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Effect of Some Rootstocks on Vegetative Growth, Nutrient Content, Yield and Quality of Thompson Seedless Grapevines and H4 Strain under Conditions of Egyptian Delta Region

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THE GENERAL trend of expanding in the cultivation of grapes in the Delta region depends on the cultivation of grafted cultivars on different rootstocks, with a preference for the cultivation of H4 strain grafted over the Thomson Seedless grafted. The aim of this study was to evaluate grafting Thomson Seedless and H4 strain cultivars on three different rootstocks (Freedom, Salt Creek, and SO4) compared with non-grafted (own rooted) to select the most suitable rootstock under clay soil conditions and surface irrigation system of the Delta region, Egypt. This experiment was conducted over four consecutive seasons (2019, 2020, 2021, and 2022), and the data were taken during the 2021 and 2022 seasons. Results showed that grafting Thomson Seedless and H4 strain cultivars on Freedom, Salt Creek and SO4 rootstocks was better than non-grafted(own rooted) on improving all studied parameters. The best results for all studied parameters were obtained when the vines were grafted on Freedom followed by Salt Creek followed by SO4. In addition, the obtained results showed that the H4 strain grafted on Freedom rootstock recorded the significant highest values as compared with Thomson Seedless grafted on Freedom in most studied parameters. Therefore, it is recommended to graft Thomson Seedless and H4 strain cultivars on Freedom rootstock under the conditions of clay soil and surface irrigation system in the Delta region, with preference planting of the H4 strain due toits good vegetative growth, high cluster weight, and yield. However, further studies to reduce the compactness coefficient of clusters are essential in this strain.

Keywords: Grape, Grafting, Rootstocks, Freedom, Salt Creek, SO4, Thompson Seedless, H4 strain.

Introduction

Grapes (*Vitis vinifera*, L.) are considered one of the most important and popular fruit crops in the world, especially in temperate, tropical, and subtropical regions. Grape berries have been used in multiple forms including edible fresh or dry berries, jam, juice, vinegar, seed oil, and wine (Kareem et al., 2022). In 2019, the global harvested area of grapevines was estimated at around 7 million ha, which produced around 77 million tons (FAOSTAT, 2021). The Thompson Seedless grapevine is considered one of the most important cultivars cultivated in Egypt. It is used as a fresh table grape, making raisins and for export. H4 is a strain of the Thompson seedless cultivar, which has been widely spread in recent years due to its high yield and weight of cluster, in addition to vigor of vegetative growth (Belal, 2019).

Grafting is an effective technique used in viticulture for overcoming biotic and abiotic stresses (Walker et al., 2014 and Jin et al., 2016). It is a practice extensively used in viticulture worldwide to over come biotic stress such aspest and pathogen infections that affect the root system of the plant, as well as a biotic stress such as low fertility soils, excess or deficiency of water, saline soils, lime soils, and other adverse conditions (Peterson and Walker, 2017).

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Grape rootstocks are of great importance for countries engaged in viticulture (Troncoso et al., 1999). Use of rootstocks in grape cultivation has been a common practice among viticulturists worldwide, where choosing the rootstock is one of the most important decisions when establishing vineyards. Rootstocks are used in grape cultivation to combat several biotic stresses (phylloxera, nematodes, root diseases and so on) a biotic stresses (soil and water salinity, active lime, water scarcity, frost tolerance and so on) and, to a lesser extent, to improve vegetative growth and fruit quality (Jogaiah et al., 2013 and Walker et al., 2014). In addition, rootstocks can be used effectively to regulate nutrient exclusion and uptake of water in vines (Walker et al., 2002). Numerous studies have also proved that rootstocks greatly affect vegetative growth, yield, berry quality and phenological stages in grapes (Koundouras et al., 2008, Rizk-Allaet al., 2011 and Silva et al., 2017). Rootstocks react differently with different soils and climates, so regional rootstock evaluations are essential in determining which rootstock is best suited to a particular environment (Shaffer, 2002).

Freedom rootstock was developed at the University of California-Davis and is a cross between Dogridge (*V. X Champini*) and 1613 Couderc (*V. Solonis X* Othello). It is susceptible to Phylloxera but highly resistant to a broad spectrum of nematode species, Armillaria root rot (*Armillariamellea*) and moderate drought tolerant. This rootstock needs further testing, especially in coarse soil sites frequently subjected to drought conditions (El-Gendy, 2013 and Hifnyet al., 2016).

Salt Creek “Ramsey” rootstock (V. champini) is characterized by good resistance to nematodes and moderately resistance to phylloxera. It is favored in light sandy soils with low fertility, and has good tolerance to salt. It grows well in slightly acidic and calcareous soils (Walker et al., 2002, Goyzueta & Peniche, 2004 and El-Gendy, 2013).

SO4 rootstock (V. berlandieri x V. riparia) has Phylloxera resistance and moderate resistance to many nematode species. It appears to confer “medium to short-cycling” on scion varieties regarding fruit and canopy maturation periods (Howell, 2005).

The aim of this study was to evaluate grafting Thomson Seedless and H4 strain grapevines on three different rootstocks (Freedom, Salt Creek, and SO4) compared with the non-grafted (own rooted) to select the most suitable rootstock under the conditions of clay soil and surface irrigation system in the Egyptiandelta region.

Materials and Methods

The field trial was conducted in a private vineyard located at El-deer village, Aga city, Dakahlia Governorate, Egypt through four successive seasons (2019, 2020, 2021, and 2022) on Thompson Seedless and H4 strain grapevine grafted on three different rootstocks (Freedom, Salt Creek, SO4, and their own roots). The studied seedlings were obtained from the grape activity of the Horticultural Research Institute in Giza. The seedlings were planted on the permanent land in March 2019 at a distance of 2m x 3m in a clay soil (Table, 1), under the surface irrigation system, and trained on a pergola trellis system. During January of the third and fourth seasons from planting, the tested vines were cane pruned and loaded with 60 eyes per vine. Ninety six vines uniform in vigor as possible were chosen for this study.All vines received the same cultural managements recommended by the Ministry of Agricultureand land Reclamation. The experiment consisted of eight treatments arranged in a randomized complete blocks design (RCBD).Each treatment included three replicates, and each replicate included four grapevines. Data were taken during the 2021 and 2022 seasons.

The experiment contained the following treatments:

1-Thompson Seedless non- grafted (own roots)
2-Thompson Seedless grafted on Freedom rootstock
3-Thompson Seedless grafted on Salt Creek rootstock
4-Thompson Seedless grafted on SO4 rootstock
5- H4 strain non-grafted (own roots)
6- H4 strain grafted on Freedom rootstock
7- H4 strain grafted on Salt Creek rootstock
8- H4 strain grafted on SO4 rootstock

The following characteristics were determined:

Bud Behavior

The numbers of bud burst and clusters per each vine were counted, and then the percentages of bud burst and fertile buds were calculated according to Samra, (2001) where,

Bud burst (%) = No. of bursted buds/ Total No. of buds × 100

Bud fertility (%) = No. of clusters per vine/ Total No. of buds × 100

TABLE 1. Physical and chemical analysis of the vineyard soil

Physical	**Sand (%)**	25.32
	Silt (%)	23.56
	Clay (%)	51.12
	Texture	Clay
Chemical	**Organic carbon (%)**	1.98
	pH (1:2.5)	7.86
	EC (Mmhos/cm)	0.62
	Ca CO_3 (%)	1.80
	N (%)	0.30
	P (%)	0.13
	K (%)	0.295

Morphological characteristics of vegetative growth

Vegetative growth parameters were evaluated from non-bearing shoots after berry set to determine the following parameters: average shoot length (cm), shoot diameter (cm) by using a vernier caliper, number of leaves/shoot and average leaf surface area (cm^2) which was calculated according to the method described by Montero et al. (2000), and total leaf area per vine (m^2) was determined by multiplying average leaf surface area by the average number of leaves/shoot by the number of shoots per vine. In addition, the coefficient of wood ripening at growth cessation was determined by the method described by Rizk and Rizk (1994).

Mineral content on the leaves

After fruit set, samples of 20 leaf petioles per each replicate from the leaves opposite to the cluster were used for determination of N, P, K, and Mg contents according to the methods described by Cottenie et al. (1982).

Biochemical studies on the leaves and canes

After fruit set, sixth and seventh leaves from the tip of the growing shoots were used for determination of total chlorophyll content following the Lichtenthaler and Wellburn (1985) protocol, using methanol, and expressed as mg/g FW. Total free amino acid in the leaves (g/100g D.W.) was determined according to the method described by Jayarman (1981) with some modifications of Chen et al. (2009) and leaf proline content (mg/g FW) was determined according to the method described by Arbona et al. (2003). In addition, total carbohydrates content in the canes (g/100g DW) at growth cessation was determined according to Hodge and Hofreiter (1962).

Yield and physical characteristics of clusters and berries

At harvest time when, SSC % of berries reached about 16-17 % in control, a representative sample of six clusters /vine was weighted and the average cluster weight was multiplied by number of clusters/vine to calculate the average yield/vine. Average cluster weight (g),average cluster length (cm), average of 100 berry weight (g), and number of berries/clusters were also determined, and the compactness coefficient of the cluster was calculated by dividing the number of the cluster berries by the cluster length (Fawzi*et al.,* 2019). Botrytis incidence (%) was determined by dividing the number of incidence clusters with the rot by number of clusters per vine also, botrytis severity (%) was measured by dividing the number of diseased berries by number of berries per cluster according to the method of Shalanand Doaa (2020).

Chemical properties of berries

The same clusters that were used to measure the physical characteristics of clusters and berries were used to measure the chemical characteristics of berries as follows: Soluble solids content (SSC %) was determined by using a hand refractometer model Master T (ATAGO Co., Ltd., Japan). Titratable acidity percentage (as g tartaric acid /100 mL juice) was determined according to the methods described by AOAC (2006). SSC/acid ratio was calculated by dividing the percentage of SSC by titratable acidity and total sugars (%) was determined by the method described by Sadasivam and Manickam (1996).

Statistical Analysis

The randomized complete block design was adopted for this experiment. The statistical analysis of the present data was carried out according to Snedecor and Cochran (1980). Average means were compared using the new L.S.D. values at 5% level (Steel and Torrie, 1980).

Results

Bud Behavior

Results presented in (Table 2) reveal that bud burst and bud fertility percentages, and the number of clusters of Thompson Seedless and H4 strain cultivars were affected by the used rootstocks. It was noticed that grafting Thompson seedless and H4 strain cultivars on Freedom, Salt Creek and SO4 rootstocks enhanced the studied parameters compared with the non-grafted (own roots). Results reveal that H4 strain grafted on Freedom, Salt Creek and SO4 rootstocks recorded the maximum percentage of bud burst and bud fertility, as well as the highest number of clusters per vine when compared to non-grafted H4 strain or Thompson Seedless grafted or non-grafted. In 2021 and 2022 seasons, respectively H4 strain grafted onto Freedom recorded the highest significant values of bud burst (75 and 85%), bud fertility (40 and 45 %) and number of clusters per vine (24 and 27). In addition, the obtained results showed that Thompson Seedless grafted on Freedom recorded the highest values of bud burst and bud fertility percentages, and number of clusters as compared with those grafted on Salt Creek and SO4 rootstock. No-significant differences were observed either between Thompson Seedless grafted on Freedom, Salt Creek and SO4 rootstocks and non-grafted or between H4 strain grafted on Salt Creek and SO4 rootstocks and non-grafted on bud fertility percentage and number of clusters in both seasons. Furthermore, the non-grafted Thompson Seedless recorded the lowest values of bud burst (51.1 and 58.3 %) bud fertility (28.8 and 33.8 %) and number of clusters per vine (17.3 and 20.3) in 2021 and 2022 seasons, followed by the non-grafted H4 strain.

Morphological characteristics of vegetative growth

Results of vegetative growth parameters such as shoot length and diameter, number of leaves/shoot, total leaf area/ vine, and coefficient of wood ripening, which are considered the indicators of vine vigor for Thompson Seedless and H4 strain grapevines are presented in Table (3). However, it is clear that grafting Thompson Seedless grapevines and H4 strain on Freedom, Salt Creek and SO4 rootstocks were the superior when compared with the non-grafted ones. In 2021 and 2022 seasons, the H4 strain grafted on Freedom rootstock had the highest values of shoot length (145.7 and 149.3 cm), shoot diameter (1.20 and 1.26 cm), number of leaves/shoot (24.3 and 24.9),total leaf area/ vine (18.9 and 22.7 m^2) and coefficient of wood ripening (0.84 and 0.85) in 2021 and 2022 seasons respectively, followed by those grafted on Salt Creek rootstock, then Thompson Seedless grafted on Freedom rootstock. No-significant differences were noticed between Thompson seedless grafted on Freedom and Salt Creek rootstocks in shoot length, number of leaves/shoot and coefficient of wood ripening. Also, the results show that Thompson Seedless and H4 strain grafted on SO4 rootstock recorded the lowest values in this regard as compared with Freedom and Salt Creek rootstocks. On the contrary, non-grafted Thompson Seedless recorded the lowest values of shoot length (130.3 and 134.6cm),shoot diameter (1.03 and 1.05 cm),leaf area/ vine (10.8 and 12.7 m^2), and coefficient of wood ripening (0.71 and 0.73) in 2021 and 2022 seasons, respectively, followed by Thompson Seedless grafted on SO4 and non-grafted H4 strain without significant differences between them.

Mineral content in the leaves

This study indicates that the used rootstocks had an important effect on nutrient levels in the used cultivars. Results in Table (4) show that grafting Thompson Seedless and H4 strain grapevines on Freedom, Salt Creek and SO4 rootstocks increased mineral content in the leaves as compared with the non-grafted grapevines. H4 strain grafted on Freedom rootstock gave the highest values of total N, P, K and Mg in leaf petioles, recording 2.74 and 2.81 % for N,0.53 and 0.59% for P, 2.44 and 2.58% for K and 166.6 and 192.2 ppm for Mg in the two seasons respectively, followed by Thompson Seedless grafted on Freedom rootstock, then H4 strain grafted on Salt Creek rootstock. In addition, results did not show significant differences between Thompson Seedless grafted on Freedom rootstock and H4 strain grafted on Salt Creek rootstock in all studied parameters except P in the first season and Mg in the second season. On the other hand,non-grafted Thompson Seedless cultivar recorded the lowest values of total N, P, K and Mg in leaf petioles recording 1.44 and 1.55% for N, 0.29 and 0.35% for P, 1.34 and 1.50% for K and 99.4 and 128.3 ppm for Mg in both seasons, respectively, followed by non-grafted H4 strain without significant differences between them regarding P only in both seasons.

TABLE 2. Effect of grafting Thompson Seedless and H4 strain grapevines on Freedom, Salt Creek and SO4 rootstocks on bud burst, bud fertility and number of clusters during 2021 and 2022 seasons

Treatments \ Characteristics		Bud burst (%)		Bud fertility (%)		Number of clusters/vine	
		2021	2022	2021	2022	2021	2022
T1	Thompson Seedless non-grafted	51.1	58.3	28.8	33.8	17.3	20.3
T2	Thompson Seedless grafted on Freedom	62.7	72.2	32.7	37.2	19.6	22.3
T3	Thompson Seedless grafted on Salt Creek	55.0	63.8	30.0	34.4	18.0	20.6
T4	Thompson Seedless grafted on SO4	53.3	59.4	28.8	33.3	17.3	20.0
T5	H4 strain non-grafted	52.7	65.5	35.0	38.8	21.0	23.3
T6	H4 strain grafted on Freedom	75.0	85.0	40.5	45.0	24.3	27.0
T7	H4 strain grafted on Salt Creek	56.6	68.8	37.7	42.2	22.6	24.3
T8	H4 strain grafted on SO4	55.5	61.1	36.6	41.1	22.0	24.7
	New LSD at 0.05	4.1	8.7	3.9	4.2	2.4	2.5

TABLE 3. Effect of grafting Thompson Seedless and H4 strain grapevines on Freedom, Salt Creek and SO4 rootstocks on morphological characteristics of vegetative growth during 2021 and 2022 seasons

Treatments \ Characteristics		Shoot length (cm)		Shoot diameter (cm)		Number of leaves/ Shoot		Leaf area/ vine (m^2)		Coefficient of wood ripening	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
T1	Thompson Seedless non-grafted	130.3	134.6	1.03	1.05	21.7	22.4	10.8	12.7	0.71	0.73
T2	Thompson Seedless grafted on Freedom	137.3	141.0	1.10	1.14	22.9	23.5	14.6	17.0	0.80	0.82
T3	Thompson Seedless grafted on Salt Creek	135.7	138.3	1.09	1.11	22.6	23.1	13.1	14.9	0.79	0.80
T4	Thompson Seedless grafted on SO4	131.3	134.0	1.04	1.08	21.9	22.3	11. 5	13.0	0.75	0.76
T5	H4 strain non-grafted	132.7	136.6	1.04	1.07	22.1	22.8	11.7	14.4	0.72	0.74
T6	H4 strain grafted on Freedom	145.7	149.3	1.20	1.26	24.3	24.9	18.9	22.7	0.84	0.85
T7	H4 strain grafted on Salt Creek	140.7	144.3	1.18	1.22	23.4	24.1	15.3	18.0	0.81	0.83
T8	H4 strain grafted on SO4	135.0	136.3	1.10	1.12	22.5	22.7	13.20	14.2	0.74	0.76
New LSD at 0.05		3.6	3.8	0.03	0.03	0.60	0.63	1.1	1.5	0.3	0.2

TABLE 4. Effect of grafting Thompson Seedless and H4 strain grapevines on Freedom, Salt Creek and SO4 rootstocks onN, P, K and Mg content in the leaves during 2021 and 2022 seasons

Treatments \ Characteristics		Leaf N (%)		Leaf P (%)		Leaf K (%)		Leaf Mg (ppm)	
		2021	2022	2021	2022	2021	2022	2021	2022
T1	**Thompson Seedless non-grafted**	1.44	1.55	0.29	0.35	1.34	1.50	99.4	128.3
T2	**Thompson Seedless grafted on Freedom**	2.56	2.66	0.43	0.50	2.10	2.27	157.2	186.2
T3	**Thompson Seedless grafted on Salt Creek**	2.41	2.54	0.40	0.46	1.92	2.11	146.2	168.2
T4	**Thompson Seedless grafted on SO4**	1.89	1.94	0.36	0.43	1.60	1.79	119.2	141.2
T5	**H4 strain non-grafted**	1.85	1.94	0.31	0.36	1.74	1.89	116.8	141.8
T6	**H4 strain grafted on Freedom**	2.74	2.81	0.53	0.59	2.44	2.58	166.6	192.2
T7	**H4 strain grafted on Salt Creek**	2.53	2.62	0.41	0.49	2.04	2.17	150.6	177.6
T8	**H4 strain grafted on SO4**	2.24	2.34	0.37	0.45	1.73	1.86	138.8	165.8
	New LSD at 0.05	0.18	0.19	0.02	0.02	0.16	0.16	8.1	8.2

Biochemical studies in the leaves and canes

Biochemical parameters in leaves and cans of Thompson Seedless and H4 strain grapevines grafted on Freedom, Salt Creek, and SO4 rootstocks were found to be significantly increased, compared with the non-grafted ones. Results presented in Table (5) show variations in levels of total chlorophyll, total free amino acids, proline in the leaves, and total carbohydrates in the canes between all the treatments used in this study. The highest content of total chlorophyll in leaves and total carbohydrates in canes were obtained when H4 strain was grafted on Freedom rootstock, recording 15.25 and 15.81 mg/g FW for total chlorophyll in leaves and 24.6 and 25.4g/100g DW for total carbohydrates in canes in both seasons, respectively, followed by Thompson Seedless grafted on Freedom rootstock with no significant differences between them in this concern except total chlorophyll in leaves in the second season only. While, non-grafted Thompson Seedless recorded the lowest content of total chlorophyll in leaves and total carbohydrates in canes, recording 11.13 and 11.5 mg/g FW for total chlorophyll in leaves and 19.6 and 20.7g/100g DW for total carbohydrates in canes in the two seasons respectively. Regarding to total free amino acids and proline in leaves, the results show that H4 strain grafted on SO4 rootstock gave the highest amount in this respect, recording 0.340 and 0.381g/100g DW for total free amino acids and 11.09 and 12.11 mg/g FW for proline content in leaves in both seasons respectively, followed by Thompson Seedless grafted on SO4 rootstock with non-significant differences between them concerning the total free amino acids while, non-grafted Thompson Seedless gave the lowest significant content in this respect, regarding 161 and 194 g/100g DW for total free amino acids and 5.55 and 5.77 mg/g FW for proline content in leaves in both seasons, followed by non-grafted H4 strain in both seasons.

TABLE 5. Effect of grafting Thompson Seedless and H4 strain grapevines on Freedom, Salt Creek and SO4 rootstocks on total chlorophyll, total free amino acids, proline in the leaves, and total carbohydrates in canes during 2021 and 2022 seasons

Treatments \ Characteristics		Total chlorophyll (mg/ g FW)		Total free amino acids (g/ 100g DW)		Proline (mg/g FW)		Total carbohy-drates in canes (g/100g DW)	
		2021	2022	2021	2022	2021	2022	2021	2022
T1	Thompson Seedless non-grafted	11.13	11.5	0.161	0.194	5.55	5.77	19.6	20.7
T2	Thompson Seedless grafted on Freedom	14.89	15.16	0.247	0.280	7.14	7.5	23.6	24.3
T3	Thompson Seedless grafted on Salt Creek	14.20	14.62	0.294	0.342	7.80	8.13	22.0	23.4
T4	Thompson Seedless grafted on SO4	13.05	13.72	0.328	0.376	8.38	8.62	21.0	22.3
T5	H4 strain non-grafted	11.18	12.04	0.212	0.262	6.32	6.57	20.3	21.1
T6	H4 strain grafted on Freedom	15.25	15.81	0.276	0.321	8.28	8.61	24.6	25.4
T7	H4 strain grafted on Salt Creek	14.34	14.65	0.303	0.348	8.65	8.78	23.0	23.7
T8	H4 strain grafted on SO4	13.28	13.97	0.340	0.381	11.09	12.11	22.3	22.6
	New LSD at 0.05	0.42	0.28	0.023	0.023	1.77	0.81	1.1	1.2

Yield and physical characteristics of clusters and berries

It is clear from the results in Table (6) that yield and physical characteristics of clusters and berries were positively affected as a result of grafting Thompson Seedless grapevines and H4 strain on different rootstocks compared to the non-grafted ones. The results show that H4 strain grafted on Freedom rootstock recorded the highest values of the yield per vine (14.72 and 16.41 kg) and cluster weight (605.3 and 608.3 g) in both seasons respectively, followed by those grafted on Salt Creek rootstock with no significant differences between them meanwhile, Thompson Seedless cultivar grafted on Freedom rootstock recorded the highest significant values of cluster length (33.7 and 34.3 cm) and 100 berry weight (253 and 258g) in both seasons respectively, followed by H4 strain grafted on Freedom roots tock in respect to cluster length and Thompson Seedless grafted on Salt Creek rootstock concerning the 100 berry weight. No significant differences were observed between Thompson Seedless grafted on Freedom or Salt Creek rootstocks in yield per vine and cluster length. On the other hand, non-grafted Thompson seedless cultivar recorded the lowest values of yield per vine (8.35 and 9.96 kg) and cluster weight (482 and 490 g) while, non-grafted H4 strain recorded the lowest significant values of cluster length (26 and 26.7 cm) and 100 berry weight (184 and 189 cm) in both seasons respectively, followed by H4 strain grafted on SO4 rootstock. Increasing in the yield per vine in H4 strain as compared with Thompson Seedless cultivar may be due to the increasing number of cluster and cluster weight for H4 strain.

Regarding the influence of Thompson Seedless and H4 strain grapevines grafted on different rootstocks on physical characteristics of berries, results in Table (7) reveal that Thompson Seedless grapevines non-grafted or grafted on the studied rootstocks show a decrease in number of berries/cluster, compactness coefficient of cluster, and Botrytis incidence and severity compared with H4 strain non-grafted or grafted on the studied rootstocks in the two seasons. In this regard, Thompson Seedless grapevines grafted on Freedom rootstock produced the lowest number of berries/ cluster (234 and 231), compactness coefficient of cluster (6.95 and 6.73), Botrytis incidence (15.4 and 11.2%) and Botrytis severity (5.0 and 4.8%) in both seasons respectively, followed by Thompson Seedless grapevines grafted on Salt Creek rootstock without significant differences between them .While, the non-grafted H4 strain recorded the highest significant values of the number of berries/cluster (329 and 321), compactness coefficient of cluster (12.66 and 12.05), Botrytis incidence (27.9 and 25.5%) and Botrytis severity (8.8 and 9.3%), in both seasons respectively, followed by H4 strain grafted on SO4 rootstock. No significant differences were noticed between the non-grafted Thompson Seedless and those grafted on Freedom, Salt Creek, and SO4 rootstocks on number of berries/ cluster or between H4strain grafted on Freedom and Salt Creek rootstocks on Botrytis incidence and Botrytis severity. The decrease in compactness coefficient of the cluster led to

TABLE 6. Effect of grafting Thompson seedless and H4 strain grapevines on Freedom, Salt Creek and SO4 rootstocks on yield, cluster weight, cluster length and 100 berry weight(g) during 2021 and 2022 seasons

Treatments	Characteristics	Yield (Kg/vine)		Cluster weight (g)		Cluster length (cm)		100 berry weight (g)	
		2021	2022	2021	2022	2021	2022	2021	2022
T1	Thompson Seedless non-grafted	8.35	9.96	482	490	27	28	223	227
T2	Thompson Seedless grafted on Freedom	10.84	12.37	551.6	554	33.7	34.3	253	258
T3	Thompson Seedless grafted on Salt Creek	9.52	11.03	529.3	534	32	32.7	240	243
T4	Thompson Seedless grafted on SO4	8.61	10.06	497.3	503.3	29	29.3	227	232
T5	H4 strain non-grafted	11.86	13.28	564.6	568.6	26	26.7	184	189
T6	H4 strain grafted on Freedom	14.72	16.41	605.3	608.3	33	33.7	212	216
T7	H4 strain grafted on Salt Creek	13.65	15.42	602.3	607.6	30	31	202	206
T8	H4 strain grafted on SO4	12.68	14.10	576.3	571.6	28	29	193	196
	New LSD at 0.05	1.37	1.44	12.8	17.3	2.1	1.8	4.0	4.0

TABLE 7. Effect of grafting Thompson Seedless and H4 strain grapevines on Freedom, Salt Creek and SO4 rootstocks on number of berries/cluster, compactness coefficient of cluster, Botrytis incidence and Botrytis severity during 2021 and 2022 seasons

Treatments	Characteristics	Number of berries/cluster		Compactness coefficient of cluster		Botrytis incidence (%)		Botrytis severity (%)	
		2021	2022	2021	2022	2021	2022	2021	2022
T1	Thompson Seedless non-grafted	234	231	8.68	8.25	23.5	16.5	5.7	5.2
T2	Thompson Seedless grafted on Freedom	234	231	6.95	6.73	15.4	11.2	5.0	4.8
T3	Thompson Seedless grafted on Salt Creek	237	236	7.42	7.213	18.20	12.8	5.6	4.7
T4	Thompson Seedless grafted on SO4	236	233	8.15	7.947	20.30	16.7	5.8	5.6
T5	H4 strain non-grafted	329	321	12.66	12.05	27.90	25.5	8.8	9.3
T6	H4 strain grafted on Freedom	304	300	9.21	8.90	23.5	19.40	8.2	7.9
T7	H4 strain grafted on Salt Creek	318	313	10.61	10.11	23.7	20.5	8.5	8.5
T8	H4 strain grafted on SO4	319	315	11.41	10.86	25.6	20.9	8.8	8.7
	New LSD at 0.05	10.0	9.0	0.83	0.66	2.9	3.0	0.71	0.69

a decrease in Botrytis incidence and Botrytis severity in the non-grafted or grafted Thompson Seedless cultivar compared with the non-grafted or grafted H4 strain. This decrease may be due to the decreased in the number of berries/cluster and the increase in cluster length.

Chemical properties of berries

It is interesting to note that chemical characteristics of the berries (soluble solids content, titratable acidity, SSC/acid ratio and total sugars) were significantly affected by rootstock type compared to the own-rooted vines as shown in Table (8). Accordingly, H4 strain grafted on Freedom rootstock recorded the highest values of SSC (18.9 and 19.2%), SSC/ acid ratio (30.4 and 32.8) and total sugars (15.1 and 15.4%), while it recorded the lowest percentage of titratable acidity (0.60 and 0.57%) in both seasons, respectively, followed by Thompson seedless cultivar grafted on Freedom rootstock and no significant differences were detected between them concerning titratable acidity, SSC/ acid ratio. On the other hand, the non-grafted Thompson seedless gave the lowest percentages of SSC (16.2 and 16.8%), SSC/ acid ratio (20.2 and 22.4) and total sugars (12.2 and 13.1%), while it recorded the highest percentage of titratable acidity (0.80 and 0.75%) in both seasons respectively, followed by the non-grafted H4 strain. Also, the results show no significant differences between Thompson Seedless grafted on SO4 rootstock and H4 strain grafted on SO4 rootstock on soluble solids content in the two seasons, as well as titratable acidity and SSC/ acid ratio in the first season.

TABLE 8. Effect of grafting Thompson Seedless and H4 strain grapevines on Freedom, Salt Creek and SO4 rootstocks on SSC, titratable acidity, SSC/Acid ratio and total sugars during 2021 and 2022 seasons

Treatments \ Characteristics		SSC (%)		Titratable acidity (%)		SSC/Acid ratio		Total sugars (%)	
		2021	2022	2021	2022	2021	2022	2021	2022
T1	**Thompson Seedless non-grafted**	16.2	16.8	0.80	0.75	20.2	22.4	12.2	13.1
T2	**Thompson Seedless grafted on Freedom**	18.2	18.4	0.60	0.57	30.3	32.3	13.7	14.2
T3	**Thompson Seedless grafted on Salt Creek**	17.6	17.8	0.67	0.66	26.3	27.0	13.2	13.7
T4	**Thompson Seedless grafted on SO4**	16.8	17.1	0.74	0.70	22.7	24.2	12.6	13.1
T5	**H4 strain non-grafted**	16.6	17.1	0.80	0.76	20.6	22.4	13.3	13.7
T6	**H4 strain grafted on Freedom**	18.9	19.2	0.62	0.58	30.4	32.8	15.1	15.4
T7	**H4 strain grafted on Salt Creek**	17.7	17.8	0.64	0.62	27.7	28.7	14.2	14.2
T8	**H4 strain grafted on SO4**	17	17.4	0.71	0.65	23.8	26.8	13.6	13.9
	New LSD at 0.05	0.3	0.4	0.04	0.03	1.3	0.9	0.3	0.4

The relationship among some studied characteristics

Data illustrated in Fig. (1, 2, 3, 4 & 5) indicated the existence of a highly positive correlation between total leaf area per vine (m^2) and yield (kg), between total leaf area per vine (m^2) and SSC in berry juice (%), between total leaf area per vine (m^2) and cane total carbohydrates (%), between total chlorophyll (mg/g F.W.) and cane total carbohydrates (%), and between leaf K (%) and total sugars in berries (%) in both seasons.

Discussion

A Feeder (Finer) roots play important roles in absorbing nutrients and water from soil, synthesis and metabolism of plant growth substances, and the storage of carbohydrates for better growth and development of vines. A greater density of roots helps the vine to achieve maximum absorption of nutrients (Richards, 1983 and Somkuwar et al., 2012). In our study, Freedom rootstock was the best for improving the studied characteristics, followed by Salt Creek then SO4 rootstock.

The positive effects of rootstocks on enhancing bud burst, bud fertility percentage and number of clusters may be due to encouraging the buds of scions to use a greater proportion of the reserved carbohydrates for flower development and decreasing the level of floral abortion (Zhongyan, 1992). Mervat et al. (2019) reported that grafting

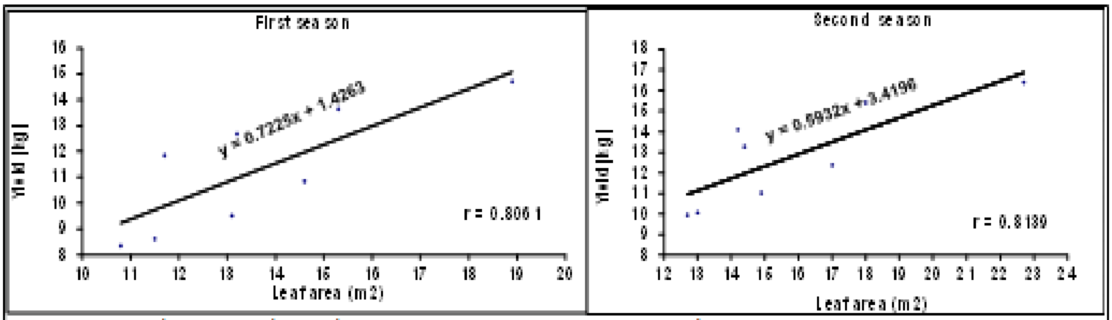

Fig (1): The relationship between the leaf area (m2) and yield (kg) in both seasons

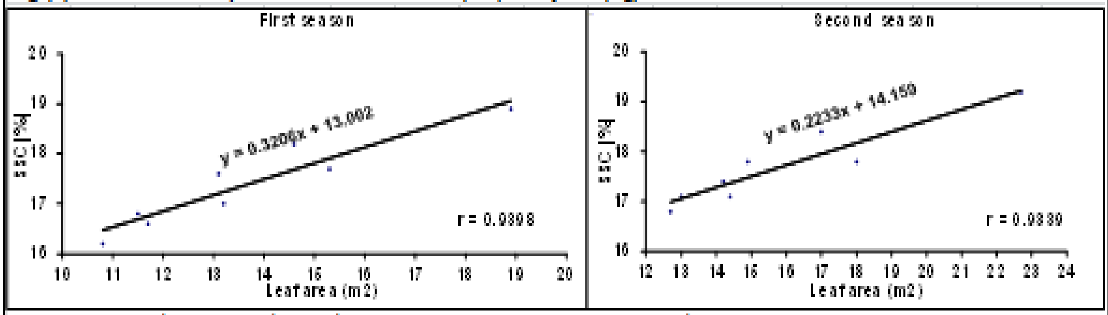

Fig (2): The relationship between the leaf area (m2) and SSC (%) in both seasons

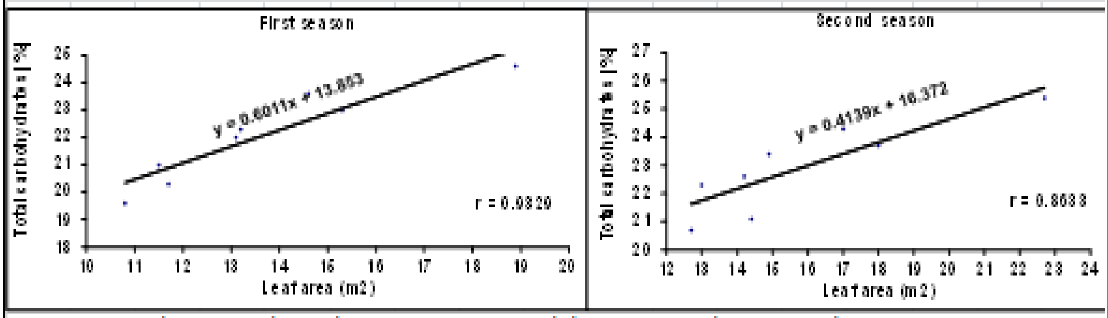

Fig (3): The relationship between the leaf area (m2) and total carbohydrates (%) in both seasons

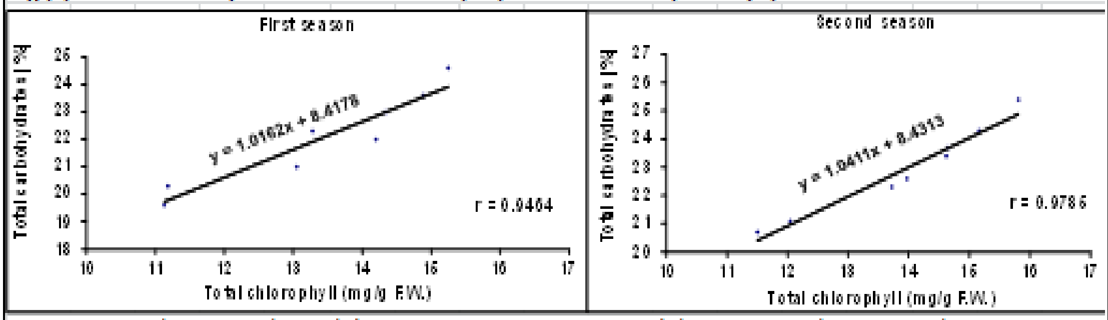

Fig (4): The relationship between total chlorophyll (mg/g F.W.) and total carbohydrates (%) in both seasons

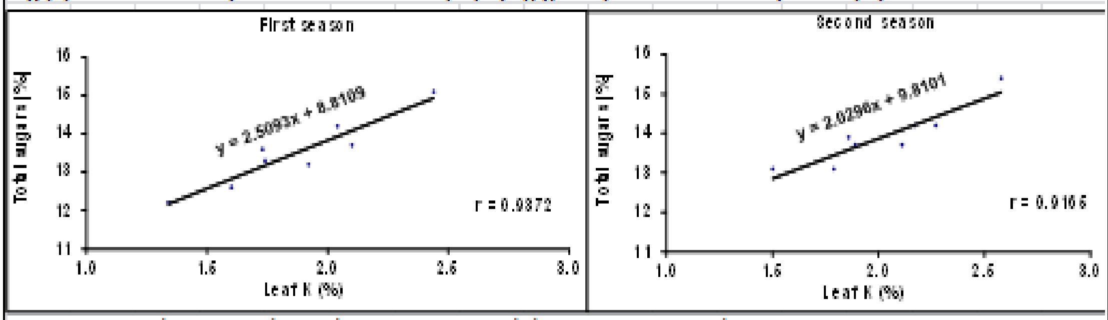

Fig (5): The relationship between the leaf K (%) and total sugars (%) in both seasons

Flame Seedless vines on different rootstocks increased bud burst and bud fertility percentage as compared with non-grafted. Superior results were attained by vines grafted on Freedom, followed by Salt Creek during study seasons. In addition, the enhancement in morphological characteristics of vegetative growth may be due to the great influence of vigorous rootstock on the growth of scion (Hartman et al., 2002). In this concern, Verma et al. (2010) reported that marked variation in leaf area of PusaUrvashi grape grafted on different rootstocks could be attributed to the genotypic influence of the rootstock. Furthermore, El-Gendy (2013) and Serra et al., (2014) reported that the positive effect of the grafting on improvement of shoot length, shoot diameter and leaf area could be attributed to the high efficacy of the rootstocks in absorbing and transporting the water and minerals via the grafted union to the shoots of the scion, as well as the favorable reciprocal relationship between stock and scion. Somkuwaret al. (2015) found that the scion grafted on different rootstocks exhibited higher shoot length compared to the non-grafted vines and might be due to high N uptake. Mohsen (2021) found that grafted Flame Seedless grapevines on some rootstocks such as Salt Creek, Richter, and Freedom significantly increased shoot length as compared with non-grafted vines (own-rooted). Also, the positive effect of rootstocks on improving the coefficient of wood ripening as shown in Table (3) may be attributed to the increase in vigour of the grafted vines as a result of increasing uptake of the nutrients such as N, P, K and Mg in the leaves, as shown in Table (4) and increasing total leaf area per vine and total chlorophyll (Table 3 and 5) and this leads to more activation of carbohydrate metabolism consequently improving the coefficient of wood ripening

The positive effect of rootstocks on improving mineral content in the leaves of the grafted cultivars and the differences in nutrient uptake among rootstocks were explained by several studies, which concluded that the differences in nutrient uptake and distribution may be due to the genetic background of rootstock, which gives different absorption capability or tendency for some specific minerals (Somkuwar et al., 2014). Somkuwar et al. (2015) reported that the rootstock with higher root volume can be more efficient in absorbing nutrients from the soil, and this explains the differences between rootstocks on leaf content of nutrients in this study. Mervat et al. (2019) found that the best results concerning shoot length, total leaf surface area per vine, nitrogen, phosphorus, and potassium leaf content were obtained when Flame Seedless grapevines were grafted on Freedom rootstock followed by Salt Creek rootstock as compared with the non-grafted (own-rooted). Abdel Rehim et al. (2022) reported that Early Sweet grapevine grafted on Freedom rootstock gave a significant increase in nitrogen and potassium concentrations as compared with Salt Creek rootstock.

Several studies have been conducted on the effect of rootstocks on biochemical processes in scion leaves. In this regard, During (1994) found that the effect of rootstock on gas exchange parameters is as scion specific and may be due to the distinct efficacy of carboxylation of grafted vines. In some cases, grafting increased the rate of photosynthesis due to changes in stomatal conductance (Jogaiah et al., 2013). Rootstocks have a preference for the uptake of nutrient elements from the soil system, which may act as coenzymes in the synthesis of several secondary metabolites involved in the synthesis of amino acids and proteins such as proline. The role of proline is to act as carbon, nitrogen and energy for cellular metabolism (Hare and Cress, 1997), possibly providing energy for the transport and accumulation of sugars (Kliewer, 1968). The effect of rootstock on photosynthetic pigments such as chlorophyll content might be due to the ability of roots to absorb enough quantities of elements such as nitrogen, zinc, iron, and magnesium, which increases the synthesis of pigments in the leaves (Mervat et al., 2019). The increase in carbohydrates content in the leaves might be due to the increment in leaf area and chlorophyll content as shown in Fig 3 and 4 (positive relationship) that resulted from high photosynthesis rate, which helps in the synthesis of more carbohydrates (Somkuwar et al., 2014). Somkuwar et al. (2015) found that Fantasy Seedless Grapes grafted on Freedom rootstock recorded high chlorophyll a content whereas the lowest content was noticed in the case of vines grafted on Salt Creek. In addition, the highest amount of total carbohydrate was recorded for St. George rootstock grafted vines.

Improvement of yield and physical and chemical characteristics of clusters and berries as a result of using different rootstocks could be due to the efficiency of the root system to transport nutrients from soil to the leaves (Mervatet al., 2019), increased leaf area, and increased total chlorophyll content in leaves as shown in Table 3 and 4, this led to an increment in the rate of photosynthesis, which led to the synthesis of more carbohydrates in leaves and the transition these carbohydrates and elements in the direction of clusters and yield Fig. 1(positive relationship), which positively affected physical and chemical characteristics of clusters and berries. Morano and Kliewer (1994) suggested that rootstocks differ in root distribution pattern and total root number, which influence the yield and quality. A rootstock having high root volume can be more efficient in absorbing nutrients from the soil. The positive effect of used rootstocks on the reduction of the compactness coefficient of clusters could be attributed to the high efficacy of the root systems in absorption and transporting water and minerals specially, nitrogen via the grafted union to the shoots of scion (El-Gendy, 2013), which induced more vegetative growth and shifted the balance of competition between blossom clusters and vegetative organs in favor of the latter which led to some falling flowers, consequently, the compactness coefficient of clusters decreased in botrytis incidence and botrytis severity. Also, decreasing the compactness coefficient of clusters may be due to the decreased number of berries/cluster and increased cluster length (Tables 6 and 7).

Also, the enhancement of chemical properties of berries such as SSC % and total sugar % may be due to increasing leaf area as shown in Fig. 2, and increasing the level of potassium in the grafted cultivars leaves as shown in Fig. 5 (positive relationship). This fact may explain the positive effect of potassium in increasing the sugar accumulation in the berries. There is a direct correlation between potassium uptake and sugar content in berries (El-Gendy, 2013). Mohsen, (2021) grafted Flame Seedless on Salt Creek, Richter, and Freedom rootstocks and found that all the used rootstocks increased yield, bunch weight and weight of 100 berries which, Flame Seedless grafted on Freedom rootstock recorded the highest values in this respect, while own-rooted vines recorded the lowest value. In addition, the author found that chemical characteristics of berries (soluble solids content, titratable acidity, and SSC/acid ratio) were significantly affected by the used rootstock type compared to own-rooted vines. Our results are in the same line with those of Bica et al. (2000), Nikolaou et al. (2000), Keller et al. (2001), Bavaresco et al. (2003), Fisarakis et al. (2004), El-Morsi et al., (2006), Somkuwar et al. (2006), Gaser (2007), El-Banna, et al. (2009), Satisha et al. (2010), Rizk-Alla et al. (2011), Desouky et al. (2015), Hifny et al., (2016), Kamila and Ochmian (2018), Mervat et al. (2019), Ghule et al. (2021, Mohsen (2021) and Graff et al. (2022).

Conclusion and future perspectives

From the above results, it could be concluded that, grafting Thomson Seedless and H4 strain grapevines on the used rootstocks (Freedom, Salt Creek, and SO4) showed significant effect on improving all studied parameters, such as vegetative growth, mineral content in the leaves, total chlorophyll in the leaves, yield and its components, chemical properties of the berries, coefficient of wood ripening, and total carbohydrates of canes as compared with non-grafted. In addition, this study showed that Freedom rootstock gave the best results with the two evaluated cultivars, followed by Salt Creek rootstock then SO4. Therefore, it is recommended to graft Thomson Seedless and H4 strain grapevines on Freedom rootstock under the conditions of clay soil and surface irrigation system in the Delta region. With preference to planting H4 strain because of its good vegetative growth and high cluster weight and yield, it needs further studies to reduce the compactness coefficient of the cluster.

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Conflicts of interest

The author declares that there are no conflicts of interest related to the publication of this study.

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تأثير بعض الأصول على النمو الخضرى والمحتوى الغذائي والمحصول والجودة للعنب الطومسون سيدليس وسلالة H4 تحت ظروف منطقة الدلتا

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- أجريت هذه الدراسة خلال أربعة مواسم متتالية (٢٠١٩ و ٢٠٢٠ و ٢٠٢١ و ٢٠٢٢) في مزرعة خاصة بقرية الدير- مركز أجا - محافظة الدقهلية على كرمات عنب الطومسون سيدلس وسلالة H4 مطعومة على أصول مختلفة وهى الفريدم والسولت كريك و SO4 وكذلك غير مطعومه ومنزرعة في تربة طينية وتروى بنظام الري بالغمر ومرباه بالطريقة القصبيه وتحت نظام التدعيم بالبرجوله .

- وكان الهدف من هذة التجربة هو دراسة تأثير أصول (الفريدم والسولت كريك و SO4 بالاضافة الى الشتلات غير المطعومة) على النموالخضرى والمحتوى الغذائي والمحصول ومكوناتة لكرمات عنب الطومسون سيدلس وسلالة H4 لإختيار أفضل هذة الأصول تحت ظروف منطقة الدلتا.

- الشتلات المستخدمة تم الحصول عليها من نشاط قسم العنب التابع لمعهد بحوث البساتين - مركز البحوث الزراعية بالجيزة وتم زراعتها فى الأرض المستديمة فى شهر مارس عام ٢٠١٩وتم أخذ البيانات والقياسات لهذه التجربة خلال موسمى ٢٠٢١ و ٢٠٢٢ (الموسم الثالث والرابع منزراعة الشتلات).

- وقد أظهرت النتائج أن تطعيم صنفى عنب الطومسون سيدلس وسلالة H4 على أصول الفريدم والسولت كريك و SO4 أعطى أفضل النتائج بالمقارنة بالغير مطعومة. وقد تم تحقيق أفضل النتائج لجميع القياسات المدروسة مع الكروم المطعومة على أصل الفريدم يليها أصل السولت كريك ثم أصل SO4. كما أظهرت النتائج أن سلالة H4 المطعومة على أصل الفريدم سجلت أعلى قيم معنوية بالمقارنة بباقى المعاملات في سلوك البراعم، قياسات النموالخضري، المحتوى المعدني في الأوراق ، الكلوروفيل الكلي في الأوراق ، المحصول/ الكرمة ، وزن العنقود ، الخواص الكيميائية للحبات ، معامل نضج الخشب ، الكربوهيدرات الكلية في القصبات بينما سجل صنف الطومسون سيدليس المطعوم على أصل الفريدم أفضل القيم لوزن الحبات، وأقل القيم لمعامل تزاحم العنقود ، ونسبة حدوث الاصابة بعفن البوتريتيس Botrytis وشدتها، وكذلك أقل القيم للحموضة الكلية القابلة للمعايرة فى الحبات.

- لذلك ، يوصى بتطعيم عنب الطومسون سيدلس وسلالة H4 على أصل الفريدم تحت ظروف التربة الطينية ونظام الري السطحي في منطقة الدلتا مع الأفضلية لزراعة (سلالة H4) لما تتميز بة من نمو خضرى جيد ومحصول عالى ولكن هذة السلالة تحتاج الى مزيد من الدراسات لتقليل معامل تزاحم العنقود.

الكلمات الدالة : العنب ، التطعيم ، أصل الفريدم ، أصل السولت كريك ، أصلSO4 ، عنب الطومسون سيدلس، سلالة H4