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MORPHOLOGICAL, BIOCHEMICAL, ANATOMICAL STUDIES AS MEASURES OF COMPATIBILITY BETWEEN SCION-ROOTSTOCK IN GRAPES

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ABSTRACT

The present investigation was carried out during the seasons of 2006 and 2007 to study grafting operations of Thompson seedless (TH), Superior (SU), Flame seedless (FL) and king ruby (KR) scions onto four grapevine rootstocks namely, SO4, 1103 Paulsen (1103 P), Teleki 5C (5C) and 140 Ruggeri (140 Ru). It was aimed to estimate the degree of graft compatibility between the partners used to create graft combinations.

Such estimation was based on a group of parameters known to play an important role in the field of graft compatibilities. They were included the calculation of grafting success percentage, the measurement of certain characteristics usually use to represent the whole growth of graft combination, the determination of certain chemical and biochemical constituents in scions leaf along at the graft union line. Furthermore, an anatomical microscopic examination on tissues from the graft union was carried out. All these studies were to be used as criteria for estimating the degree of graft compatibility among scions and rootstocks tested in this study. Consequently, it could pointed to the best rootstock successfully combined with the used scions.

INTRODUCTION

Grapes are one of the most important and popular fruit crops in Egypt. The total planted area with grape cultivars reached about 160.000 fed. The fruitful ones are about 144.624 fed total annual with production of 1391749 ton(The Ministry of Agriculture Statistics of 2007).Grafting has become the most important method used to propagate most fruit trees. Propagation via grafting has shown a good utility with Grapevines and other fruit trees. The success of this technique helps to clear difficults to several Grapevine species and cultivars, which were selected for fruit qualities, do not have a good root system in terms of growth rate, disease resistance, soil adaptation, Hartmann and Kester (1975). There are outlined seven major reasons for choosing rootstocks in the order of importance as phylloxera resistance and nematode resistance along with adaptability to high pH soils, to saline soils, to low pH soils, to wet or poorly drained soils and to drought, Reynolds and wardle (2001).

Before going further in explaining our results it is of interesting to indicate a brief description of the used grape rootstocks. The rootstock characterized features were represented in Table (1)

Table (1): Brief description of the used rootstocks

Rootstock	Characteristics	References
SO4	- Moderate to vigorous rootstock. - Tolerant to strong acid soils. - Resistant to nematodes. - Grows best in light, well-drained soils of low fertility.	Himelrick (1991), Mullins *et al*., (1992), Shaffer *et al*., (2004).
1103 Paulsen	- Very vigorous rootstock. - Its root system is deeply grown and strongly developed and adapted to a wide range of soil conditions. - Highly tolerant to drought.- - Highly susceptible to ring nematodes. - Salt tolerant rootstock.	Shaffer *et al.,* (2004), Ezzahouani and Williams (1995), Walker *et al*., (2002)
Teleki 5C	- Moderate to vigorous rootstock. - Good choice for heavy soils. - Has a low drought tolerant. - Susceptible to both ring and dagger nematodes	Shaffer *et al*., (2004).
140 Ruggeri	- Moderate to vigorous rootstock. - Performs well in shallow, dry, calcareous soils and well-drained deep soils. - Very drought tolerant rootstock. - Susceptible to ring nematode.	Shaffer *et al*., (2004).

MATERIALS AND METHODS

The present investigation was carried out during the two successive seasons of 2006 and 2007 at the nursery of El-Egeizy vineyard at Sadat city in Monofia governorate. Four important commercially Grapevine cultivars,Thompson seedless, Superior, Flame seedless, King ruby (*Vitis vinifera L.*) were used as source of scions. These scions were grafted onto four grape rootstocks namely, SO4 and Teleki 5C (*Vitis berlandieri* × *Vitis riparia*) as well as 1103 Paulsen and 140 Ruggeri (*Vitis berlandieri* × V*itis rupestris*).

Rootstock preparation

One-year-old mature canes of each rootstock Grapevines were taken, prepared as rootstock cuttings such cuttings were 30 cm in length and removed all buds to avoid suckers grown on them.

Scion preparation

The Scion was taken as cuttings 7 cm in length each with one eye from the selected canes of fruiting vines. It was prepared to leave 5 cm below the eye (to make the mechanical grafting process easier) and 2 cm above it. The scion cuttings almost were similar to rootstocks in diameter to be convenient for successful bench grafting (Winkler *et al.,* 1974).

Grafting operation

Grafting was done in the last week of January in both seasons of study using an Omega grafting set and the grafted seedlings were put in callusing room for 21 day then planted in black Sacs, and transferred to grow under conditions of greenhouse.

This study included 16 graft combinations represented four kinds of grape scions each onto four rootstocks. Such graft combinations are presented in Table (2) and each combination consisted of 30 grafts divided to three replicates of10 grafts each in randomized complete design.

Table (2): Graft combinations of Thompson seedless, Superior, Flame seedless and King ruby grapevine scions each onto SO4, 1103 Paulsen, Teleki 5C and 140 Ruggeri rootstocks.

Serial No.	Graft partners	
	Scion	Rootstock
1	Thompson seedless	SO4
2		1103 Paulsen
3		Teleki 5C
4		140 Ruggeri
5	Superior	SO4
6		1103 Paulsen
7		Teleki 5C
8		140 Ruggeri
9	Flame seedless	SO4
10		1103 Paulsen
11		Teleki 5C
12		140 Ruggeri
13	King ruby	SO4
14		1103 Paulsen
15		Teleki 5C
16		140 Ruggeri

The measurements of graft combinations

The measurements of graft compatibility degree between the tested scions and rootstocks were as follows:

I. Grafting success percentage

The grafting operation was considered successful when the scion was still green and started sprouting and continued growth for six weeks from planting date in greenhouse. Success percentage was calculated on grafts in April of both seasons of study.

II. The whole growth vigor of grafts: It was represented by the measurements of 5 characteristics on 9-month-old grafted seedlings.

1- Number of leaves per shoot: Results were expressed as an average leaves number / shoot / graft combination.

2- Shoot length (cm): Results were expressed as an average shoot length/ scion / graft combination.

3- Shoot diameter (cm*)*: It was recorded at 2cm from the basal end of the Shoot. Results were expressed as an average shoot diameter / graft / graft combination.

4- Total leaf surface area (cm^2): It was estimated according to the following equation that used by (Jain and Misra, 1966). Results were expressed as an average total leaf area / graft / graft combination.

$$\text{Leaf area } (cm^2) = \frac{3.14\times (\text{leaf diameter})^2}{4}$$

5- Leaves fresh and dry weights (g): Results were expressed as an average fresh and dry weights in g / graft / graft combination.

III. Leaf chlorophyll contents (SPAD units): Leaf chlorophyll contents were determined at 6-month-old (July), chlorophyll reading was taken on seventh intact leaf from top of shoot according to the method described by Yadava, (1986) using a Minolata SPAD chlorophyll meter model. The results were expressed as SPAD units /leaf / graft combination.

IV. Leaf NPK contents

1- Leaf nitrogen contents: As described by Pregle (1945).

2- Leaf phosphorus contents: As described by Jackson (1967).

3- Leaf potassium contents: According to Black (1965).

V. Lignin percentage in the cell walls

It was determined at, 2 cm above and 2cm below the graft union on 10-month-old grafts according to the method previously described by Byrd *et al.,* (1965). It was based on hydrolysis of the cell wall components other than lignin by using mixture of 75% sulfuric acid and 89% phosphoric acid at 35ºc. Lignin percentage was calculated according to the following formula:

$$\text{Lignin content } \% = \frac{W\,1}{W\,2}\times 100$$

Where: W1 = weight of lignin oven dried in gm.
W2 = dry weight of piece meal in gm.

VI. Anatomical study

The histological studies were carried out only on the graft union line of Superior scion onto SO4 rootstock and Thompson seedless scion onto Teleki 5C rootstock at 10-month-old grafts. Tissue samples were taken from the graft union line and immediately killed and fixed in FAA solution (85 ml ethyl alcohol 70%, 10 ml formalin and 5 ml glacial acetic acid). The samples dehydrated in series concentration of ethanol and embedded in paraffin wax at 52-54 ^{0}C). Cross and longitudinal sections at 20-25 µm thick were prepared using a rotary microtome, stained in saffranin-light green combination, cleared in clove oil and mounted in Canada balsam (Gerlach, 1977) and examined by microscope supplemented with photographical unit.

Statistical analysis

The obtained data were subjected to statistical analysis using technique of the randomized complete design according to Snedecor and Cochran (1980) using the revised least significant (RLSD) at 5% level.

Table (3): Values of chemical and mechanical analysis of the experimental planting soil of grafts.

Chemical analysis	Values
Organic matter	1.53 %
Calcium Carbonate	1.95 %
Saturation percentage	35 %
EC (extraction 1:5)	0.81 $ds.m^{-1}$
pH (suspension 1:2.5)	7.92
Available Macro- Nutrients (ppm)	
N	46
P	3.8
K	325
Mechanical analysis	**Values**
Coarse sand	1.93 %
Fine sand	49.46 %
Silt	39.21 %
Clay	9.40 %
Texture class	Sandy

RESULTS AND DISCCUSSION

1- Grafting success percentage

According to diagram in Figure (1) it could be explained the grafting success % of each scion onto the used rootstocks in descending order as follows:

1. Thompson seedless onto SO4, 1103 Paulsen (1103 P), 140 Ruggeri (140 Ru) and Teleki 5C (5C) with the values in the first season 45, 30, 27 and 20 %, respectively. The corresponding values of the second season were 50, 34, 28 and 22 %. These values indicated that the most compatible rootstock with TH is SO4 followed by 1103 P, whereas the least degree of compatibility was onto 5C rootstock.
2. Superior (SU) onto SO4, 1103 P, 140 Ru and 5C with the values in the first season, respectively, 50, 37, 28 and 20 %. The corresponding values of the second season were 60, 40, 34 and 30 %. The most compatible rootstock with SU is SO4 followed by 1103 P, whereas the least degree of compatibility was onto 5C rootstock.
3. Flame seedless (FL) onto SO4, 140 Ru, 1103 P and 5C with the values in the first season, respectively, 47, 44, 31 and 19 %. The corresponding values of the second season were 57, 45, 37 and 27 % respectively. These values indicated that the most compatible rootstock with FL is SO4 followed by 140 Ru, whereas the least degree of compatibility was onto 5C rootstock.
4. King ruby (KR) onto SO4, 140 Ru, 1103 P and 5C with the values in the first season, respectively, 37, 34, 30, and 23%. The corresponding values of the second season were 43, 40, 36 and 32%. These values indicated that the most compatible rootstock with KR is SO4 followed by 140 Ru, whereas the least degree of compatibility was onto 5C rootstock.

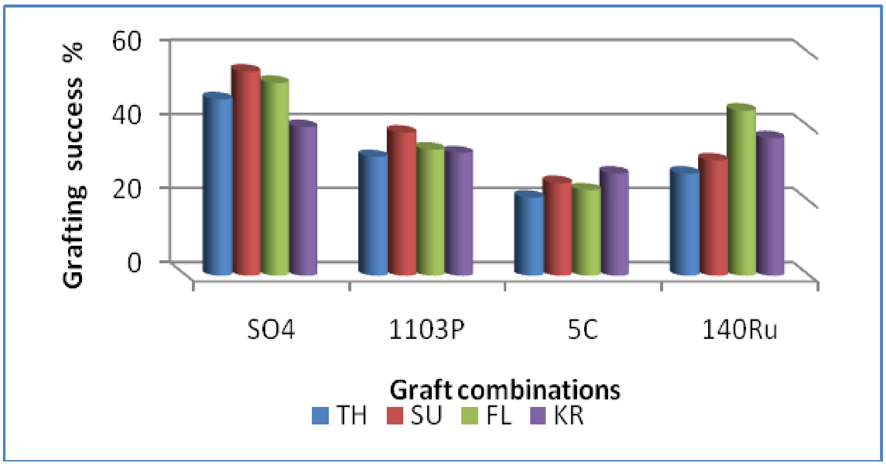


Figure (1): Diagram showing average grafting success percentage of grapevine graft combinations in 2006 and 2007 seasons.
Scions: TH=Thompson seedless SU=Superior
FL=Flame seedless KR=King ruby
Rootstocks:1103P=1103 Paulsen, 5C=Teleki 5C, 140Ru=140 Ruggeri

The acceptance of this parameter as an index for graft compatibility as previously confirmed in the studies of Hartmann *et al.,* (1990 a); Misra *et al.,* (1995) and samaan *et al.,* (2000), it could be stated from the obtained results that SO4 is the most compatible rootstock to produce the strongest successful union with the tested grape scions in both seasons. On the other hand, 5C rootstock had the least compatible degree. These results are in agreement with the studies on grapes of Celik and Odabas (1998) who found that the highest rates of grafting success percentage were of grape cv. cavus onto SO4 rootstock (86.3%) and of grape cv. Alphonse lavallee onto SO4 (100%). Gaser (2007) mentioned that Teleki 5C rootstock recorded the lowest percentage of successful grafts as compared with those of Dogridge, Salt creek, Freedom, Harmony, SO4, and Paulsen 1103 rootstocks.

2- Whole growth vigor indices measured

According to the tabulated data in Tables (4 & 5), it could be arranged the degree of graft compatibility in descending order as follows:

1- Thompson seedless scion onto SO4, 1103 P and 140 Ru rootstocks. This arrangement was based on the number of whole growth characteristics measured the higher values. The TH / SO4 grafts measured the higher values for 5 characteristics with the average values for both seasons, 47.3 leaf / shoot, 178.1 cm / shoot length, 0.77 cm / shoot diameter, 262.6 cm^2 / leaf area/ graft, 30.6 g / fresh and 6.7 g / dry weight of leaves/ graft, respectively. As for the rootstock 1103 P, it was ranked the second order in that respect measuring the next higher values for 5 characteristics also with the average values for both seasons, 37.4 leaf / shoot, 152.3 cm / shoot length, 0.71 cm / shoot diameter , 203.7 cm^2 / leaf area / graft, 25.2 g / fresh and 5.6 g / dry weight of leaves/ graft. On the other hand, the lower values were measured on Thompson seedless onto 5C rootstock grafts. They were measured the lower values on all the above characteristics with the average values of, 25.5 leaf / shoot, 105.4 cm / shoot length, 0.52 cm / shoot diameter, 172 cm^2 / leaves , 16.6g / fresh and 3.8 g / dry weight of leaves/ shoot.

2- Superior scion onto SO4, 1103 P and 140 Ru rootstocks. This arrangement also was based on the number of characteristics measured the higher values. The SU / SO4 grafts measured the higher values for 5 characteristics with the average values for both seasons , 42.3 leaf / shoot, 154.3 cm / shoot length, 1.08 cm / shoot diameter, 179.6 cm^2 / leaf area / graft, 36.5 g / fresh and 9.3 g / dry weight of leaves/graft. The rootstock 1103 P was the next in that respect with the average values for the same 5 characteristics were, 38.6 leaf / shoot, 142.4 cm / shoot length, 0.95 cm / shoot diameter, 175.2 cm^2 / leaf area / graft, 34.6 g / fresh and 7.3 g / dry weight of leaves/ graft. On the other hand, the lower values were measured on Superior scion onto 5C rootstock grafts as it measured the lower values on all the above characteristics with the average values, 25.1 leaf / shoot, 89.4 cm / shoot length, 0.59 cm / shoot diameter, 137.3 cm^2 leaf area / graft, 21.9 g / fresh and 5.3 g / dry weight of leaves / graft.

3- Flame seedless scion onto, SO4, 140 Ru and 1103 P rootstocks. This arrangement was based on the number of characteristics measured the higher values. The FL / SO4 grafts measured the higher average values for 5 characteristics were , 43.0 leaf / shoot, 168.1 cm / shoot length, 0.90 cm / shoot diameter, 408.1 cm^2 / leaf area / graft, 40.2 g / fresh and 9.9 g / dry weight of leaves/graft . The rootstock 140 Ru was the next in that respect with the higher values for only 4 characteristics with the average values of both seasons, 41.5 leaves / shoot, 152.6 cm / shoot length, 0.96 cm / shoot diameter, 256.5 cm^2 / leaf area /graft,. As for 1103 P rootstock it was ranked the third order with the higher average values in both seasons for 2 characteristics, 45.3 g / fresh and 11.0 g / dry weight of leaves/graft . On the other hand, the lower values were measured on Flame seedless onto 5C rootstock grafts with the lowest values for all the above characteristics as they were, 23.7 leaf / shoot, 94.8 cm / shoot length, 0.75 cm / shoot diameter, 180.1 cm^2 / leaf area / graft, 19.6 g / fresh and 4.0 g / dry weight of leaves/graft.

4- King ruby scion onto SO4, 140 Ru and 1103 P rootstocks. This arrangement was based on the number of characteristics measured the higher values. The KR / SO4 grafts measured the higher values for 5 characteristics with the average values for both seasons 28.0 leaf / shoot, 111.4 cm / shoot length, 0.93 cm / shoot diameter and 220.6 cm^2/ leaf area/ graft, 36.4 g / fresh and 8.0 g / dry weight of leaves/ graft. The rootstock 140 Ru as the second order was measured the higher values only for 4 characteristics with the average values of both seasons, 26.5 leaf / shoot, 104.9 cm/ shoot length, 0.96 cm / shoot diameter, 187.7 cm^2/ leaf area / graft. As for 1103 P rootstock it takes the rank of 3 as the higher average values were measured in both seasons for 2 characteristics, 45.6 g / fresh and 10.5 g / dry weight of leaves/ graft. The tabulated results once again pointed to 5C rootstock as lowest one, it measured the lowest values on all the above characteristics with the average values of both seasons, 22.6 leaf / shoot, 86.6 cm / shoot length, 0.68 cm / shoot diameter, 149.4 cm^2 / leaf area / graft, 17.4 g / fresh and 3.3 g / dry weight of leaves/ graft.

Measurement of the 5 physical characteristics in both seasons completely confirmed the results of the previous parameter. Once again the super rootstock to produce the best successful union was SO4 rootstock with Thompson seedless, Superior, Flame seedless and King ruby scions. The same results also pointed to 1103 P rootstock as the most compatible with the former 2 scions and 140 Ru as the most compatible with the later 2 scions. The findings from the measurement of the whole growth characteristics are in line with the results of several studies correlated between the values of whole growth vigor characteristics and the degree of scion – rootstock compatibility in grape graft combinations (Bica *et al.,* 2000 ; Castro *et al.,* 1990 ; Sallam, 1992; Stefanini *et al.,* 1997 and Koundouras *et al.,* 2008). A similar correlation was also found in grafts of other fruit trees (Simon, 1986 ; Taha *et al.,* 1987 ; Moreno *et al.,* 1993 ; El-Ezaby, 1994 ; Misra *et al.,* 1995 ; Mitov and Licher, 1995).

The effect of rootstock on graft compatibility as indicated in this parameter was also the subject of several studies carried out by El-Ezaby, (1994) ; Colldecarrera *et al.,* (1997) ; Stefanini *et al.,* (1997) and Gaser, (2007). They all confirmed that the used rootstock had an effective role in producing successful graft combinations. The positive or negative effect of the used rootstock was based on the capability of it to restrict or allow water flow from the root to the shoot or to remove or keep substances, particularly minerals and plant growth regulators from the transpiration stream (Jones, 1984).

Table (4): Leaves number, length and diameter of shoot in graft combinations in 2006 and 2007 seasons.

Graft partners		Number of leaves			shoot length (cm)			shoot diameter (cm)		
Scion	Rootstock	2006	2007	Average	2006	2007	Average	2006	2007	Average
Thompson Seedless	SO4	38.2	56.2	47.3	154.0	202.2	178.1	0.75	0.78	0.77
	1103P	36.3	38.5	37.4	145.3	159.3	152.3	0.71	0.71	0.71
	5C	29.2	21.8	25.5	116.7	94.0	105.4	0.56	0.48	0.52
	140Ru	32.7	28.6	30.7	131.0	140.7	135.9	0.64	0.59	0.62
Superior	SO4	37.8	46.7	42.3	128.7	179.9	154.3	0.94	1.22	1.08
	1103P	33.2	43.9	38.6	120.7	164.0	142.4	0.84	1.05	0.95
	5C	27.7	22.4	25.1	93.7	85.1	89.4	0.58	0.60	0.59
	140Ru	31.8	29.9	30.9	116.4	119.6	118.0	0.65	0.75	0.70
Flame seedless	SO4	38.6	47.4	43.0	154.3	181.8	168.1	0.80	0.99	0.90
	1103P	36.0	35.5	35.8	144.0	141.8	142.9	0.75	0.93	0.84
	5C	22.4	25.0	23.7	89.7	99.8	94.8	0.70	0.80	0.75
	140Ru	37.5	45.5	41.5	149.8	155.4	152.6	0.81	1.10	0.96
King ruby	SO4	26.3	29.6	28.0	104.5	118.3	111.4	0.78	1.07	0.93
	1103P	25.7	23.4	24.6	100.4	93.6	97.0	0.65	0.92	0.79
	5C	23.8	21.3	22.6	88.0	85.2	86.6	0.59	0.76	0.68
	140Ru	26.1	26.8	26.5	102.7	107.1	104.9	0.82	1.10	0.96
RLSD at 5%		1.78	4.22	---	6.76	21.94	---	0.06	0.05	---

Table (5): Total leaf surface area (cm^2), fresh and dry leaves weight (g) / shoot in 2006 and 2007 seasons.

Graft partners		Total leaf surface area (cm^2)			Fresh leaves weight (g)			Dry leaves weight (g)		
Scion	**Rootstock**	**2006**	**2007**	**Average**	**2006**	**2007**	**Average**	**2006**	**2007**	**Average**
Thompson Seedless	SO4	242.8	282.3	262.6	33.5	27.7	30.6	6.6	6.8	6.7
	1103P	225.5	181.9	203.7	26.2	24.2	25.2	5.2	6.0	5.6
	5C	217.9	126.0	172.0	17.5	15.6	16.6	3.7	3.8	3.8
	140Ru	224.9	171.9	198.4	20.7	19.4	20.1	4.2	4.2	4.2
Superior	SO4	187.9	171.3	179.6	42.4	30.6	36.5	9.6	8.9	9.3
	1103P	147.4	202.9	175.2	35.8	33.4	34.6	7.0	7.6	7.3
	5C	126.4	148.2	137.3	20.0	23.8	21.9	4.6	5.9	5.3
	140Ru	142.1	156.4	149.3	29.0	31.3	30.2	6.7	6.2	6.5
Flame seedless	SO4	458.6	357.5	408.1	40.5	39.8	40.2	9.7	10.1	9.9
	1103P	207.6	201.8	204.7	46.3	44.2	45.3	11.0	10.9	11.0
	5C	199.4	160.8	180.1	19.7	19.5	19.6	3.9	4.1	4.0
	140Ru	267.3	245.7	256.5	42.1	33.6	37.9	8.7	7.8	8.3
King ruby	SO4	272.7	168.5	220.6	34.0	38.7	36.4	7.7	8.2	8.0
	1103P	182.3	138.7	160.5	45.5	45.6	45.6	10.7	10.3	10.5
	5C	163.9	134.8	149.4	17.0	17.8	17.4	3.2	3.4	3.3
	140Ru	224.0	151.4	187.7$	30.2	30.4	30.3	6.1	5.8	6.0
RLSD at 5%		27.56	6.22	---	4.54	10.91	---	0.75	0.73	---

3- Total leaf chlorophyll contents

The determination of this characteristic is based on the strong and direct relationship between leaf total chlorophyll content and the rate of photosynthesis in plant. Furthermore, the finding of Morinaga and Ikeda (1990) reported that photosynthetic capacity and dry matter production are correlated with the scion-rootstock compatibility and other factors.

It is clear from Table (6) that in case of TH graft combinations the highest leaf chlorophyll contents were in leaves of TH scion onto 1103 P and SO4 rootstocks in both seasons of study. The former graft recorded the values 31.66 and 34.27 SPAD units along with 30.75 and 33.63 SPAD units for the later one in 2006 and 2007 seasons, respectively. The differences among values of these 2 graft combinations in both seasons were insignificant. TH / 140 Ru graft was the next in that respect with the values 30.67 and 30.69 SPAD units in the 2 tested seasons, respectively.

On the other hand, the lowest values were in leaves of TH/5C graft with the values 27.52 and 27.70 SPAD units in both seasons of study, respectively.

As for SU scion, data in the same Table showed a similar results to those of TH scion. The leaves of SU scion onto SO4 and 1103 P rootstocks contained the higher chlorophyll contents with the values 34.58 and 35.62 SPAD units with the former rootstock along with 32.02 and 35.26 SPAD units with the later one in 2006 and 2007 seasons, respectively. Otherwise, the lowest value was in leaves of graft combination onto 5C rootstock with the values 23.00 and 32.02 SPAD units in both seasons, respectively.

Concerning FL scion, the concerned results pointed to 140 Ru and SO4 rootstocks as the super ones in that respect. The tested scion on them determined the highest values of leaf chlorophyll contents, 35.41 and 33.44 SPAD units for the former rootstock along with 33.53 and 33.17 SPAD units for the later one in 2006 and 2007 seasons, respectively. The used Teleki 5C rootstock with this scion once again recorded the least values in that respect.

As for KR scion the higher leaf chlorophyll contents were onto 140 Ru (39.21 and 40.57 SPAD units) and SO4 (32.90 and 39.78 SPAD units), whereas the graft combination of the same scion onto 5C rootstock tabulated the lowest chlorophyll contents with the values, 31.59 and 35.10 SPAD units in 2006 and 2007 seasons, respectively.

On the bases of the tabulated values for leaf chlorophyll contents of the tested four grape graft combinations and the acceptance of this parameter as an index of the degree of graft compatibility (Morinaga and Ikeda, 1990), it could be reported that TH and SU scions onto either SO4 or 1103P rootstocks formed higher compatible graft combinations. The same was true in case of FL and KR scions onto 140 Ru or SO4 rootstocks. Otherwise, the least degree of graft compatibility was resulted in graft combinations of the tested scions each onto Teleki 5C rootstock.

Such results are in agreement with Gaser (2007) who reported that SU/1103P rootstock gave the highest value of total chlorophylls in leaves as compared with other rootstocks. In the same line, Bica *et al.,* (2000) found that the effect of rootstocks was significant on chlorophyll contents

4- Leaf (N, P and K) contents

4.1. Leaf nitrogen contents (%)

The concerned results in Table (6) indicated that TH scion onto 140Ru and 1103P rootstocks in both seasons of study recorded the highest N value in leaf petioles. The former graft recorded the values 2.87 and 2.84% along with 2.68 and 2.59 % for the later one in 2006 and 2007, respectively. On the other hand, the lowest values were in leaves of TH/5C graft with the values 2.30 and 2.27%. The rest TH graft combination tabulated values between these 2 extremes. Therefore, the degree of graft compatibility was higher between TH and either 140Ru or 1103P rootstocks if compared with the other TH grafts.

As for SU scion the same table showed similar results to those of TH scion. The rootstocks 140Ru and 1103P were the most compatible, since SU scion leaves on these two rootstocks recorded N values 2.93 and 2.90% with the former rootstock as well as 2.67 and 2.62 % with the later one in 2006 and 2007 seasons, respectively. Otherwise, the lowest values were on graft combination using 5C rootstock with N values 2.49 and 2.38%.

Concerning FL scion, the tabulated results once again pointed to 140Ru and 1103P rootstocks as the super ones in that respect. The tested scion on them showed the highest degree of graft compatibility with N contents in leaf petioles valued 2.97 and 2.93% for the former rootstock along with 2.73 and 2.67 % for the later one in 2006 and 2007 seasons, respectively. Teleki5C rootstock also was indicated the least compatibility with FL scion.

The results in Table (6) concerning KR scion came to a similar result to those of the other 3 scions indicated above. The most compatible rootstocks were also 140Ru (2.83 and 2.91%) and 1103P (2.73 and 2.69 %), whereas the graft combination of the same scion onto 5C rootstock indicated the lowest degree of compatibility with leaf petioles N content valued 2.56 and 2.44%.

4.2. Leaf phosphorus contents (%)

The concerned results in Table (6) pointed to the rootstocks 140Ru and 1103P as the most effective rootstocks causing the highest P contents in leaf petioles of the 4 tested scions. In case of TH scion, the values were 0.43 and 0.41 % for 140Ru along with 0.39 and 0.37% for 1103P rootstocks in 2006 and 2007 seasons, respectively. As for SU scion such values for the former rootstock were 0.47 and 0.42% along with the later one were 0.40 and 0.38%, respectively. The corresponding values for FL scion were 0.45 and 0.43% with the former rootstock, along with the later one they were 0.40 and 0.39%. Results in the same table for KR scion onto 140Ru rootstock indicated the values 0.44 and 0.45% and onto 1103 P one the values were 0.42 and 0.40% in 2006 and 2007 seasons, respectively. On the other hand, the least P contents in leaf petioles of all these scions were in graft combinations using 5C rootstock with values ranged from 0.26 to 0.35% in both seasons of study. The rest combinations tabulated values between these 2 extremes.

4.3. Leaf potassium contents (%)

Data in Table (6) concerning the effect of different rootstocks on K contents in leaf petioles of each of the scions under study showed that among the tested rootstocks, 1103P and SO4 ones were the best to cause the higher increasing effects. The tested scions onto them determined the highest K contents in their leaf petioles. The superiority was to 1103 P in that respect, since in 2006 and 2007 seasons, respectively the scions onto it contained in their leaves the values 1.84 and 1.74% for TH scion, 1.91 and 1.80% for SU scion, 1.95 and 1.85% for FL scion as well as 2.03 and 1.96% for KR scion. The corresponding values in leaf petioles of the same scions onto SO4 rootstock were 1.68 and 1.57% for TH scion, 1.71 and 1.62% for SU scion, 1.75 and 1.68% for FL scion as well as 1.83 and 1.74% for KR scion. On the other hand, 5C rootstock once again was of the least effect on leaf petioles K content of the tested scions with values ranged from 1.09 to 1.29%.

Considering the results indicated above for N P K contents in leaf petioles of the 4 tested grape cvs. Onto each of the 4 different rootstocks used, it was observed differences in these nutrients uptake and distribution according to the type of rootstock and the kind of nutrient. In that respect, it was cleared that 140Ru rootstock had relatively the super absorption capability and translocation of N, P and a moderate one on K to scion leaf petioles. This in turn reflects the higher degree of graft compatibility between this rootstock and each of the used scions. The next degree in that respect was to 1103P rootstock followed by SO4 one. Otherwise, the lower degree appeared with 5C rootstock, since the scion leaf petioles onto it tabulated the fewest values of N P K in both seasons of study. These findings are in harmony with those reported by Ulicevic and Pojovic, (1984) who indicated that Potassium content in grape scion leaves was greatly affected by rootstock and it was markedly higher with 1103 Paulsen or 140 Ruggeri rootstocks.

The differences in nutrients uptake, translocation and distribution according to rootstock type also were previously explained by Grant and Matthews, (1996) who reported that the different rootstocks have different ability to absorb phosphorus. Ruhl (2000) came to a similar result with K absorbing mechanism on some grape rootstocks. More recent, keller *et al.,* (2001) reported that some nutrients might be assimilated mostly by roots, thus reducing the amount of hormones translated to the shoots. They also discovered that over 85% of nitrogen was assimilated through vine roots metabolism.

Table (6): Total leaf chlorophyll contents (SPAD units) and NPK (%) in leaf petioles on the basis of dry weight of graft combinations tested in 2006 and 2007 seasons.

Graft partners		Total leaf chlorophyll contents (SPAD units)			N (%)			P (%)			K %		
Scion	**Stock**	**2006**	**2007**	**Average**	**2006**	**2007**	**Average**	**2006**	**2007**	**Average**	**2006**	**2007**	**Average**
Thompson Seedless	SO4	30.75	33.63	32.19	2.52	2.45	2.49	0.35	0.33	0.34	1.68	1.57	1.63
	1103P	31.66	34.27	32.97	2.68	2.59	2.64	0.39	0.37	0.38	1.84	1.74	1.79
	5C	27.52	27.70	27.61	2.30	2.27	2.29	0.27	0.35	0.31	1.18	1.09	1.14
	140Ru	30.67	30.69	30.68	2.87	2.84	2.86	0.43	0.41	0.42	1.29	1.23	1.26
Superior	SO4	34.58	35.62	35.10	2.55	2.41	2.50	0.36	0.34	0.35	1.71	1.62	1.67
	1103P	32.02	35.26	33.64	2.67	2.62	2.65	0.40	0.38	0.39	1.91	1.80	1.86
	5C	23.00	32.02	27.51	2.49	2.38	2.44	0.27	0.26	0.27	1.24	1.15	1.20
	140Ru	31.57	34.00	32.79	2.93	2.90	2.92	0.47	0.42	0.45	1.33	1.27	1.30
Flame seedless	SO4	33.53	33.17	33.35	2.52	2.51	2.52	0.37	0.35	0.36	1.75	1.68	1.72
	1103P	32.49	31.24	31.87	2.73	2.67	2.70	0.40	0.39	0.40	1.95	1.85	1.90
	5C	29.63	29.88	29.76	2.43	2.41	2.42	0.28	0.27	0.28	1.26	1.15	1.21
	140Ru	35.41	33.44	34.43	2.97	2.93	2.95	0.45	0.43	0.44	1.41	1.34	1.38
King ruby	SO4	32.90	39.78	36.34	2.64	2.57	2.61	0.38	0.36	0.37	1.83	1.74	1.79
	1103P	32.20	36.15	34.18	2.73	2.69	2.71	0.42	0.40	0.41	2.03	1.96	2.00
	5C	31.59	35.10	33.35	2.56	2.44	2.50	0.30	0.28	0.29	1.29	1.22	1.26
	140Ru	39.21	40.57	39.89	2.83	2.91	2.87	0.44	0.45	0.45	1.44	1.39	1.42
RLSD at 5%		2.18	1.52		0.04	0.04		0.01	0.00		0.04	0.03	

5. Lignin contents percentage in the cell walls

This part of study concerned with determination of lignin percentage in cell walls at, 2 cm above and 2 cm below the graft union to be used as a criterion for the degree of graft compatibility in the grafted combinations tested. This is based on the statement of Buchloh (1960) that the lignifications of adjoining cell walls at the line of the union is responsible for the formation of strong union in graft combinations.

Accordingly, our results presented in Table (7) showed that in case of TH graft combinations the strongest graft union was between TH scion and 1103P rootstock, since it tabulated at the graft union in both seasons the values 62 and 72 %. A similar trend was found at 2cm above the graft union with the values 78.7 and 79.7 % also, it recorded the highest values at 2cm below the graft union (82.3 and 75 %). Graft combinations of the same scion onto SO4 rootstock could be considered the next in that respect, since it was indicated almost a constant amount of lignin contents in all walls in 2006 and 2007 seasons with the values 67 and 65 % at the graft union, 57 and 58.5 % at 2cm above the graft union and 61 and 69.3 % at 2cm below the graft union, respectively.

As for SU scion, data in the same Table showed similar results to those of TH scion. The rootstocks, 1103P and SO4 recorded the highest values of lignin contents for the 3 positions tested as they were for the former rootstock 54 and 62 % at the graft union, 70.5 and 66 % at 2cm above and 68 and 80.3 % at 2cm below the graft union. The later rootstock recorded the values 48 and 59 % at the graft union, 59 and 57.5 % at 2cm above and 60 and 58 % at 2cm below the graft union in 2006 and 2007 seasons, respectively.

Concerning FL scion, the recorded results in Table (7) pointed to 140Ru and SO4 rootstocks as the super ones in that respect. The tested scion on them showed the highest degree of graft compatibility with lignin content at the graft union valued 75 and 67 % for the former rootstock along with 59 and 74 % for the later one in 2006 and 2007 seasons, respectively. At 2cm above the graft union, the values were 56 and 71 % for SO4 and 52 and 61 % for 140Ru rootstocks, at 2cm below of graft union the values were 69 and 67 % for 140Ru and 68 and 61 % for SO4 rootstocks in 2006 and 2007 seasons, respectively.

Table (7): Lignin (%) at, 2 cm above and 2 cm below the graft union in 2006 and 2007 seasons.

Graft combination partners		Lignin contents (%)								
		graft union zone			2 cm above graft union			2 cm below graft union		
Scion	**Rootstock**	**2006**	**2007**	**Average**	**2006**	**2007**	**Average**	**2006**	**2007**	**Average**
Thompson seedless	SO4	67.0	65.0	66.0	57.0	58.5	57.8	61.0	69.3	65.2
	1103P	62.0	72.0	67.0	78.7	79.7	79.2	82.3	75.0	78.7
	5C	48.0	51.0	49.5	47.0	49.0	48.0	47.0	59.0	53.0
	140Ru	52.0	60.0	56.0	52.7	50.0	51.4	59.0	62.0	60.5
Superior	SO4	48.0	59.0	53.5	59.0	57.5	58.3	60.0	58.0	59.0
	1103P	54.0	62.0	58.0	70.5	66.0	68.3	68.0	80.3	74.2
	5C	35.0	38.0	36.5	50.0	41.7	45.9	50.0	44.0	47.0
	140Ru	39.7	54.0	46.9	59.0	45.5	52.3	58.0	53.0	55.5
Flame seedless	SO4	59.0	74.0	66.5	56.0	71.0	63.5	68.0	61.0	64.5
	1103P	61.0	52.0	56.5	47.0	57.0	52.0	45.0	47.0	46.0
	5C	50.7	49.0	49.9	42.0	51.5	46.8	37.0	41.0	39.0
	140Ru	75.0	67.0	71.0	52.0	61.0	56.5	69.0	67.0	68.0
King ruby	SO4	61.0	79.0	70.0	66.0	73.0	69.5	48.3	52.0	50.2
	1103P	52.0	54.0	53.0	38.0	55.0	46.5	45.0	47.0	46.0
	5C	35.0	45.0	40.0	32.0	51.0	41.5	37.0	42.0	39.5
	140Ru	74.0	75.0	74.5	45.0	58.5	51.8	64.0	60.0	62.0
RLSD at 5%		8.53	7.79	---	11.50	9.16	---	13.22	7.55	---

As for KR scion, the most compatible rootstocks were 140Ru (74 and 75 %) and SO4 (61 and 79 %) at the graft union. A similar trend was found at 2cm below the graft union with the values 64 and 60 % for the former rootstock and 48.3 and 52 % for the later one. At 2cm above the graft union the lignin contents valued (66 and 73 %) for SO4 rootstock and (45 and 58.5 %) for 140Ru in 2006 and 2007 seasons, respectively. Otherwise, the lowest degree was with graft combination onto 5C rootstock for all the 4 tested scions with lignin content values ranged from 35 to 51% at the graft union, 32 to 51.5 % at 2cm above the graft union and 37 to 59% at 2cm below the graft union in both seasons.

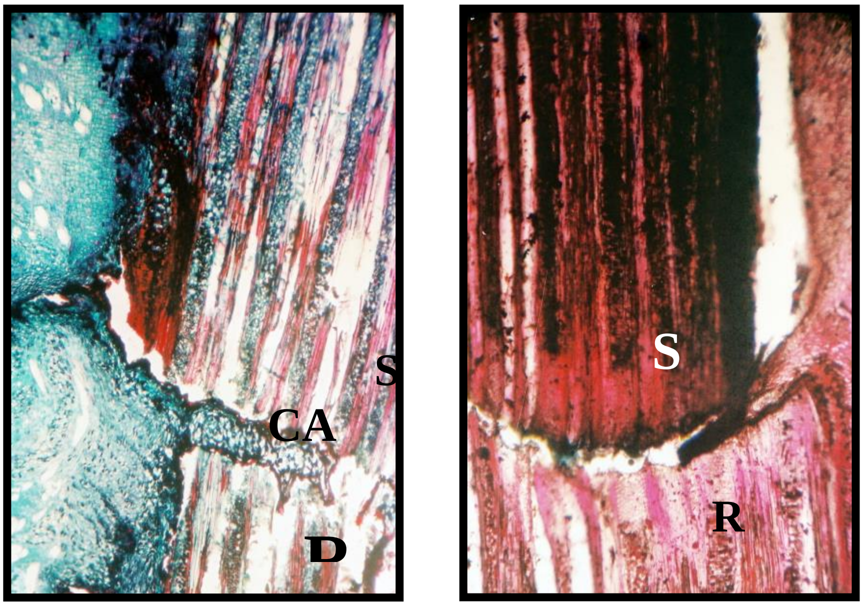
The use of lignin contents especially in cell walls at the graft union as a criterion for the degree of scion – rootstock compatibility was based on the main role of lignin in the formation of strong union. The relationship between quantity of lignin at the line of union and the degree of graft compatibility was previously explained in various studies Buchloh (1960 & 1963), Samaan *et al.,* (1981), working on pear/quince graft combinations reported a positive relationship between quantity of lignin in cell walls at the graft union and the degree of graft compatibility. The significant effect of lignin content in that respect was attributed to its contribution in the lignifications establishment of cell walls and natural middle lamella between the two combined graft partners .Consequently, the formation of strong union zone was occurred. Quessada and Macheix (1984) with apricot grafts pointed to lignifications process occurs imperfectly near the graft union of incompatible grafts. They also reported that the weak affinity in the incompatible combinations could be responsible for the defective lignifications at the graft union. In the same line, Santamour, (1988 a) with Chinese chestnuts correlated between peroxidase enzyme and the polymerization of cinnamic alcohol into lignin as well as the bounding lignin to carbohydrates of the primary cell walls which in turn mediated to form a strong graft union. Also, he suggested that dissimilarities in isoperoxidases composition between stock and scion could result in abnormal lignifications and also a lack of vascular connections at the graft union resulting in an incompatible combination. Based on this hypothesis, it is well established that different isoperoxidases are involved in the production of structurally different lignin that may have different bonding (with cell wall carbohydrates) characteristics (Santamour, 1988 b). Hartmann *et al.,* 1997 suggested that graft incompatibility may be caused by lack of lignifications in cells interlocked at the graft union.

The present results of lignin quantity in cell walls at the graft union clearly agreed with those of leaf chlorophyll contents. Both parameters confirmed the superiority of either 1103P or SO4 rootstocks as the most compatible ones to produce a higher degree of graft compatibility with Thompson seedless and Superior scions. A similar trend also was presented among Flame seedless and King ruby scions onto each of 140 Ru and SO4 rootstocks. The fewest degree of scion – rootstock compatibility was of all the tested scions onto Teleki 5C rootstock.

6. Anatomical study

This part of the present investigation was carried out at the graft union line of graft combination examples characterized by either high degree or low degree of graft compatibility in order to explain the successive stages to form stronger graft union on the former graft and the weaker one on the later graft. Microscopic photographs of cross and longitudinal sections were taken at the graft union representing such stages explained. Before going further in this explanation, it might be important to report herein that the stem structure of both scion and rootstock in grapes is resembled the description of dicotyledons woody stem **(**Pandey and Chadha, 2001).

The anatomical study on the graft union line characterized on the higher compatible grafts of Superior scion onto SO4 rootstock with certain features during stages of the formed graft union were not observed in the same union line at graft combination of the lowest degree of graft compatibility (Thompson seedless/Teleki 5C). Such features concerned with callus tissue formation (Figure 2), after that some callus parenchyma cells dedifferentiate into vascular cambium which is produced new xylem and phloem tissues (Figure 3). Later, the vascular cambium of both scion and rootstock appear as a continuous cylinder (Figure 4). Production of these new vascular tissues allows a perfect connection between the graft participator vasculars and in turn permits the full passage of water and nutrients. These signs are the main factors to determine success of grafting operation.



(A) (B)

Fig. (2): Microscopic photography of Longitudinal sections (A & B) at graft union line between the graft components showing development of callus tissue (CA) at both side between Superior scion (S) onto SO4 rootstock (R). (Obj. X4. OC. X10) .

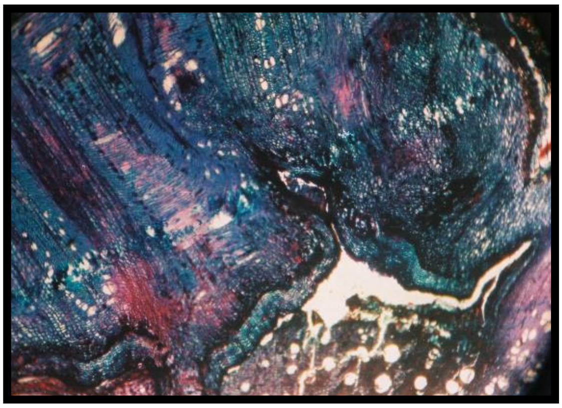


Fig. (3): Microscopic photography of cross section at graft union line of Superior scion onto SO4 rootstock showing callus cells at the first stage of dedifferentiation into vascular cambium and produce new xylem and

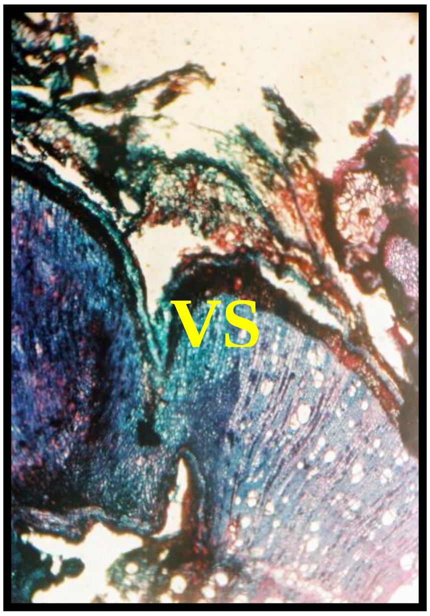


Figure (4): Microscopic photography of cross section at graft union line showing a continuous vascular cambium cylinder (VS) between Superior scion onto SO4 rootstock. (Obj. X4. OC. X10).

On the other hand, Teleki 5C rootstock is not recommended for any of the tested grape scions because of its graft combination recorded the fewest values for the parameters used. Likewise, the anatomical study at the graft union line of Thompson seedless scion onto this rootstock (low graft compatibility) indicated characterized features are not convenient to form strong graft union which it is lacking the vascular connection between scion and rootstock (Figure 5).

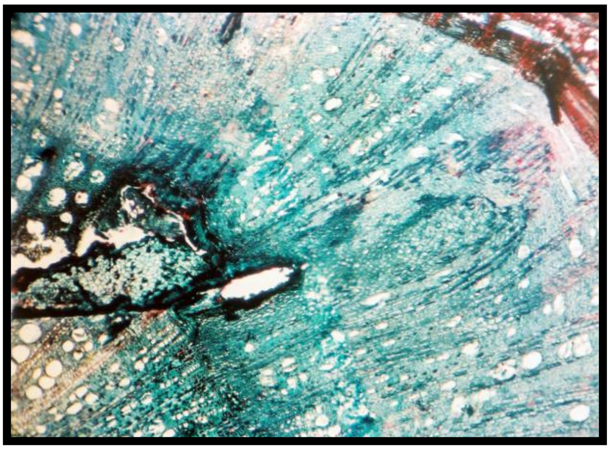


Figure (5): Microscopic photography of cross section at the graft union line showing slowly callus formation and wound healing between Teleki 5C rootstock and Thompson seedless scion (Obj. X4. OC. X10).

Hartmann *et al.,* (1990 b) noted that, badly matching cambial layers between both scion and rootstock may delay the successful grafting or may prevent the graft union from taking place. Moreover, Moore (1983) suggested that graft incompatibility may be caused by lack of vascular redifferentiation and regeneration of both phloem and xylem tissues, or by cellular necrosis at the graft interface. These anatomical features may be explain lack successful grafting between Thompson seedless scion and Teleki 5C rootstock.

Considering the forecited results of the 6 parameters used as indices for the degree of graft compatibility of 4 grape cvs. (scions) onto each of 4 grape rootstocks, it could be observed a complete harmony among these results. They all confirmed each other to the use of either SO4 or 1103 Paulsen rootstocks as the most compatible ones to make strong union (successful grafting) with Thompson seedless and Superior scions. These graft combinations among the tested one tabulated the higher grafting success %, values on the whole growth characteristics measured, values for leaf chlorophyll contents, quantity of lignin in cell walls at the graft union. Likewise, in case of Flame seedless and King ruby scions the higher successful grafts were onto either 140 Ruggeri or SO4 rootstocks, since they tabulated a higher values for most of the tested parameters.

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دراسات مورفولوجية وبيوكيمائية وتشريحية كمقاييس للتوافق بين الأصل والطعم في العنب

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أجريت هذه الدراسة خلال موسمي ٢٠٠٦ و ٢٠٠٧ بمشتل مزرعة العجيزى لدراسة تطعيم أربعة من أهم الأصناف التجارية للعنب الأوربي فى مصر وهما البناتى والسبريور والفليم والكنج روبى (تم الحصول على خشب التطعيم من أشجار منزرعة بنفس المزرعة) على أربعة من أصول العنب الأمريكي وهى SO4 والبولسن والتيلكى والروجيرى والتي تم الحصول عليها من نفس المزرعة وذلك بغرض الوصول إلى أفضل الأصول المتوافقة مع الطعوم المختبرة لإنتاج شتلات ذات مواصفات قياسية وللوصول إلى هذا التقدير تم استخدام ستة طرق مختلفة هي حساب النسبة المئوية للتطعيمات الناجحة وقياسات النمو الخضرى للشتلات المطعومة وتقدير محتوى الأوراق من الكلوروفيلات ومحتواها من عنصر النتروجين والفوسفور والبوتاسيوم وتقدير النسبة المئوية لكمية اللجنين فى جدر الخلايا فى ثلاث مواقع (عند وأعلى وأسفل منطقة التطعيم) على طول ساق الشتلة المطعومة بالإضافة إلى الدراسة التشريحية لمنطقة الالتحام بين الأصل والطعم , هذا و قد تمثلت قياسات النمو الخضرى للشتلات المطعومة فى قياس وتقدير لخمسة صفات هى عدد الأوراق وطول الفرخ وكذلك سمك نمو الطعم على بعد ١ سم من قاعدة الفرخ والمساحة الورقية لكل شتلة تحت الدراسة بالإضافة إلى تقدير الوزن الطازج والجاف للأوراق

ويمكن تلخيص أهم النتائج المتحصل عليها من التركيبات التطعيمية المختبرة فيما يلي :

١- التركيبات التطعيمية للبناتى والسبريور كطعوم أظهرت أن SO4 و البولسن هى أكثر الأصول توافقا معهما حيث سجلت أعلي نسبة مئوية للتطعيمات الناجحة وكذلك أعلى قياسات لقوة النمو الخضرى للشتلات المطعمة وأعلى محتوى ورقى من الكلوروفيلات وأعلى نسبة مئوية من اللجنين فى جدر الخلايا عند منطقة الالتحام بين الأصل والطعم وكذلك أعلى محتوى للأوراق بالنسبة لعنصر البوتاسيوم.

٢- بالنسبة إلى طعوم الفليم والكنج روبى كانت أكثر الأصول توافقا معهما هى SO4 والروجيرى فقد سجلت أعلى نسبة مئوية للتطعيمات الناجحة وكذلك أعلى قياسات لقوة النمو الخضرى للشتلات المطعمة وأعلى محتوى ورقى من الكلوروفيلات وأعلى نسبة مئوية من اللجنين فى جدر الخلايا عند منطقة الالتحام بين الأصل والطعم بالإضافة إلى ذلك فقد سجل الأصل روجيرى أعلى محتوى للأوراق من عنصر النتروجين والفوسفور بالنسبة لكيلا الطعمين.

٣- أظهرت نتائج المقارنة بين التركيبات التطعيمية المختلفة أن اقل درجة للتوافق بين الأصل والطعم كانت عند تطعيم جميع أصناف الطعوم على اصل التيلكى حيث سجلت اقل نسبة مئوية لنجاح التطعيم وكذلك اقل قياسات لقوة النمو الخضرى ومحتوي الأوراق من الكلوروفيل وعناصر النتروجين والفوسفور والبوتاسيوم وكذلك اقل محتوى للجنين فى جدر الخلايا.

٤- أظهرت الدراسة التشريحية لمنطقة الالتحام بين الأصل و الطعم أن تطعيم السبريور على أصل SO4 أعطى أعلى درجة من التوافق فقد بينت القطاعات العرضية المأخوذة عند منطقة الالتحام سرعة تكوين الكلس والاتصال الوعائى بين الأصل والطعم بالإضافة إلى ذلك فقد أظهرت الدراسة التشريحية أن اقل التركيبات التطعيمية توافقا كانت عند تطعيم البناتى على أصل التيلكى.