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Effect of Rootstocks on Vegetative Growth, Yield and Fruit Quality of Cucumber

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Abstract: Effectiveness of grafting cucumber cultivars 'Kattia' and 'Hesham' onto Ferro and 'Shintoza' as rootstocks on growth and yield was evaluated during two successive seasons 2015/16 and 16/17 under plastic house. Stem length, both No. of leaves and fruits plant^{-1} were periodically measured after 30, 45, 60 and 90 days from transplanting. At harvest, in 130-days old plants, both No. of branches and nodes, stem diameter(cm) and leaf area (cm^2), yield (kg plant^{-1} and kg m^{-2}); fruit quality as dry weight (g), water content (%), length (cm),diameter (mm) and SSC (%) of fruits were estimated. Concentrations of N, P and K in leaves and roots were also determined. Results cleared that 'Kattia' cv. plants were more affected by grafting for vegetative parameters such as stem length, No. of leaves, branches and nodes as well as stem diameter more than 'Hesham' cv. Enhancement of vegetative growth was paralleled with high K content in roots. Grafting delayed the fruiting in both cultivars. Grafting decreased both SSC% and water content (%) in fruits in both cultivars. 'Hesham' cv. had the highest leaf area and yield plant^{-1} with high concentration of N in leaves and roots as well as P in roots. Yield increased by 70.7 and 67.6% in 'Hesham' cv. after grafting on Ferro rootstock in both seasons, respectively. 'Hesham' cv. was more compatible with Ferro rootstock than 'Shintoza', due to earlier formation of adhering layer and callus as well as xylem vessels differentiation. It can be concluded that, Ferro is suitable rootstock for cucumber grafting to increase the yield and improve quality of fruits.

Keywords: *Cucumis sativus,* L. grafting, vegetative growth, yield, fruit quality, NPK, histology

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most important vegetables grown in Egypt, especially under greenhouses, due to the short growing cycle and its high economic value in off-season harvest. In 2016, the cultivated area was 23046 ha produced about 519858 tones in Egypt compared to 2.1 million ha produced about 80 million tones worldwide (FAO State, 2016). Great efforts have been made to increase vegetables yield and quality by traditional breeding or by genetic transformation (Cuartero *et al.,* 2006). The use of grafted vegetables seedlings have been increased in greenhouses due to increase both fruit yield and quality where production faces with abiotic stressors such as low temperature, low light intensity, high humidity, salinity and heavy metals (Lee and Oda, 2003). Also, grafting was shown to be a vital tool to produce high resistant seedlings against different kinds of soil-borne fungi, such as *Fusarium* and *Verticillium* and nematodes which had strong negative effects on cucumber production under greenhouses (Abou-Hadid *et al.,* 1992). Yield is a sum of photosynthetic process of scion and transportation of water and minerals via rootstock (Hopkins and Huner, 2004). Effective rootstocks ought to be distinguished and described for the power usage of grafting. Grafting cucumber onto Cucurbita rootstocks had variable results (Moradipour *et al.,* 2010; Huang *et al.,* 2010). Notwithstanding of diseases, the performance of grafted plant relies upon the compatibility of rootstock with the scion, environmental conditions, and cultivation techniques (Andrews and Marquez, 1993). At times, the rootstock's vigorous root system expands the proficiency of water and nutrient consumption bringing about upgraded growth and yield, notwithstanding disease control (Lee, 1994). Moreover, if grafting has low compatibility, yield reduction, poor fruit quality and early plant collapse could occur (Andrews and Marquez, 1993). Davis *et al.* (2008) revealed that rootstock/scion combinations should be carefully selected for specific climatic and geographic conditions. Grafting is an important horticultural and physiological phenomenon that is not well understood and it may be an alternative solution for increasing yield and improved the quality of cucumber. Therefore, the current study was conducted to investigate the behavior of two cultivars 'Hesham' and 'Kattia' after grafting on two rootstocks, 'Ferro' and 'Shintoza'. Vegetative growth of plants and fruit qualitative traits as well as the modification of tissues in union region were investigated.

MATERIALS AND METHODS

Plant materials, treatments and growth conditions:

The present study was carried out during the two successive seasons of 2015/16 and 2016/17 in a plastic house at the Experimental Research Farm, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. Six treatments were used, i.e. two scion cultivars ('Hesham' and 'Kattia') grafted onto two rootstocks ('Ferro' F1 and 'Shintoza' F1) and two un-grafted cultivars (control). Seeds of two commercial cucumbers (*Cucumis sativus* L.) cvs. 'Hesham' and 'Kattia', released by Erma zadan (Poland) and Graines Voltz (France). It was sown two days before the seeds of the rootstocks. Cucurbita rootstocks 'Ferro' F1 and 'Shintoza' F1 (*Cucurbita maxima x Cucurbita moschata*), released by Rijk-Zwaan and G.S.I seeds (the Netherlands). Seeds were sown in 216 cell Styrofoam trays under plastic house conditions. The trays were filled with soil mixture (peat moss, perlite) mixed in (1:1 v/v). The environmental conditions for germination were 24-28ºC and 85-95% relative humidity. The

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seedlings were grown under controlled plastic house with 25/20ºC day/night temperatures. When both cotyledons and first true leaf start to develop, the rootstock plant is ready to graft (7 to 10 days after sowing). The seedlings were grafted by "Splice Grafting" according to Lee and Oda (2003) at the cotyledon stage. One cotyledon, along with the visible growing point, was cut with a razor blade following the angle of the leaf petiole. The hypocotyl of the scion was cut on 45 angle on one side only. The two cut surfaces were matched and held together with a silicone clip.

Grafted plants were transferred to a healing chamber for seven days at RH >95 % and 24 □C. Grafted plants were left in closed tunnels for three days to facilitate graft adhering. The plastic cover was opened slightly every day to allow reduction in relative humidity for acclimization and was removed 6 days after grafting. After acclimization, the plants were transferred to the plastic house and maintained at 24 to 30ºC until the scion is connected well with the rootstock.

The plants were transferred to the plastic greenhouse. The between and within-row spacing were 80 and 40 cm respectively. The plants were grown horizontally, irrigated using drip irrigation lines and fertilized with 1 m^3 farmyard manure, 22 kg N, 9 kg P_2O_5 and 25 kg K_2O/100 m^2. Other cultural practices; such as plant protection against weeds, diseases, and insects were performed whenever they were thought to be necessary as recommended for commercial cucumber production under protected cultivation. The experimental design consisted of randomized complete blocks with four replications.

Vegetative parameters, fruit yield and quality:

The vegetative traits as stem length (cm), both No. of leaves and fruits $plant^{-1}$ were recorded on 20 plants in the middle of each treatment after 30, 45, 60 and 90 days after transplanting. Stem diameter (mm) was measured with a caliper, No. of lateral branches and nodes /plant as well as leaf area (cm^2) by scanning the 3rd leaf with a leaf area meter (AM 300)at harvest (130 days) were done. Yield (kg $plant^{-1}$ and kg m^{-2}) was recorded for each plant 4 times (at early, second, third and fourth harvesting period, 30, 45, 60 and 90 days of transplanting). Also, fruit dry weight (g) at 70° C to constant weight, water content (%), length (cm) and diameter (cm) were determined at harvest.

Soluble solids content (SSC %):

From each fruit, 20 g of pulp were homogenized in 80 ml distilled water for one min. A disposable pipette was used to transfer 1 ml of homogenate onto a LCII-Digital refractometer (Medline scientific, United Kingdom, SR-95) for SSC (%) determination (Drake et al., 1988).

Nitrogen, phosphorus and potassium concentration in leaves and roots:

Random sample from 3rd leaf and 3rd secondary root from each replicate was dried at 70◦ C until constant weight. Then, 0.5 g of ground powdered material was digested separately from each replicate using a mixture of sulfuric acid and hydrogen peroxide and brought to a volume (50 ml) with distilled water. Leaves N (%) were calculated by Kjeldahl Method (Jackson, 1958). Percentage of K^+ was determined by flame photometer (Horneck and Hanson, 1998). Phosphorous (%) was estimated by phosphomolybdate (blue complex) spectrophotometrically (UV/VIS spectrophotometer, PG instrument Ltd, USA) at 660 nm (Olsen *et al.,* 1954).

Histological studies:

The grafting union zone specimens from second season seedlings of 'Hesham' cv. grafted onto 'Ferro' and 'Shintoza' after 4, 5, 6, 7 and 8 days of grafting, were fixed in Formalin acetic acid, dehydrated in ethyl alcohol series, embedded in Paraffin wax, sectioned to thickness of 15 µm, double stained with Safranin and Light green, cleared in Xylene and mounted in Canada balsam, according to Willey (1971). All measurements were calculated by eyepiece micrometer.

Statistical analysis:

All data were statistically analyzed as randomized complete blocks design (Steel *et al.,* 1997). Analysis of variance (one-way analysis; ANOVA) and means comparisons (Duncan's multiple range tests, 5%) were performed using the MSTAT-C statistical package (M-STAT, 1990).

RESULTS

Periodic analysis of stem length and leaves number/plant:

In general, the stem length and No. of leaves/plant were higher in un-grafted plants of 'Hesham' cv. than 'Kattia' cv. at all periods in both seasons (Fig 1). Also, both 'Kattia' and 'Hesham' cvs. grafted onto both rootstocks ('Ferro' and 'Shintoza') had higher values of the previous parameters than un-grafted ones. 'Ferro' as rootstock had beneficial effect on stem length and No. of leaves/plant than 'Shintoza' one, for both cvs. Although 'Hesham' cv. grafted onto 'Ferro' gave the tallest stem (220.5 and 223.5; 213.75 and 221.5 cm $plant^{-1}$) and the highest leaves number (49 and 49; 48.25 and 50 $plant^{-1}$) in 1st and 2nd seasons, respectively but response of 'Kattia' cv. to grafting was more effective on previous parameters. In this respect, at harvest, in 130-days old plants, grafting of 'Kattia' cv. on both rootstocks gave the highest increment of stem length and leaves No. in both seasons as shown in Fig (1). Stem length and leaves No. were increased by 33.8 and 44.5% in1st season and 34.7 and 43.6% in 2nd season, respectively in 'Kattia' cv. grafted onto 'Ferro' and by 30.1 and 35.4% in 1st season and by 32.4 and 25.4% in 2nd season, respectively when 'Shintoza' used as rootstock. However, stem length and leaves No. were increased by 18.1 and 35.1% in1st season and 17.0 and 19.5% in 2nd season, respectively in 'Hesham' cv. grafted onto 'Ferro' and by 14.5 and 33.1% in 1st season and by 15.9 and 21.9% in 2nd season, respectively as grafted onto ''Shintoza'' rootstock.

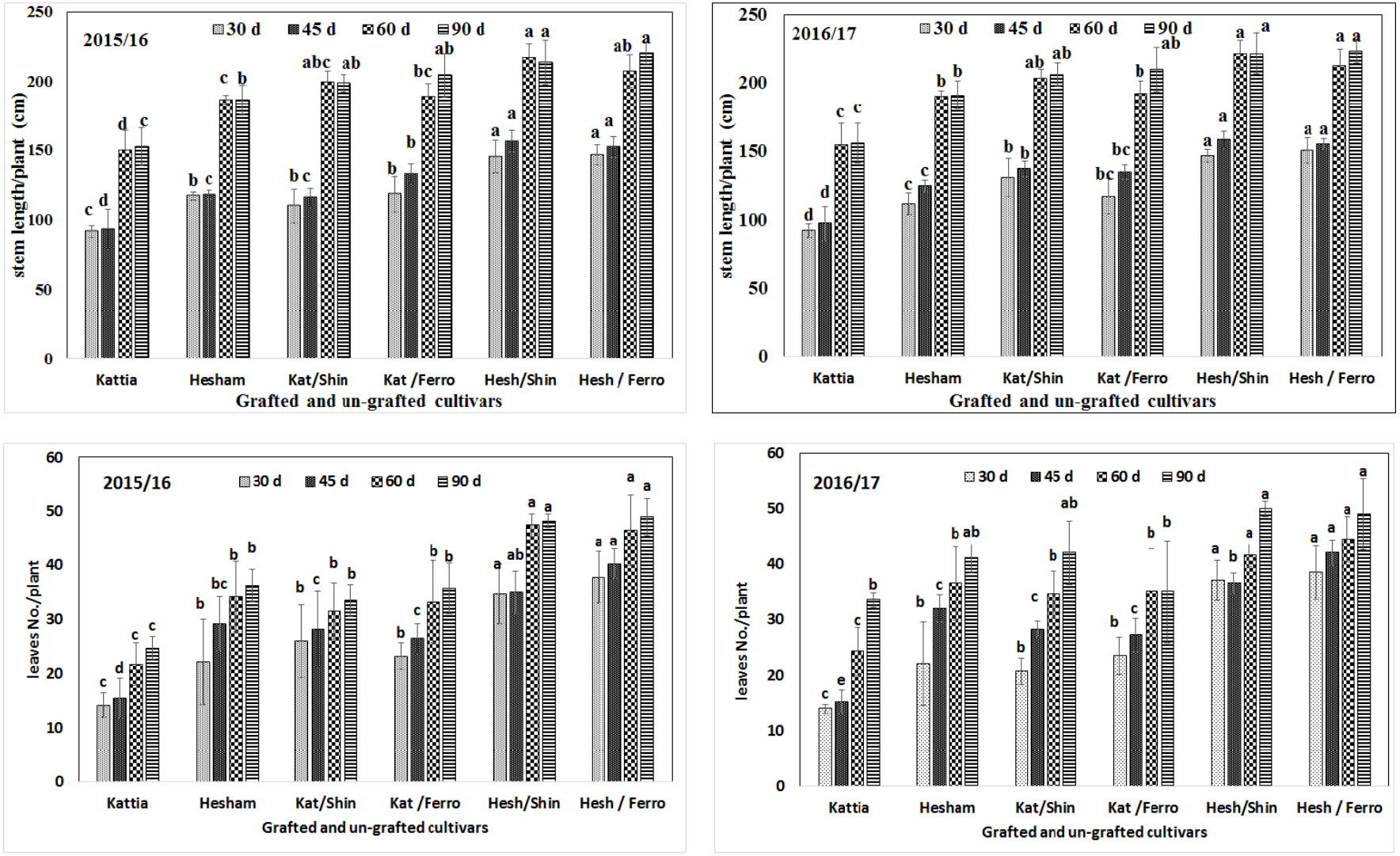

Fig (1): Stem length (cm) and No. of leaves/plant after 30, 45 and 60 days of transplanting as well as at harvest (90 days) during cultivated seasons 15/16 and 16/17 in grafted and un-grafted cucumbers

Periodic analysis of fruits number/plant:

Figure (2) showed that un-grafted plants of both 'Kattia' cv. and 'Hesham' cv. as well as 'Kattia' grafted onto ''Shintoza'' were fruited early (30 days after transplanting) in both seasons. Generally, the highest fruit No. was obtained at the third harvest (after 60 days of transplanting) in un-grafted plants and at the forth harvest (after 90 days of transplanting) in grafted plants of both cultivars. The highest value of total No. of fruits (4 harvests) was recorded in 'Hesham' cv. grafted onto 'Ferro' in both seasons. Grafting of 'Hesham' cv. onto 'Ferro' increased the total No. of fruits/plant by 76.2 and 63.9% compared to 61.7 and 51.4% of increment when grafted onto ''Shintoza'' in both seasons, respectively. Moreover, grafting of 'Kattia' cv. onto ''Shintoza'' increased the total No. of fruits/plant by 60.6 and 63.9% compared to 55.7 and 47.5% of increment as grafted onto 'Ferro' in both seasons, respectively.

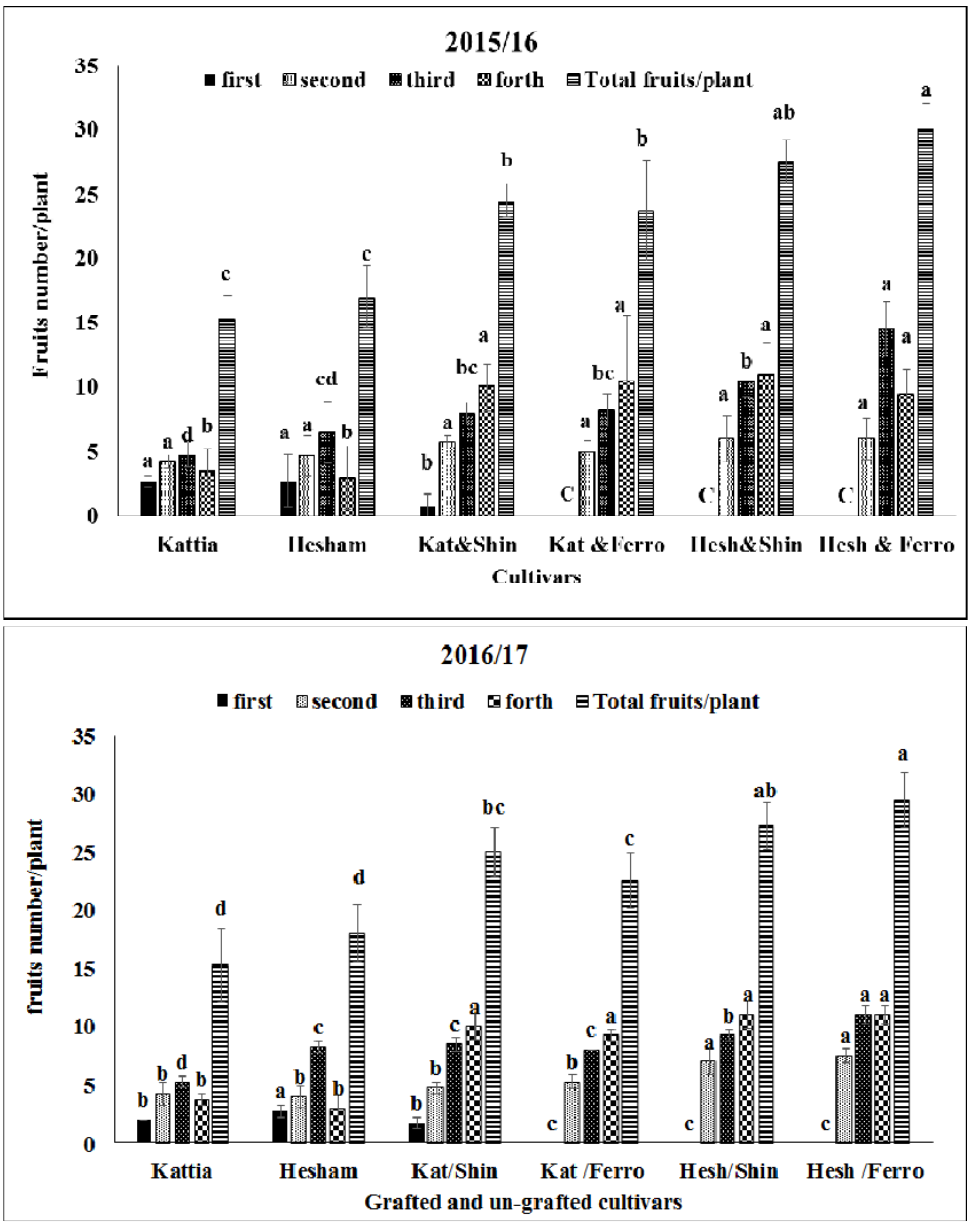

Fig. (2): No. of fruits/plant at first, second, third and fourth harvest as well as the total No. of fruit/plant during cultivated seasons 15/16 and 16/17 in grafted and un-grafted cucumbers

Vegetative parameters at harvest:

At harvest (130-days old plants), the maximum significant values of both No. of branches and nodes, stem diameters and leaf area/plant were recorded in 'Hesham' cv. grafted onto 'Ferro' in both seasons than un-grafted or those grafted onto ''Shintoza'' plants (Table 1). Grafting of 'Kattia' cv. onto 'Ferro' or 'Hesham' cv. onto ''Shintoza'' hadn't any effect on No. of branches/plant. However, Grafting of 'Kattia' cv. onto ''Shintoza'' increased the No. of branches/plant by 200 and 50% as well as by 40 and 23% in 'Hesham' grafted onto 'Ferro' in both seasons, respectively. The highest increment of node No./plant (54.5 and 40.2%) was recorded in 'Kattia' cv. grafted onto 'Ferro'

Table (1): Vegetative parameters in un-grafted Kattia and Hesham cvs. and grafted one onto two rootstocks, at harvest in 2015/16 and 2016/17 seasons under plastic house

Cultivars	Number of				stem diameter (cm)		Leaf area (cm^2 $plant^{-1}$)	
	Branches $plant^{-1}$		Nodes $plant^{-1}$					
Season	15/16	16/17	15/16	16/17	15/16	16/17	15/16	16/17
Kattia (Cont.)	1.00 c	2.00 c	16.50 b	19.25 c	0.91 d	0.92 c	204.3d	207.0 d
Kattia onto Shintoza	3.00 bc	3.00 bc	17.75 b	20.00 c	1.21 c	1.26 b	275.5 c	286.8bc
Kattia onto Ferro	1.25 c	2.50 c	25.50 a	27.00 ab	1.30 b	1.39 a	282.5 c	279.0 c
Hesham(Cont.)	5.00 ab	4.25 ab	21.50 ab	24.00 b	0.95 d	0.98 c	207.5 d	209.75 d
Hesham onto Shintoza	5.00 ab	4.25 ab	26.25 a	30.25 a	1.24 c	1.28 ab	293.0 b	293.5ab
Hesham onto Ferro	7.00 a	5.25 a	27.25 a	31.25 a	1.39 a	1.38 a	304.0 a	303.25a

Mean values followed by the same letter in each column show non-significantly different at the $P < 0.05$ probability level

followed by 26.7 and 30.2% of increment in 'Hesham' cv. grafted onto 'Ferro' in 1st and 2nd seasons, respectively. Also, 'Kattia' cv. grafted onto 'Ferro' had the highest increment of stem diameter (42.8 and 51.1%) followed by 46.3 and 40.8% of increment in 'Hesham' cv. grafted onto 'Ferro', in both seasons, respectively. Grafting of 'Hesham' cv. onto 'Ferro' increased the leaf area of plant by 46.5 and 44.5% over the control, followed by 41.2 and 39.9% as grafted the same cultivar onto ''Shintoza'' in both seasons, respectively.

Yield as Kg/plant and Kg/m^2:

The maximum significant value of fruit yield/plant was recorded in 'Hesham' cv. grafted onto 'Ferro' (4.49 and 4.46 kg/plant in 1st and 2nd seasons, respectively) with 70.7 and 67.6% of increment, followed by 60.7 and 59.6% of increment in 'Kattia' cv. grafted onto 'Ferro' over the un-grafted ones. In the same trend, the square meter of plastic house gave the highest yield (12.12 and 12.15 kg) with 26.6 and 26.9% of increment in 'Hesham' cv. grafted onto 'Ferro' over the un-grafted plants, followed by 24.1 and 24.2% of increment in 'Hesham' cv. grafted onto ''Shintoza'' in both seasons, respectively.

Table (2): Yield in un-grafted Kattia and Hesham cvs. and grafted one onto two rootstocks, at harvest during 2015/16 and 2016/17 seasons under plastic house:

Cultivars	Yield			
	(kg $plant^{-1}$)		(kg m^{-2})	
Season	15/16	16/17	15/16	16/17
Kattia (Cont.)	2.42 c	2.45 c	9.33 b	9.87 b
Kattia onto Shintoza	3.76 b	3.78 b	11.60 a	11.64 a
Kattia onto Ferro	3.89 b	3.91 b	11.62 a	11.54 a
Hesham(Cont.)	2.63 c	2.66 c	9.57 b	9.57 b
Hesham onto Shintoza	3.96 b	3.98 b	11.88 a	11.89 a
Hesham onto Ferro	4.49 a	4.46 a	12.12 a	12.15 a

Mean values followed by the same letter in each column show non-significant different at the $P < 0.05$ probability level.

Fruit quality:

Results in (Table 3) showed that grafting of 'Kattia' cv. onto 'Ferro' resulted in accumulation of the maximum amount of dry weight in fruits (11.92 and 12.16 g /fruit) with increment 20.6 and 11.6%, followed by the same cultivar grafted onto ''Shintoza'' by 10.8 and 11.1% of increment over the un-grafted fruits in both seasons, respectively. However, increment % of fruit dry weight in 'Hesham' grafted onto both rootstocks was very low. Grafting reduced the percentage water content in fruits in both cultivars grafted onto the two rootstocks from 93.3 or 93.9% in un-grafted 'Kattia' or 'Hesham' cvs, to 92.6 and 91.7% in grafted ones, respectively. The maximum significant values of fruit length (16.19 and 16.18 cm) was achieved (with increment 21.2 and 23.5% over control) in 'Hesham' cv. grafted onto 'Ferro' in 1st and 2nd seasons, respectively. Although the highest fruit diameter (28.19 and 27.32 mm) was found in 'Hesham' cv. grafted onto 'Ferro', but the highest increment in fruit diameter was 11.3 and 11.1% in 'Kattia' grafted onto 'Ferro', in both seasons, respectively. Grafting decreased the SSC% in fruits from 5.7 or 5.78 in un-grafted 'Kattia' or 'Hesham' cvs. to 5.1 or 4.6 in grafted ones, respectively.

Table (3): Cucumber fruit characteristics in un-grafted Kattia and Hesham cvs. and grafted one onto two rootstocks

Cultivars	Dry weight (gfruit^{-1})		water content (%)		Length (cm)		Diameter (mm)		SSC (%)	
	15/16	16/17	15/16	16/17	15/16	16/17	15/16	16/17	15/16	16/17
Kattia (Cont.)	9.88 c	10.89 b	93.3 a	92.7 a	12.72c	13.20 d	24.56d	24.45c	5.58 a	5.70a
Kattia onto Shintoza	10.95b	12.10 a	92.6 b	91.9 b	14.18 b	14.30 c	26.61bc	26.73ab	5.13 b	5.25 b
Kattia onto Ferro	11.92a	12.16 a	93.1 a	93.0 a	15.49 a	15.10 b	27.34ab	27.17 a	5.20 b	5.10 b
Hesham (Cont.)	10.66b	11.41ab	93.2 a	92.8 a	13.35 c	13.10 d	25.89c	25.92 b	5.6 a	5.78 a
Hesham onto Shintoza	10.92b	11.78ab	92.3 b	91.8 b	16.01a	15.93 a	27.29ab	26.75ab	4.68 c	4.83c
Hesham onto Ferro	11.57ab	12.19 a	92.2 b	91.9 b	16.19a	16.18 a	28.19a	27.32 a	4.68 c	4.60c

Mean values followed by the same letter in each column show non-significant different at the $P < 0.05$ probability level

Concentration of N, P and K in leaves and roots:

In most cases, nitrogen, phosphorous and potassium concentrations in leaves and roots were increased with grafting in both cultivars using two rootstocks over un-grafted plants. The highest concentration of nitrogen (54.33 and 45.33 mg/g DW in leaves and roots occurred in 'Hesham' cv. grafted onto 'Ferro' with 9.3 and 21.4% of increment over un-grafted plants. Non-significant differences in phosphorous and potassium concentrations in leaves of grafted or un-grafted plants of both cultivars were found. However, the maximum significant values of phosphorous in roots (11.57 and 11.34 mg/g DW), was detected in 'Hesham' grafted onto 'Ferro' and ''Shintoza'', with 78.0 and 74.4% of increment over un-grafted plants, respectively. The highest concentration of potassium (66.0 mg/g DW) was determined in roots of 'Kattia' grafted onto 'Ferro' with 5.4% of increment over un-grafted plants.

Histological modification of grafting zone:

A high affinity between 'Hesham' and 'Ferro' scion rootstocks than 'Hesham' and ''Shintoza'' was observed. Therefore, the histological modifications in union region of grafting zone between them were examined. Completed adhering region (AR) and union cells (UC) was observed after 4 days of grafting in union region between 'Hesham' cv. and 'Ferro' rootstock earlier than 'Hesham' and ''Shintoza'', as shown in Fig (3). However, callus (C) region and non-adhering region were noted in grafting zone of 'Hesham' onto ''Shintoza''. Five days after grafting, the adhering region was completely formed in both regions with both rootstocks. In the sixth day, the new tracheids (NT) were earlier differentiated from paranchymatous cells in 'Hesham' onto 'Ferro' compared to ''Shintoza''. Reoriented vessels from rootstock to scion was detected in 'Hesham' grafted onto ''Shintoza''. New vessels between scion vessels and rootstock was earlier differentiated in the eighth day in 'Hesham' cv. grafted onto 'Ferro' than ''Shintoza''.

Table (4): Macronutrient concentrations as mg g^{-1} DW in 3rd leaf and 3rd secondary root of un-grafted Kattia and Hesham cvs. and grafted one onto two rootstocks in 2016/17 seasons at harvest.

Cultivars	N		P		K	
	3rd leaf	3rd root	3rd leaf	3rd root	3rd leaf	3rd root
Kattia (Cont.)	49.00 b	35.33d	5.27 a	6.67 d	63.33a	62.67 ab
Kattia onto Shintoza	52.67a	41.00b	5.33a	9.67c	66.67a	61.33b
Kattia onto Ferro	52.0a	40.33b	5.20a	10.61b	67.33a	66.00a
Hesham(Cont.)	49.67 b	37.33c	5.37 a	6.50 d	65.00a	63.00ab
Hesham onto Shintoza	53.0 a	44.00a	5.37a	11.34ab	67.0 a	65.67a
Hesham onto Ferro	54.33 a	45.33a	5.47a	11.57a	68.0a	64.67ab

Mean values followed by the same letter in each column show non-significantly different at the $P < 0.05$ probability level

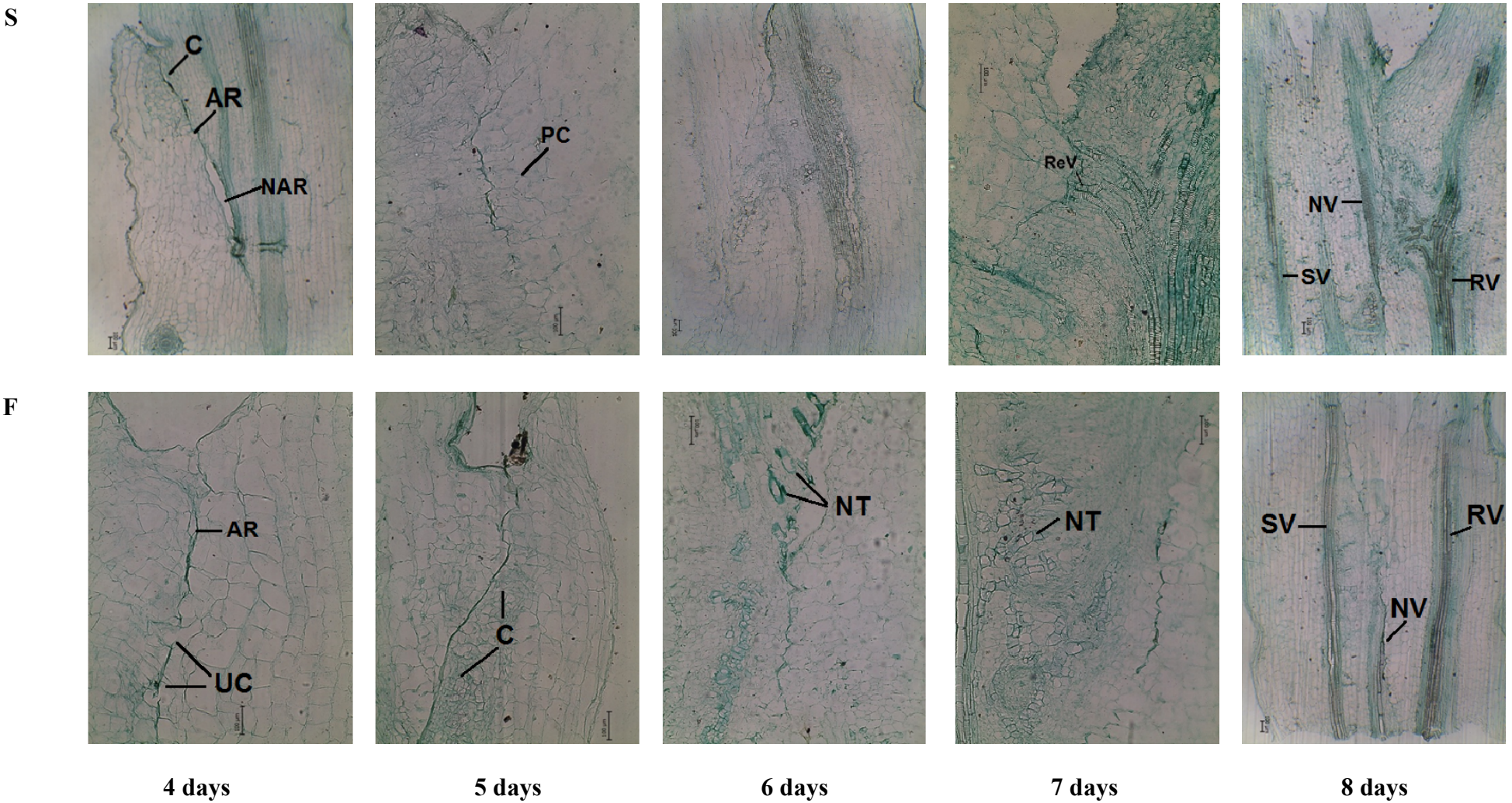

Fig. (3): Histological modifications of grafting zone of Hesham scion grafted onto Ferro and Shintoza 4, 5, 6, 7 and 8 days after grafting. C, Callus; AR, Adhesion reagon; NAR, non-adhering region; UC, Union cells, ReV, Reoriented vessels; NT, New tracheids; SV, Scion vessels; NV, New vessels; RV, Rootstock vessels; PC, paranchymatous cells

DISCUSSION

Under plastic house conditions, plants of 'Hesham' cv. were more vigorous than 'Kattia' cv. according to increased stem length and leaves No. plant^{-1} as shown in (Fig 1). This could be attributed to its genetic structure and positively response with environmental conditions (Naegele and Wehner, 2016). However, grafting increased most of the vegetative parameters as stem length, No. of leaves, branches and nodes, stem diameters and leaf area/plant (Fig 1 and Table 1) in both cultivars using two rootstocks with some significant differences, indicating the relationship between rootstock and scion (Table 1). Lee and Oda (2003) demonstrated different responses of vegetative growth to the grafted combinations related to the vigor of rootstocks and compatibility of rootstocks and scions. Other researchers attributed rootstock effect to several factors such as increase of cytokinin production (Salehi *et al.,* 2010), higher root activity (Salehi *et al.,* 2009), extensive root system (Edelstein *et al.,* 2004), increase in resistance to soil-borne diseases and other unfavorable soil conditions as well as increasing synthesis of plant growth substances (Yetisir and Sari, 2003). The stimulatory effect of rootstock genotype on cucumber growth was presumably associated with a better nutritional status especially that of nitrogen in both leaves and roots as well as phosphorus and potassium in roots as shown in (Table 4). Nitrogen was increased by 9.3 and 21.4% in leaves and roots, respectively over un-grafted plants after grafting of 'Hesham' cv. onto 'Ferro'. Literatures clarified that N stimulate the vegetative growth of plants through synthesis of amino acids, nucleic acids, chlorophylls and phytohormons especially auxins (Lawlor *et al.,* 2001). Hopkins and Huner (2004) revealed that auxins stimulate differentiation of unspecialized parenchyma cells such that founded in union region of grafting zone into specialized cells such as xylem tracheids or vessels which transport water and nutrients from rootstock to scion as obvious in Fig (3). Results were similar with Colla *et al.* (2010) who found that grafting melon onto selected rootstocks increased N uptake efficiency and improved the nitrogen using efficiency. However, high concentration of nitrogen in grafted leaves or roots (Table 4) correlated with increment of paranchymatous cells in grafting region as shown in (Fig 3), which easily adhere with middle lamella components or regenerated to callus cells. Results showed that, the adhering region between scion and rootstock was completely formed early (after 4 days) in 'Hesham' grafted onto 'Ferro' than 'Hesham' grafted onto ''Shintoza''. Therefore, the compatibility between 'Hesham' cv. was more efficient with 'Ferro' than with ''Shintoza'' rootstocks. Andrews and Marquez, 1993, revealed that early formation of Callus Bridge in adhering region between scion and rootstock as well as its earlier differentiation into xylem and phloem was the first factor of successful grafting. Also, phosphorus concentration in roots was increased by 78.0 and 74.4% in 'Hesham' cv. plants after grafting on 'Ferro' and ''Shintoza'', respectively over the un-grafted control. It is well known that P enhances different physiological process as photosynthesis, nitrogen assimilation and energy conservation as well as it is a structural component of nucleic acids, membrane phospholipids and high energy compounds such as ATP and NADPH which stimulate the division of cells (López-Arredondo *et al.,* 2014). Therefore, callus formation was firstly observed after 4 or 5 days after grafting with both rootstocks. Results are in accordance with those, reported for grafted watermelon by Chouka and Jebari (1999), Alexopoulos *et al.* (2007), Mohamed *et al.* (2012) where the promoted vigor and vegetative growth of grafted plants were correlated with potential of root system in water and inorganic nutrients uptake.

Although grafting of 'Hesham' cv. onto 'Ferro' increased the leaf area of plant by 46.5 and 44.5% over the control in both seasons, respectively. However, 'Kattia' cv. grafted onto 'Ferro' accumulated the maximum amount of dry weight in fruits (11.92 and 12.16 g/fruit). High accumulation of photosynthetic products in fruits depend on different factors such as high photosynthetic rate and translocation efficiency (Hopkins and Huner, 2004). This finding may correlate with high increment of potassium concentration in roots (5.4%) in 'Kattia' grafted onto 'Ferro' over the control. Literatures cited that, K is an enzyme activator of both photosynthesis and respiration processes, osmoregulator responsible for opening and closure of stomatal guard cells, and contributed in sugar translocation (Zörba *et al.,* 2014).

Un-grafted plants of both 'Kattia' and 'Hesham' cvs. as well as 'Kattia' grafted onto ''Shintoza'' were fruited early (30 days after transplanting) in both seasons. This finding was coordinated with Hoyos (2001) who found that grafting delayed fruiting in cucumber, but increased the total yield than un-grafted plants. In contrary, Huang *et al.* (2010) cleared that grafting increased cucumber vigour, yield, earliness and tolerance to stress conditions.

High vegetative growth and high fruit yield are the result of the combination between scion and rootstock. A higher fruit yield was obtained from both cultivars grafted onto two rootstocks 'Ferro' and ''Shintoza''. Yield/plant was enhanced by 70.7 and 67.6% over the un-grafted ones in 'Hesham' cv. grafted onto 'Ferro' in 1st and 2nd seasons, respectively. This might result from increase of macronutrients uptake in roots as shown in Table (4). Similar results were obtained by Cheshmemanesh *et al.* (2003) on cucumber cv. Royal 24198 and Vilmorian after grafting onto fig leaf squash rootstock. Moradipour *et al.* (2010) reported that, rootstocks type had a significant effect on the yield and other growth characteristics.

Significant differences were found among two rootstocks for several fruit quality such as fruit size, water content and SSC (%) as shown in Table (3). Grafted plants of both cultivars under study produced length and diameter of fruits more than un-grafted plants. These results are in agreement with Huang et al., (2009) and Cheshmemanesh *et al.* (2003), which might be resulted from the effects of diverse rootstocks

and experimental conditions. Decreasing of SSC % in fruits with grafting in both cultivars compared to un-grafted ones was paralleled with reduction of fruit water content % as shown in Table (3). These results are in the same line with Davis *et al.* (2008) who noted the reduction of SSC and pH of fruits of grafted cucumber, eggplant, and tomato plants. Also, Lee *et al.* (1999) reported that Cucurbita rootstocks may deteriorate the cucumber fruit quality such as decreasing the fruit soluble sugar.

CONCLUSIONS

Results showed the substantial differences in the quantitative response between grafted and un-grafted cucumber plants. The use of a proper rootstock for grafted cucumber would be a useful tool in increasing marketable yield and fruit quality. Histological analysis of the grafting zone indicated that the cv. 'Hesham' was more compatible with the rootstock 'Ferro' than ''Shintoza''. Grafting of cucumber plants onto different rootstocks was established as an acceptable eco-friendly method.

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تأثير التطعيم على أصول مختلفة على النمو الخضري و المحصول و جودة الثمار في الخيار

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تم تقييم كفاءة استخدام التطعيم لصنفي الخيار كاتيا & هشام على أصول الفيرو & شانتوزا من حيث النمو والمحصول خلال موسمي الزراعة المتعاقبة ٢٠١٥-٢٠١٦ ، ٢٠١٦-٢٠١٧ تحت ظروف الصوبة البلاستيكية. تم قياس طول الساق وكلا من عدد الأوراق والثمار على فترات متعاقبة بعد ٣٠ ، ٤٥ ، ٦٠، ٩٠ يوم من الشتل. وفي وقت الحصاد تم تقييم كلا من عدد الأفرع والعقد وقطر الساق (سم) ومساحة الأوراق (سم^2) والمحصول (كجم/نبات ، كجم/م^2) وجودة الثمار من حيث الوزن الجاف والنسبة المئوية للمحتوى المائي وطولها (سم) وقطرها (مم) ونسبة المواد الصلبة الذائبة. كما تم تقدير تركيزات النيتروجين والفوسفور والبوتاسيوم في الأوراق والجذور. أوضحت النتائج أن الصنف كاتيا أكثر تأثراً بعملية التطعيم من خلال تقييم القياسات الخضرية مثل طول الساق وعدد الأوراق والأفرع والعقد وكذلك قطر الساق أكثر من الصنف هشام. إرتبطت الزيادة في النموات الخضرية بزيادة محتوى الجذور من البوتاسيوم. كما أدى التطعيم إلى تأخير ميعاد الأثمار في كلا الصنفين. أدى التطعيم إلى نقص كلا من النسبة المئوية للمواد الصلبة الذائبة والمحتوى المائي للثمار في كلا الصنفين. سجل الصنف هشام أعلى قيم للمساحة الورقية ومحصول الثمار/نبات مع زيادة في تركيز عنصر النيتروجين في الأوراق والجذور وكذلك الفوسفور في الجذور فقط. زاد المحصول بنسبة ٧٠.٧ ، ٦٧.٦٪ في الصنف هشام المطعوم على أصل فيرو. أوضحت النتائج أيضاً أن الصنف هشام كان أكثر توافقاً مع الأصل فيرو مقارنة بالأصل شانتوزا بسبب سرعة تكوين منطقة الإلتحام والكالس وكذلك سرعة تميز العناصر الخشبية. يمكن استنتاج أن الأصل فيرو يعتبر أنسب الأصول لتطعيم الخيار لزيادة المحصول وجودة وتحسين الثمار.

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