves drought resilience but also contributes to more consistent vine performance in challenging environments. In addition to its agronomic benefits, 110R has been associated with increased concentrations of phenolic

compounds in grape skins, including flavones' and anthocyanin, which are important for wine structure and color. Its performance is particularly appreciated in red wine grape production due to its positive impact on fruit composition (Tenore et al., 2022).

SO4 rootstock: It is hybrid between (*V. Riparia* x *V. Berlandieri*), has moderate vigor and resistance to many nematode species, Phylloxera resistance, Tolerant of calcareous soils (Howell, 2005). It is commonly used in cooler, wetter regions due to its moderate drought tolerance. It offers good resistance to phylloxera and graft compatibility with a wide range of *Vitis vinifera* cultivars, which has contributed to its widespread adoption. However, SO4 rootstock tends to produce thinner basal shoots compared to rootstocks like Freedom, which may affect grafting efficiency and early vine development. Additionally, some studies suggest that SO4 may reduce anthocyanin accumulation in grape skins, potentially impacting wine color intensity. Despite these limitations, SO4 remains a popular choice for regions with sufficient water availability and for cultivars where moderate vegetative growth is desired (Köse et al., 2022)

Bioactive compounds:

Bioactive compounds, play a crucial role in promoting better growth in plants by modulating metabolic processes. These compounds, including polyphenolic compounds, carotenoids, anthocyanin, and tannins, exhibit diverse beneficial effects such as antioxidant activity and modulation of gene expression. However, the bioavailability of these compounds varies significantly, and factors like food sources and chemical interactions influence their effectiveness (Carbonell-Capella et al., 2014)

Grapevines, particularly *Vitis vinifera*, are rich in various bioactive compounds that offer numerous health benefits. Some of the key bioactive compounds found in grapevines include, Proanthocyanidins a class of polyphenols that have antioxidant and cardio protective effects. Anthocyanin are pigments that give red grapes their color and have antioxidant properties. Flavones' and Phenolic acids such as Gallic acid and Caffeic acid are another group of polyphenols with antioxidant and anti-inflammatory properties. Moreover, bioactive compounds are found in different parts of the grapevine, including the skin, pulp, seeds, and leaves (Dai and Mumper, 2021).

Phenolic compounds are one of the main factors responsible for the antioxidant activity of fruits and vegetables. The concentration of these compounds varies depending on many factors, e.g., species, cultivars, climatic conditions, geographical region, and agrochemical treatments performed during vine growth and development (Lesser et al., 2004, La Porte et al., 2010 and Lang et al., 2021).

However, the nutrient content, phenolic compound concentration, and anthocyanin content are quality parameters that should be taken into account when growing grapes, mainly to ensure better selection of the most effective variety and rootstock combination (Serafini et al., 2009).

Grapes are considered a major source of phenolic compounds, compared to other fruits and vegetables, but there is a wide variety of cultivars with different levels of these compounds in grapes (Pérez-Jiménez et al., 2023). In grapes and their by-products, phenolic compounds are directly related to sensory attributes such as color and flavor.

The objective of this study is to fine-tune the selection of an appropriate rootstock for 'Starlight' grapevines that is most compatible with Egypt's unique climatic and soil conditions. This is expected to bolster the overall growth and health of the plants, with the ultimate aim of producing a bountiful and quality harvest that is economically beneficial.

MATERIAL AND METHODS

The following trial took place in a vineyard located at 30.7503° E and 28.1099° N El-Menia Governorate, where this area is characterized by hot climate, in the two seasons 2024 and 2025. Seven-year-old seedless table grape "Starlight" spaced at 2 x 3 m, grown in a sandy loam soil were used in this investigation.

Table (1). Physical and chemical characteristics of soil

Parameter	Values
Sand (%)	64.8
Silt (%)	22.5
Clay (%)	12.2
Texture	Sandy loam
FC (%)	13.6
WP%	5.97
Bulk density g/ m^3	1.56
Organic matter (%)	0.41
pH	7.73
EC Mmhos/cm	1.83
Ca $^{++}$ meq/L	12
Mg $^{++}$ meq/L	5.2
Ca Co3 (%)	3.12
N (%)	0.91
P (%)	0.11
K (%)	0.54

*Soil analyses were conducted at the laboratory of the Faculty of Agriculture, Minia University

Vines were trellised by Gable system and spur pruned on a quadrilateral cordon system, retaining 72 buds per vine. Pruning was carried on the 2nd week of December and irrigated via a drip irrigation system. Vines in the chosen vineyard was grafted on Freedom, Richter 110R and SO4 besides ungrafted vines. The experiment was carried out to study the effect of the three rootstocks (Freedom, Richter 110R, and SO4, in addition to un-grafted vines as a control) on the growth, yield and fruit quality of "Starlight" grapevines.

Sixty vines were selected for this trial, comprised four treatments arranged in randomize complete block design each had three replicates inclusive five vines for each. The study was conducted over two seasons on the same set of vines, all of which were subject to the standard agricultural practices advised by the Ministry of Agriculture and harvested at the end of May and mid-June as follow:

T1. Control (un-grafted).
T2. Starlight grafted on Freedom rootstock.
T3. Starlight grafted on Richter 110R rootstock.
T4. Starlight grafted on SO4 rootstock.

Measurements data:

1. **Bud Behavior**:

a. Bud burst percentage was calculated according to the following equation:

Bud burst (%) = Number of burst buds/ Number of bud load per vine x 100

b. Fruitful buds percentage was calculated according to the following equation:

Fruitful buds (%) = Number of fruitful buds per vine/Number of burst buds per vine x100

2. **Yield Characteristics:**

a. Yield/vine (Kg)
b. Average cluster weight (g).

3. **Morphological measurement of berry:**

a. Average berry size (cm^3).
b. Average berry weight (g).

4. **Chemical characteristics of berries and leaves**:

Representative random samples of 15 clusters /treatment (5 cluster from each replicate) were collected when clusters reached their full color and total soluble solids reached about 18 – 20, according to Badr and Ramming (1994).

The following determinations were carried out:

a. Refractometric total soluble solids (TSS %) and titratable acidity as gram of tartaric acid per 100 ml of juice (A.O.A.C., 2023) and TSS / acid ratio.
b. Leaf pigments content (chlorophyll) were

measured in the mature leaves of the sixth and seventh positions from the apex by using the nondestructive Minolta chlorophyll meter model SPAD 502 (SPAD is an acronym for soil plant analysis development (Wood et al., 1992).

c. Total anthocyanin in berry skin (mg/100g) using spectrocolourimeter at 250 µm according to Yildiz and Dikmen (1990)

d. Bioactive compounds: Fresh grapevine leaves and berries were collected, washed to remove surface contaminants, and immediately frozen in liquid nitrogen. The samples were then lyophilized and ground into a fine powder using a mortar and pestle. Approximately 1.0 g of the dried leaf powder was used for the extraction of bioactive compounds. Then the following measurement were done:

Proline:

The acid-ninhydrin colorimetric method **(**Bates et al., 1973) was employed to determine proline content in leaves. The absorbance of the resulting chromophore was measured at 520 nm, and proline concentration was calculated using a standard curve. Results were expressed as mg/g proline per gram dry weight of leaves.

Total phenolics:

The Folin–Ciocalteu colorimetric method was employed to determine total phenolic acids, with absorbance measured at 765 nm using a spectrophotometer. Gallic acid served as the calibration standard, and results were expressed as mg gallic acid equivalents per gram dry weight of the grape berry skin sample (Singleton and Rossi, 1965).

Tannins:

Tannins in grapevine leaves were quantified using the butanol–HCl assay. The reaction mixture was heated at 95°C for 40 minutes, and absorbance was measured at 550 nm. Cyanidin equivalents were used for expression of results (Porter *et al.,* 1986).

5. Vegetative growth:

Ten vegetative shoots and ten fruitful shoots per vine were labeled and measured at growth cessation as follow:

a. Leaf area (cm^2) Samples of leaves, usually taken from the 4th to 6th leaf from the shoot apex (tip), were randomly collected from each treatment for leaf area determination at harvest (using leaf area meter, Model CI 203, U.S.A.).

b. Basal shoot diameter (mm)

c. Shoot length (cm)

6. Statistical analysis: The statistical analysis of the present data was obtained according to Snedecor and Cochran (1980). Averages were compared using the new L.S.D. values at 5% level using a randomized complete block.

RESULTS AND DISCUSSSION

1. Bud Behavior:

- Bud burst and Fruitful buds percentage:

Data displayed in **Table (2)** illustrate the influence of different grapevine rootstocks on bud behavior traits. The rootstocks Freedom, Richter 110R, and SO4 significantly enhanced bud burst percentage and the proportion of fruitful buds compared to 'Starlight' vines grown on their own roots. Among these, Freedom showed a notable improvement in promoting bud activity, followed closely by Richter 110R rootstock, which also demonstrated a positive impact on bud fertility. (Mervat et al., 2019). In contrast, SO4 rootstock, exhibited the lowest values for both bud burst and fruitful bud percentages among the tested rootstocks. Nonetheless, it is evident that even Richter 110R contributed to improved bud performance relative to un-grafted vines, emphasizing its comparative advantage over un-grafted plants. Based on the specific environmental conditions of this study, Freedom rootstock, emerged as the most effective rootstock in enhancing bud-

related characteristics. These outcomes align with the findings of Ibacache et al. (2016) who reported that the highest enhancement in bud behavior obtained for vines grafted on Freedom.

Table (2). Influence of different grape rootstocks on Bud Behavior of 'Starlight' grape cultivar in both seasons 2024–2025

Treatments	Bud burst (%)		Fruitful buds (%)	
	2024	2025	2024	2025
1- Control (un-grafted)	59.2	61.5	52.2	58.4
2- Grafted on Freedom	78.5	80.7	69.9	73.0
3- Grafted on Richter	71.3	77.8	62.3	66.8
4- Grafted on SO4	68.7	71.4	60.6	65.4
New LSD at 0.05	**2.1**	**1.8**	**1.9**	**2.2**

2. Yield characteristics:

- The effect of rootstocks on the yield/vine (kg), average cluster weight (g), average berry size (cm^3), average berry weight (g).

Results displayed in **Table (3)** show the effect of grape rootstocks on yield parameters. Vines grafted onto Freedom, Richter 110R, and SO_4 rootstocks significantly increased average cluster weight, berry size, berry weight, and overall yield per vine compared to un-grafted "Starlight" vines in both seasons. Among the tested rootstocks, Freedom exhibited the highest values in these parameters, followed by Richter 110R, both showing strong positive effects on grape yield and its attributes. Although the SO4 rootstock exhibited the smallest improvement in yield and fruit characteristics among the grafted rootstocks, it still resulted in better performance compared to un-grafted (control)"Starlight" vines. This indicates that while SO4's effect was less pronounced than that of Freedom and Richter 110R, it still provided a measurable and beneficial contribution to vine productivity under the study's conditions. These findings align with those reported by Hifny et al. (2016), who found that vines grafted on Freedom rootstock, showed the greatest increases in yield components, followed by Richter 110R rootstock, and then SO4 rootstock. Therefore, under the specific conditions of this study, Freedom rootstock demonstrated the highest potential for enhancing grape yield.

Table (3). Influence of different grape rootstocks on yield characteristics of 'Starlight' grape cultivar in both seasons 2024 – 2025.

Treatments	Yield/vine (Kg)		Average cluster weight (g)		Average berry weight (g)		Average berry size (cm^3)	
	2024	2025	2024	2025	2024	2025	2024	2025
1- Control (un-grafted)	13.0	13.2	435.4	441.6	4.0	4.2	3.6	4.1
2- Grafted on Freedom	17.7	18.0	589.7	597.3	5.5	5.9	5.2	5.6
3- Grafted on Richter	16.8	17.2	562.1	575.8	4.9	5.1	4.7	4.9
4- Grafted on SO4	15.3	15.7	512.5	523.0	4.6	4.9	4.2	4.4
New LSD at 0.05	**0.4**	**0.2**	**9.0**	**11.2**	**0.1**	**0.2**	**0.3**	**0.4**

3. Chemical characteristics of berries and leaves:

- The effect of rootstocks on the refractometric total soluble solids (TSS%) and titratable acidity:

Data showcased in **Table (4)** highlighted the substantial effects of grape rootstocks on a variety of parameters crucial for determining the grapes quality and composition. However, Freedom, Richter 110R, and SO4 rootstocks displayed a significant enhancement in refractometric total soluble solids (TSS %) and titratable acidity compared to "starlight" on its original rootstock (control).

Upon analysis, it was evident that the rootstock Freedom exhibited a pronounced tendency to increase these parameters, indicating its potential for improving grape quality (Mervat et al., 2019). Following closely, Richter 110R rootstock also demonstrated positive effects of these parameters, showing promising results in enhancing the quality of the grapes these findings are aligned with those of Lo'ay and Hamza (2020) who stated that Freedom rootstock recorded the highest percentage of TSS and TSS / acid ratio. Conversely, SO4 rootstock showed comparatively lower values in these parameters when compared to the other studied rootstocks, indicating its limited impact on the enhancement of grape chemical characteristics as mentioned by Wang et al. (2019) who indicated that SO4 tends to reduce TSS% and increase titratable acidity, potentially delaying berry ripening.

Under the specific conditions of the study, it can be concluded that the rootstock Freedom displayed the highest potential for increasing the quality parameters of grapes, including TSS % and decreasing the titratable acidity. Additionally, it is worth noting that even though SO4 rootstock, had the least impact followed by the control on these parameters, grapes grafted onto Richter 110R rootstock still outperformed vines, suggesting some level of improvement in grape quality despite its lower efficacy compared to Freedom rootstock.

- Total anthocyanin in berry skin:

Furthermore, among the evaluated rootstocks, Freedom has been associated with the highest anthocyanin accumulation in grape berry skins compared to the other rootstocks and the control **(Table 4).** This is likely due to its enhanced nutrient uptake and stress resilience, which support the biosynthesis of anthocyanin pigments such as Maldivian and delphinine derivatives. These findings are supported by Kurtural et al. (2016), who reported that Flame Seedless vines grafted onto Freedom exhibited superior berry coloration and pigment intensity compared to other rootstocks. Richter 110R followed with moderate anthocyanin levels, attributed to its efficient water use and moderate vigor, which can influence secondary metabolite pathways. In addition, this rootstock may contribute to an elevated total phenolic content, thereby bolstering antioxidant capacity and anthocyanin as discussed by Navarro et al. (2021). In contrast, SO4 consistently resulted in the lowest anthocyanin concentrations, although it still contributed to pigment synthesis when paired with specific scion cultivars. This trend is consistent with the metabolomics and transcriptomic analyses by Zhong et al. (2022), which demonstrated that SO4 induced lower expression of anthocyanin biosynthesis genes compared to other rootstocks such as Richter 110R**.**

- Leaf pigments content (chlorophyll):

Several studies have demonstrated that grapevines grafted onto different rootstocks exhibit significant variation in leaf chlorophyll content, largely due to differences in nutrient uptake efficiency and stress tolerance. In our study, among the commonly used rootstocks, Freedom has been shown to support the highest chlorophyll content **(Table 4),** particularly when grafted with cultivars such

as 'Starlight'. This is attributed to its superior uptake of essential nutrients like magnesium and nitrogen, which are crucial for chlorophyll biosynthesis (Clingeleffer, 2022 and Mansour, 2024). Additionally, Richter 110R rootstock, exhibits moderate chlorophyll levels; it performs well under water-limited conditions due to efficient stomata regulation and moderate nutrients use but does not surpass Freedom rootstock under optimal conditions (Pérez-Álvarez et al., 2023). Conversely, among the three tested rootstocks, SO_4 rootstock, exhibited the lowest chlorophyll content, followed closely by the ungrafted (un-grafted) vines. It is often associated with limited magnesium uptake and weaker physiological responses to abiotic stress, which negatively impact chlorophyll stability and photosynthetic activity (Chen et al., 2024 and Mansour, 2024).

Table (4). Influence of different grape rootstocks on chemical characteristics of berries and leaves of 'Starlight' grape cultivar in both seasons 2024 – 2025.

Treatments	Total soluble solids (TSS %)		Titratable acidity (%)		TSS/acid ratio		Total anthocyanin (mg/100g fw)		Chlorophyll SPAD	
	2024	2025	2024	2025	2024	2025	2024	2025	2024	2025
1- Control (un-grafted)	15.8	16.0	0.55	0.57	28.7	28.1	25.1	26.2	30.2	31.8
2- Grafted on Freedom	17.1	17.3	0.46	0.47	37.1	36.8	34.5	37.5	37.6	38.9
3- Grafted on Richter	16.5	16.7	0.50	0.51	33.0	32.7	32.0	31.6	35.8	36.7
4- Grafted on SO4	16.2	16.3	0.53	0.55	30.6	29.6	30.4	29.8	33.7	34.1
New LSD at 0.05	**0.2**	**0.1**	**0.02**	**0.01**	**1.7**	**1.2**	**1.1**	**1.7**	**1.2**	**0.9**

Bioactive compounds:

In our study, another perspective reveals the intricate influence of grapevine rootstocks on the levels of bioactive compounds, including Proline, Total Phenolic, and Tannins, as extensively documented exhibiting another trend **(Table 5).**

Proline:

Our results revealed that non-grafted vines and those grafted onto Richter 110R rootstock exhibited significantly elevated proline concentrations in leaves. This finding suggests that these treatments had limited tolerance to environmental stresses, as elevated proline levels are often indicative of stress responses. Consistent with our observations, Hayat et al. (2012) reported that proline accumulation in leaves serves as a marker of stress, triggered by various environmental factors. In addition, proline plays a crucial role in osmotic adjustment, oxidative stress protection and nitrogen storage during fruit development, thereby supporting smoother ripening processes under varying environmental conditions (Ashraf and Foolad, 2007). Similarly, the SO4 rootstock promoted moderate proline accumulation, contributing to balanced berry development. In contrast, Freedom tended to exhibit lower proline levels, suggesting a less direct influence on grape quality traits. Notably, un-grafted vines (control) displayed the highest proline concentrations among all treatments, potentially reflecting increased exposure to environmental stress due to the absence of rootstock-induced tolerance (Jahantigh et al., 2016). These findings align with previous research indicating that grapevines grafted onto Richter 110R rootstock exhibit higher proline levels compared to those grafted onto Freedom (Chalker-Scott, 2017).

While proline accumulation is a well-established physiological response to abiotic stresses (Ashraf and Foolad, 2007), its interpretation should be contextualized alongside other vine performance indicators. The elevated proline observed in un-grafted vines likely indicates heightened physiological stress, whereas the lower proline levels in Freedom-grafted vines may reflect reduced stress exposure, possibly due to improved adaptation or stress avoidance mechanisms.

This implies that Freedom rootstock may provide superior tolerance to prevailing conditions compared to Richter 110R, as it maintains lower stress-related biochemical responses while supporting vine performance. Therefore, based on proline accumulation patterns, Freedom appears to be the more favorable rootstock under the tested conditions.

Total Phenolics:

Through our recorded data, it was found that the un-grafted vines followed by Richter 110R rootstock contained the highest accumulation of total phenolic compounds in grape berry skin then Freedom ranking second, which also exhibited relatively high phenolic content, contributing positively to color stability and mouthfeel. In contrast, SO4 rootstock tended to result in lower phenolic concentrations, suggesting a more moderate influence on grape sensory properties. As mentioned by Abd El-Aziz et al. (2024) and Hornedo-Ortega et al. (2020), who emphasized the importance of phenolic content in determining grape quality traits. In the present study, since vines grafted onto Richter 110R rootstock showed significantly higher total phenolic content than those grafted onto Freedom and Phenolic compounds are key elements in the plant's antioxidant system and are typically synthesized in response to various abiotic stresses, including drought and oxidative stress (Mpelasoka et al., 2003), therefore, the lower phenolic content observed in vines grafted onto Freedom suggests that this rootstock conferred better stress buffering capacity and more favorable physiological conditions to the scion, making it a more suitable rootstock under the studied environmental conditions.

Tannins:

In this study, un-grafted grapevines and grafted onto Richter 110R rootstock exhibited higher tannin concentrations than those grafted on SO4 rootstock, with moderate tannin levels, followed by Freedom the lowest of all **(Table 5).** Tannins, as flavonoid-derived compounds, are known to accumulate in plant tissues in response to various stressors, including drought, excessive sunlight, and pathogen exposure (Teixeira et al., 2013). Their biosynthesis is typically upregulated as part of the plant's secondary defense mechanisms. Thus, elevated tannin levels in Richter-grafted vines may reflect a stronger stress response or greater stress perception. In contrast, the lower tannin levels observed in Freedom-grafted vines suggest a more stable physiological environment, indicating that Freedom rootstock may offer superior stress mitigation, making it more suitable for the prevailing conditions.

Table (5). Influence of different grape rootstocks on bioactive compounds of 'Starlight' grape cultivar in both seasons 2024 – 2025.

Treatments	Proline (mg/g DW)		Total phenolics (mg GAE/g DW)		Tannins (mg/g DW)	
	2024	2025	2024	2025	2024	2025
1- Control (un-grafted)	8.6	8.9	16.2	16.5	5.2	5.4
2- Grafted on Freedom	4.2	4.4	13.5	13.7	2.6	2.8
3- Grafted on Richter	6.2	6.5	14.8	15.0	3.9	4.1
4- Grafted on SO4	5.1	5.3	12.6	12.9	3.1	3.4
New LSD at 0.05	**0.4**	**0.3**	**0.7**	**0.9**	**0.2**	**0.3**

*GAE is referring to Gallic Acid Equivalents

The vegetative growth

Leaf area:

In terms of leaf area, the results indicate a substantial disparity in the growth parameters of the examined rootstocks across both the 2024 and 2025 seasons **(Table 6).** Notably, Freedom rootstock consistently exhibited the largest leaf area, suggesting enhanced vegetative vigor and

potentially greater photosynthetic capacity. Richter 110R rootstock, ranked second, maintaining relatively strong leaf expansion, which supports its classification as a moderately vigorous rootstock. In contrast, SO_4 rootstock, showed the lowest leaf area values among the tested rootstocks, followed by the un-grafted (control) vines, indicating a more limited canopy development. These differences are critical, as increased leaf area is directly linked to higher assimilate production, which can influence overall vine performance, berry development, and yield potential. These findings are consistent with the observations of El-Kenawy et al. (2022), who reported that rootstock-induced differences in leaf morphology significantly affect vine vigor and canopy architecture.

Basal shoot diameter:

It's obvious that among the three rootstocks **(Table 6),** Freedom significantly produces the thickest basal shoots, making it highly suitable for grafting and nursery propagation due to its vigorous vegetative growth (Abd El-Wahab et al., 2015). In contrast, Richter 110R rootstock, supports moderate shoot diameter, reflecting its balanced vigor, which is beneficial for both canopy development and stress adaptation, especially in arid conditions (Clingeleffer, 2022). While SO4 rootstock followed by un-grafted vines tend to produce thinner basal shoots compared to Freedom and 110R rootstocks. Studies have shown that vines grafted onto SO4 exhibit reduced shoot diameters, which may influence vine vigor and necessitate tailored management strategies (Köse et al., 2022).

Shoot length:

Analysis of shoot length among three distinct rootstocks, as well as un-grafted plants, indicated pronounced differences as depicted in **Table (6).** It was evident that Freedom rootstock exhibited superior performance compared to the other two rootstocks, displaying the highest values, followed by Richter 110R and SO4 rootstocks, which demonstrated comparatively lower values. Past studies have suggested that Freedom rootstock tends to promote longer shoot growth when compared to Richter 110R, which exhibits a more moderate growth trend, followed by SO4 rootstock, associated with the shortest shoot lengths. These outcomes are in agreement with the findings of Dattola et al., (2023), where it was observed that shoot length was shorter when grafted onto Richter 110R and SO4 rootstocks, while longer when grafted onto Freedom rootstock.

Table (6). Influence of different grape rootstocks on the vegetative growth of 'Starlight' grape cultivar in both seasons 2024 – 2025.

Treatments	Leaf area (cm^2)		Basal shoot diameter (mm)		Shoot length (cm)	
	2024	2025	2024	2025	2024	2025
1- Control (un-grafted)	75.5	80.1	5.4	4.9	88.6	85.3
2- Grafted on Freedom	120.9	119.3	7.1	7.8	123.4	126.7
3- Grafted on Richter	98.2	94.8	6.7	7.4	112.6	115.5
4- Grafted on SO4	80.4	79.0	6.3	6.8	96.3	99.1
New LSD at 0.05	**3.6**	**2.8**	**0.2**	**0.3**	**2.4**	**3.2**

CONCLUSION

In conclusion, the performance of grapevines grafted onto Freedom, Richter 110R, and SO_4 rootstocks differed notably in vegetative growth and berry quality traits. Freedom rootstock consistently showed the highest values for bud burst percentage, fruitful buds, yield, berry size, TSS%, leaf area, shoot length, and basal shoot diameter, reflecting strong vegetative vigor. In contrast, un-grafted vines recorded the lowest values in all measured growth and yield traits, indicating limited potential under the tested conditions. Freedom

rootstock also had the highest total anthocyanin content, and lower levels of certain bioactive compounds. Richter 110R rootstock showed moderate shoot growth with relatively higher levels of bioactive compounds (proline, total phenolics, and tannins), followed by SO_4 and Freedom rootstocks. This suggests that Freedom supports healthier vine physiology and lower stress exposure, contributing to better adaptation and performance. SO_4 rootstock exhibited the lowest shoot diameter and modest growth, but relatively higher proline and tannin contents than Freedom. These findings emphasize that rootstock selection significantly affects canopy development and berry biochemistry, and should align with production goals. Overall, Freedom is the most recommended rootstock for 'Starlight' under the present conditions due to its superior agronomic and physiological performance.

These differences highlight that rootstock selection influences both canopy development and berry biochemical composition, and must be matched carefully to the desired production objectives, whether focused on yield, fruit quality, or grape composition.

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الملخص العربى

تقييم التطعيم على بعض الأصول الجذرية المختلفة من حيث المحصول وخصائص الحبات والمركبات الحيوية النشطة في صنف العنب "ستارلايت"

هيثم محمد علام محمد و عبد الجواد صبحى شعبان أحمد

قسم بحوث العنب، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر

في هذه الدراسة، تم تقييم تأثير التطعيم على ثلاثة أصول مختلفة للعنب وهي (فريدوم، ريختر R110، و SO4) من حيث كمية المحصول، جودة الثمار وتراكم المركبات الحيوية النشطة في صنف العنب "ستارلايت". أُجريَت التجربة فى الموسمين المتتاليين 2024 و2025 في مزرعة خاصة بمحافظة المنيا. تم إجراء أربع معاملات كما يلي: كنترول "غير مطعوم"، مطعوم على أصل فريدوم، مطعوم على أصل ريختر R110، ومطعوم على أصل SO4 على كرمات عنب عمر 7 سنوات.

أظهرت النتائج أن تطعيم صنف "ستارلايت" على أصول مختلفة أدى بشكل عام إلى تحسين النمو والإنتاجية وجودة الثمار وتراكم المركبات الحيوية النشطة (مثل البرولين، المركبات الفينولية الكلية والتانينات)؛ كما أوضحت النتائج أن الكروم المطعومة على أصل فريدوم حققت أعلى إنتاجية وجودة ثمار، بجانب تحسين نمو الأفرع ومساحة الأوراق، وحجم ووزن الحبة، مقارنة بباقي الأصول والكنترول؛ كما أظهرت القياسات الكيميائية، أن الكرمات المطعومة على أصل فريدوم كان أعلى فى نسبة المواد الصلبة الذائبة الكلية (TSS%) ونسبة TSS إلى الحموضة، في حين كانت نسبة الحموضة أقل في العصير، مع زيادة فى محتوى الأنثوسيانين. بالإضافة إلى ذلك، أدى أصل ريختر 110 R إلى تراكم أعلى للمركبات الحيوية النشطة مقارنةً بأصلي SO4 وفريدوم، حيث تفوق أصل SO4 على فريدوم في هذه الخصائص .