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The effect of grafting on vegetative and reproductive traits of tomato

ABSTRACT

Relevance. Tomato (Solanum lycopersicum L.) is one of the most important vegetables in the world. Every year the number of identified viruses and diseases increases, infection with which causes significant crop losses and significantly worsens the quality of agricultural products, especially in tomatoes.

Material and methods. In the present study we compared the growth of the vegetative and reproductive traits of tomato plants 'Dokia', 'TY Red 250' and 'Pilabi' grated onto bacterial wilt (caused by Ralstonia solanacearum) and Fusarium wilt (Fusarium oxysporum) diseases tolerant rootstock "Spider" (Takii seed, Japan). The non-grafted (control - CT) and grafted tomato plants (GR) were transplanted on 4 March of 2021 to the four season (vinyl) greenhouse on substrate perlite (mixture of perlite no.1 and no.3) and cultivated until September 20.

Results. The results showed that responses of the tomato cultivars to grafting combination was different, where agronomical traits depends on the each cultivar's features can be ranged. The reduction of the values of stem diameter (SD), leaf length and width (LW), fresh fruit weight (FFW), fruit diameter (FD), fruit pericarp thickness (FPT) and fruit hardness (FH) with aging of plants and rising ambient temperature was detected. However, fruit soluble solids among all cultivars regardless of treatments were slightly increased. The index of fruit yield per truss (FYT) significantly decreased among all cultivars after 10th truss regardless of the treatments when the daily temperature increased from July to August. In grafted tomato 'TY Red 250' were identified the highest fruit yield per plants (FYP) than in CT plants, whereas in other tomatoes did not found similar differences between CT and GR plants.

KEYWORDS:

tomato, rootstock, scion, plant, stem, leaf, flowering, fruit, yield, hardness, soluble solids

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Влияние прививки на вегетативно-репродуктивные признаки томата

РЕЗЮМЕ

Актуальность. Томат (Solanum lycopersicum L.) является одной из важнейших овощных культур в мире. С каждым годом увеличивается количество выявленных вирусов и болезней, заражение которыми приводит к значительным потерям урожая и существенно ухудшает качество сельскохозяйственной продукции, особенно томатов.

Материал и методы. В настоящем исследовании сравнили рост вегетативных и репродуктивных параметров растений томата 'Dokia', 'TY Red 250' и 'Pilabi', заокулированные к подвою 'Spider', устойчивому к бактериальному увяданию (вызванному Ralstonia solanacearum) и фузариозному увяданию (Fusarium oxysporum) (Takii seed, Япония). Непривитые (контроль – CT) и привитые растения томата (GR) 4 марта 2021 года были пересажены в четырехсезонную (виниловую) теплицу на перлитовый субстрат (смесь перлитов №1 и №3) и культивировали до 20 сентября.

Результаты. Результаты показали, что реакция сортов томата на сочетание прививки была разной, при этом агрономические особенности можно ранжировать в зависимости от особенностей каждого сорта. Выявлено уменьшение значений диаметра стебля (SD), длины и ширины листа (LW), массы плодов (FFW), диаметра плода (FD), толщины околоплодника плода (FPT) и твердости плода (FH) с возрастом растений и повышением температуры окружающей среды. Однако содержание растворимого сухого вещества в плодах среди всех сортов, независимо от варианта, было немного увеличено. Показатель продуктивности плодов с одной кисти (FYT) после 10-й кисти значительно снизился среди всех сортов независимо от вариантов при повышении дневной температуры с июля по август. У привитого томата 'TY Red 250' выявлена самая высокая продуктивность (FYP) с растения, чем у растений в CT, тогда как у остальных сортов томата не обнаружено подобных различий между растениями в CT и GR.

КЛЮЧЕВЫЕ СЛОВА:

томат, подвой, привой, растения, стебля, листья, цветение, плод, урожайность, твердость плода, растворимые вещества

Introduction

Global climate changing and a gradual increase in the world's population are posing new challenges to scientists to solve food security. In recent decades, the primary objective of agriculture was to increase the yield and productivity, where new investigations have created a chance to improve yield and quality of products based on an accurate genotype selection, optimization of environmental conditions and agricultural practices such water and fertilization management, growth system, harvesting stage and grafting techniques in horticulture [1-5].

Nowadays, with developing greenhouse technologies, there is a significant opportunity to increase production of agricultural crops during all season. However, investigation and applying new technologies in practice at greenhouses is actual and needs to be continued. According to recent studies, the rootstock plays an important role in production of tomatoes [3-7], since grafting technique rapidly develops in order to increase the yield of vegetables in greenhouses and open ground, mainly in order to combat adverse biotic factors such as pests and diseases, and biotic factors salinity, extreme temperatures, drought and reduced fertilization [1,3,4,6-8].

Meanwhile, in literature there are several conflicting reports on changes in growth and productivity and fruit quality due to grafting among tomatoes [3,9], therefore depending on the using of grafting technique and plant materials (scion and rootstocks) the investigations in this area should be continued. Moreover, it was reported that the rootstock–scioncombination may alter the amounts of hormones produced and their influence on sex expression and flowering order of grafted plants [10], or, on the contrary, flowering and harvesting may delayed [11,12].

Furthermore, recently it was recommended, that the growing system and different environmental conditions should be taken into consideration when evaluating the effects of grafting onquality [2].

Therefore, the aim of the present paper is to identify the influence of the rootstock "Spider" (Takii seed, Japan) on vegetative and reproductive traits by using grafting technique in tomato (red type) cultivars 'Dokia', 'TY Red 250' and 'Pilabi' in greenhouse cultivation season spring-summer.

Materials and Methods

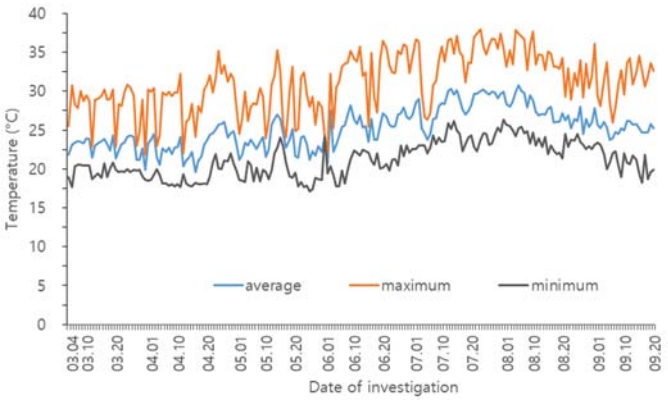
Plant material and growth conditions

Indeterminate tomato cultivars 'Dokia', 'TY Red 250' and 'Pilabi' having red fruit color, round shape with average fruit weight 300, 280 and 270 grams respectively were used as scion and grafted on bacterial wilt (caused by *Ralstonia solanacearum*) and Fusarium wilt (*Fusarium oxysporum*) diseases tolerant rootstock "Spider" (Takii seed, Japan). Vegetative grafting of tomato seedlings was performed when the stem diameter reached 1.6-1.8 mm in the phase of 2-3 true leaves. As a control, non-grafted plant varieties were used.

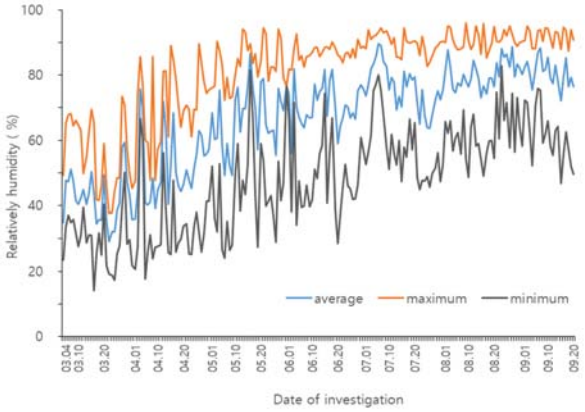
All tomato cultivars seedlings grafted (GR) and non-grafted (control, CT) having the first truss were transplanted with spacing between plants 30 cm on 4 March of 2021 to the four season greenhouse on substrate perlite (mixture of perlite no.1 and no. 3). Investigations were continued until September 20 of 2021. The structure of the four season greenhouse (covered with vinyl) which was built in 2020, has a length 135 m, width 40 m, height in center 14 m and in both lateral parts 4.7 m and total area was 5400 m^2. In each truss were left on 3-4 normal fruits.

Temperature and relatively humidity regulations

The daily minimum and maximum temperatures and relatively humidity was monitored and recorded in greenhouse during the period of the tomato plants cultivation using data logger (WatchDog 1450, Spectrum Technologies Inc., Aurora, USA). The maximal temperature over 30°Cwere detected from June to August and the minimal below 20°C from March to May (Figure S1). Cooling system- Forced ventilation (open above 25°C), cooling through fog system (on above 28°C).In general, daily average temperature was within 24...28°C. The average relative humidity (RH) was kept within approximately 40%-80% in greenhouse during growth period, respectively (Figure S2).



Supplemental Figure 1. The daily temperature ranging in greenhouse during the tomato growing season in spring-summer. Data was recorded with one hour interval from March 04 to September 20 in 2021.



Supplemental Figure 2. The daily relatively humidity ranging in greenhouse during the tomato growing season in spring-summer. Data was recorded with one hour interval from March 04 to September 20 in 2021.

Diseases and pest controls

Diseases and pest controls were conducted as described below. Briefly, pesticide alternating 9 chemicals were used with interval once a week- Jijon,

Farmhannong, Spiromesifen 20% Maestro, Seongbo chemical, Buprofezin 20% Hero, Hankooksamgong, Buprofezin 12.5% Benebia, Farmhannong, Cyantraniliprole 10%Phantom, Nonghyup chemical, Dinotefuran 20% Raimon, Hankooksamgong, Novalturon 10% Transform, Farmhannong, Sulfoxaflor 7% Rempeiji, Hankooksamgong, Chlorofenapyr 5% Captin, Kyungnong, Fluxametamide 9%.

Irrigation and fertigation managements

Drip irrigation systems are used 1 hour after sunrise and 1.5 hour before sunset with interval 100J integrated solar radiation and watered 200-250 mL per plant in each time, within 6 to12 times per day. Moreover, fertilizers were diluted with the ratio to 1 000 liter of water (KCl – 4.0 kg; 5{$Ca(NO_3)_2.2H_2O$}.NH_4NO_3 – 44.2 kg; KNO_3 – 22.0 kg; Fe EDTA (13%) – 1.46 kg; KH_2PO_4 – 21.46 kg; $MgSO_47H_2O$ – 55.73 kg; K_2SO_4 – 30.36kg; KNO_3 – 24.76 kg; $MnSO_4$ H_2O – 245.0 g; $ZnSO_4$ $7H_2O$ – 173.0 g; H_3BO_3 – 297.0 g;$CuSO_4$ $5H_2O$ – 21.0 g and Na_2MoO_4 $2H_2O$ – 13.0 g) for fertigation of tomato plants. Electrolyte conductivity of the supplied water was within 2.5-2.8 dS/m and pH 5.5-5.8.

Data collections

The twelve independent biological plants from CT and GR plants were randomly selected among one hundred twenty plants for measurement the vegetative and reproductive parameters. The vegetative parameters including plant height (PH), stem diameter (SD), and length and width of leaf (LL and LW) were measured. The PH were started to record on 15day after transplanting (DAT) of seedlings, and then with interval 30 days were measured until 150 DAT. The dimension of the SD and LL and LW were done within 2nd, 5th, 10th and 15th truss (the first leaf below truss). Days to flowering were also recorded from 2nd, 5th, 10th and 15th truss, when 3/1 part of flowers were opened.Small and abnormal fruits were removed from each truss and within 3-5 of normal fruits were left in each truss. The fruit yield per truss (FYT) and per plant (FYP) were measured from the first to the fifteen trusses. Twelve fruits of each treatment were randomly collected from 2nd, 5th, 10th and 15th truss of plants in CT and GR were measured the fresh fruit weight (FFW), fruit length (FL), fruit diameter (FD), fruit hardness (FH), fruit pericarp thickness (FPT), fruit soluble solids (FSS) using a digital electron Micro Weighing Scale MW-II (CAS), a ruler, a caliper and refractometer (°Brix, ATAGO, Japan), respectively.

Data analysis

The experimental design of this study was completely randomized. Mean values of vegetative and reproductive parameters between CT and GR plants were compared with a significance level of 5% using Duncan's multiple range test which performed using the SAS Enterprise Guide 7.1 (SAS Institute Inc., NC, USA), and the Student's t-testat $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ levels by using EXCEL 2016 software (Microsoft Co. Ltd.,USA).

Results

Effect of the grafting on the vegetative traits

The vegetative parameters including PH, SD, LL and LW were investigated among tomato cultivars'Dokia', 'TY Red 250' and 'Pilabi'in CT and GR treatments. Evaluation of the effect of rootstock on growth rate of tomatoes showed different response, where PH significantly reduced in plants of 'Dokia',which were grafted on 'Spider' rootstock and this trend was persisted during all growth period (Fig. 1A). While, in contrast, the index of PH was significantly decreased in CT plants of 'TY Red 250', but this tendency was persisted for 90 DAT and then observed no significant difference between CT and GR plants (Fig. 1B). Meanwhile, the significant difference of the PH no identified between both treatments in plants of 'Pilabi' (Fig. 1C).

The effect of rootstock on SD was different depending on the tomato cultivars and growth period, where regardless of treatment and cultivars the index of SD showed reduction with rising of the ambient temperature and aging of plants. During all growth period, there was not observed significant difference in SD between plants of 'TY Red 250' and 'Pilabi' under CT and GR conditions(Fig. 1E and F), whereas in 'Dokia' was identified significant reduction of SD in GR plants compared to non-grafted within 5-10 truss (Fig. 1D).

Comparison of the reduction of the SD values between 2nd and 15th truss among tomatoes during cultivation period showed that in grafted plants of 'Dokia', TY Red 250' and 'Pilabi' were found the highest decline of the SD values on 70.4, 77.2 and 70.2%, respectively, whereas in CT plants it reduced within on 68.6, 70.8 and 63.0%, respectively. It means that in all grafted tomato plants were observed remarkable reduction of the SD with aging of plants, than in CT treatment plants.

Next, estimation the effect of grafting on the LL and LW showed different response in tomato cultivars and as mentioned above in measurement of the SD the values of the LL and LW were declined regardless of treatment and cultivars during the growth period. The values of the LL and LW were significantly reduced in GR plants of 'Dokia' in the beginning of the growth and in the end compared to CT (Fig. 1G and J), but there no identified differences between the 5th and 10th truss in both treatments. While, in tomatoes 'TY Red 250' and 'Pilabi' practically no observed significant difference in values of the LL and LW in CT and GR plants (Fig. 1H, I, K, L), except for the cultivar 'TY Red 250' (Fig. 1H).

As mentioned above in measurement of the growth rate of SD, the LL and LW index regardless of the cultivars and treatments were declined with aging of plants on 15th truss. However, there no identified big difference in reduction of the index LL between CT and GR plants among tomatoes 'Dokia', 'TY Red 250' and 'Pilabi', where the percentage of differences between 2nd and 15th truss were within 23.7-24.7%, 35.1-35.6% and 29.2-30.3%, respectively. And, the same trend was persisted in the investigation of the LW index, where it declined among cultivars within 38.1-38.2, 45.6-46.6 and 46.4-46.3%, respectively.

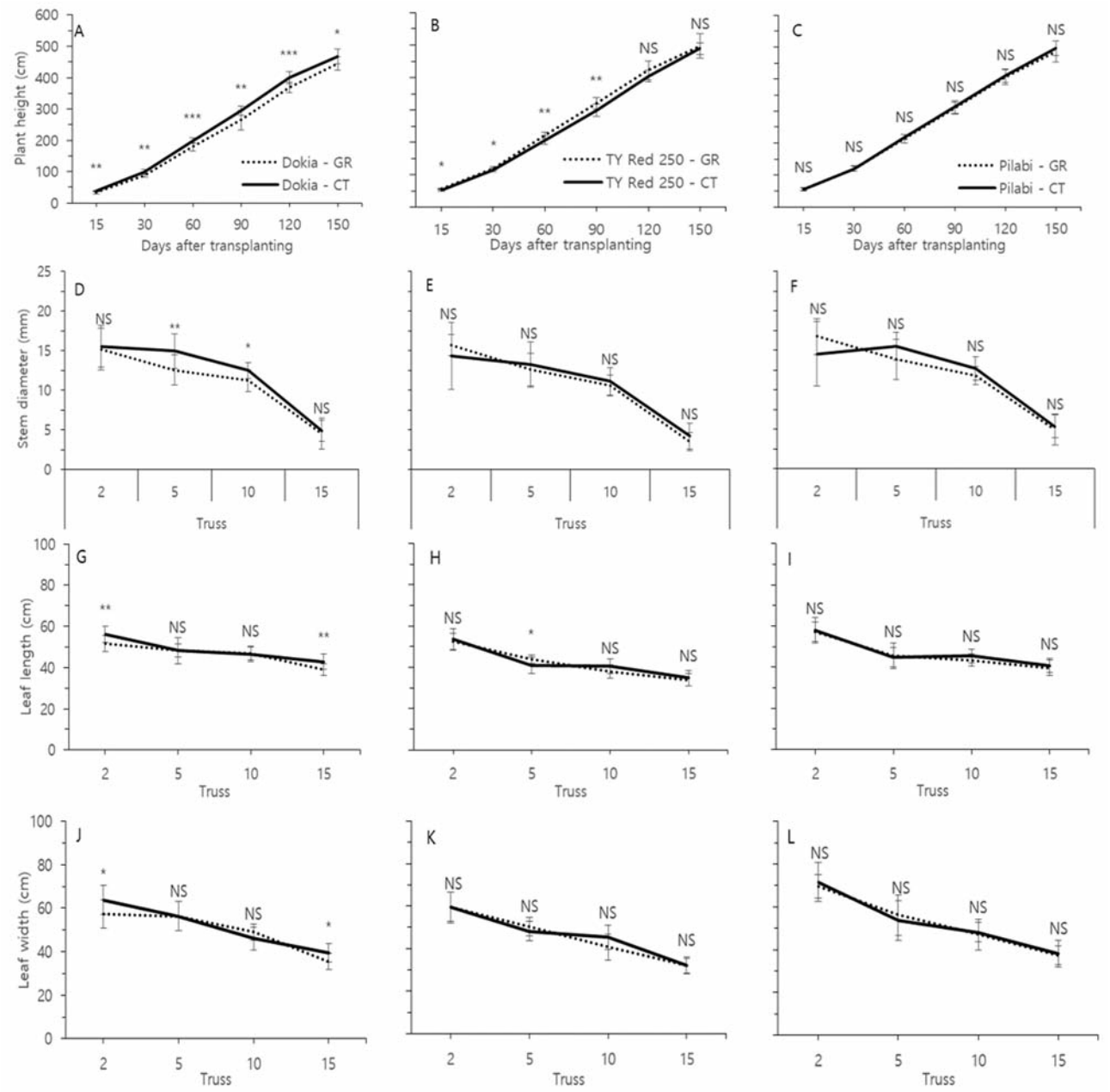


Figure 1. The effect of rootstock on plant height, stem diameter, leaf length and widthamong tomato cultivars- 'Dokia', 'TY Red 250' and 'Pilabi'. Significant differences were evaluated with Student's t-test (p≤0.05, p≤0.01, and p≤0.001) and denoted by *, **, and ***, respectively. NS indicates not significant and bars indicate ± standard deviation (n=12)

Effect of the grafting on the reproductive traits

As well known, the reproductive parameters of agricultural crops are used as the main indicator for evaluation the plants response on the abiotic and biotic stress. Before introduction the grafting techniques into agriculture sector the estimation of the effects of the different rootstocks on reproductive traits such as floral and fruit organs development is playing important role.

Therefore, in the present research, we studied the beginning of flowering between CT and GR plants among tomato cultivars. Thus, on 2nd and 5th truss growth stage were identified significantly early flowering in GR plants among tomato cultivars in comparison with CT ones, except in truss 5th of 'TY Red 250' (Table 1). While, in the next 10 and 15th truss were observed not remarkable difference in flowering between CT and GR plants. In general, the lowest duration of flowering within 93.6 days between 2nd and 15th truss growth stage were determined in CT plants of 'Pilabi' and the longest within 101.3 days in 'Dokia' in combination with rootstock 'Spider'.

The results reveal that regardless of the tomato cultivars in combination with rootstock the fruit yield index per truss was reduced significantly with aging of plants, especially it was characteristic for all tomatoes regardless of treatment from 8th truss (Fig. 2).On the other hand, almost no significant differences were observed in the FYT in CT and GR plants among all tomatoes, except in some cases, where in GR plants of 'TY Red 250' were harvested higher yield from 1st, 5th, 6th and 7th truss than in CT (Fig. 2B), and only in 2nd truss from 'Dokia' (Fig. 2A) and in 15th truss from 'Pilabi', respectively (Fig. 2C).

The significant differences in reduction of the index FYT between CT and GR plants among tomatoes 'Dokia', 'TY Red 250' and 'Pilabi' were identified with aging of plants, where the percentage of differences in reduction between 2nd and 15th truss were within 67.4-74.8%, 83.5-81.1% and 53.4-80.5%, respectively.

Table 1. Flowering date among tomatoes in four season greenhouse

Cultivars	Truss				Duration of the flowering from 2nd to 15th truss, days
	2	5	10	15	
Dokia - CT	32.1±1.6b	52.2±2.2ab	92.8±4.8b	130.9±7.2a	98.8
Dokia - GR	29.6±3.5c	51.6±3.2b	93.2±3.9b	130.9±6.1a	101.3
TYRed 250 - CT	34.0±2.2ab	53.9±4.2ab	97.6±5.7a	131.6±5.46a	97.6
TYRed 250 - GR	32.0±1.5b	52.0±1.7ab	93.0±3.5b	129.9±4.7a	97.9
Pilabi - CT	35.6±2.9a	54.3±3.4a	95.3±5.6ab	129.2±5.0a	93.6
Pilabi - GR	33.0±2.1b	52.8±2.3ab	93.9±5.2ab	130.2±6.5a	97.2

Notice: Different letters within columns indicate significant differences by Duncan's multiple range test (p<0.05), values are mean standard deviation (n=12)

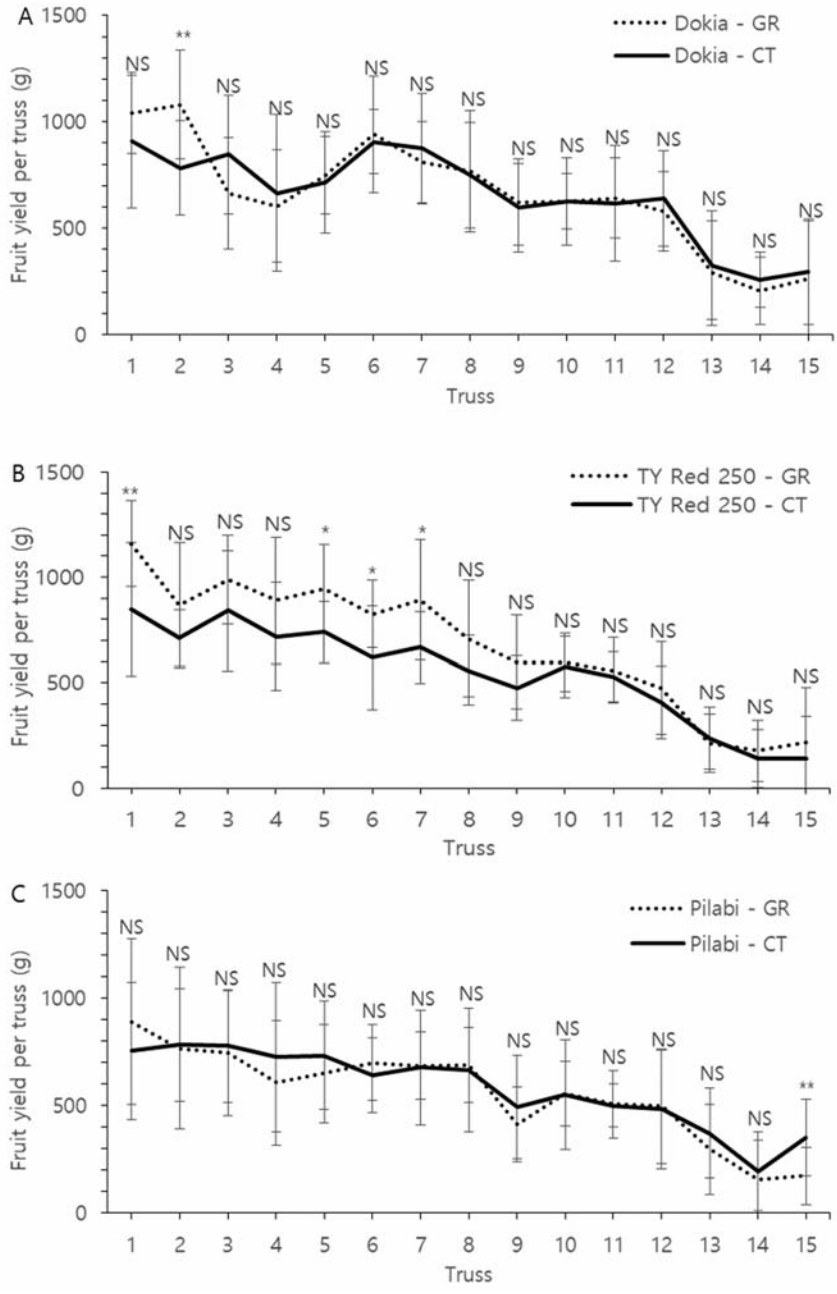


Figure 2. The effect of rootstock on fruit yield per trussamong tomato cultivars (A - Dokia, B - TY Red 250 and C - Pilabi). Significant differences were evaluated with Student's t-test (p≤0.05 and p≤0.01) and denoted by * and **, respectively. NS indicates not significant and bars indicate ± SD (n=12)

Table 2. Yield parameters in tomato cultivars between grafted and non-grafted plants

Cultivar	Treatment	Average fruit yield per truss (g)	Difference, %	Fruit yield per plant (kg)	Difference, %
Dokia	Control	655.6±78.4 a		9.43±1.11 a	
	Grafted	653.5±63.2 a	-0.3	9.51±1.09 a	0.8
TYRed 250	Control	543.8±78.1 b		7.88±1.35 b	
	Grafted	667.6±91.4 a	22.8	9.82±1.88 a	24.5
Pilabi	Control	570.3±105.0 b		8.12±1.82 b	
	Grafted	562.0±85.9 b	-1.5	8.07±1.45 b	-0.7

Notice: Average fruit yield per truss and plant data were calculated from 1st to 15th trusses. Different letters within columns indicate significant differences by Duncan's multiple range test ($p<0.05$), values are mean standard deviation ($n=12$)

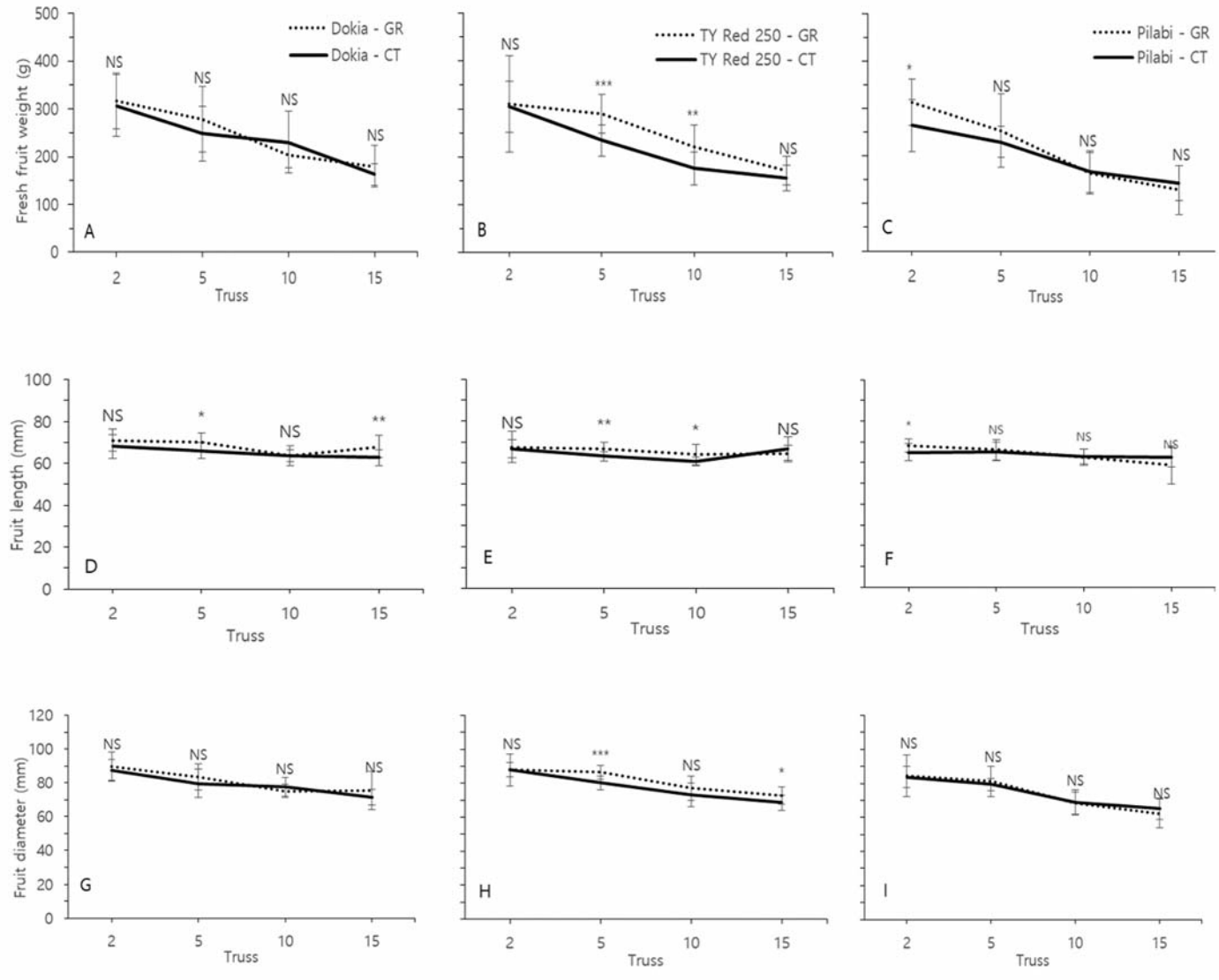


Figure 3.Changing of the fresh fruit weight and size parameters in tomato cultivars 'Dokia', 'TYRed 250' and 'Pilabi' between grafted and non-grafted plants, in fruits collected from 2nd, 5th, 10th and 15thtrusses. Significant differences were evaluated with Student's t-test ($p\leq0.05$, $p\leq0.01$ and $p\leq0.001$) and denoted by *, ** and ***. NS indicates not significant and bars indicate ±SD ($n=12$)

Tomato plants of 'TY Red 250' growing on rootstock 'Spider' produced a bigger yield of fruits per truss and per plant 667.6 gram and 9.82 kg than non-grafted on 22.8 and 24.5% higher, respectively (Table 2). While, in tomatoes 'Dokia' and 'Pilabi' no identified significant differences in CT and GR plants and the highest stable yield per truss and plants were harvested in 'Dokia'.

Effect of the grafting on the fruit quality traits

The results of the current evaluations concerning fruit quality composition showed the regardless of the treatments and tomato cultivars the index of FFW slightly decreased in the end of the study on the 15th truss, but there persisted the varietal distinction (Fig. 3).Thus, rootstock had no significantly effect on FFW in 'Dokia' during all growth period (Fig. 3A), whereas in 'Pilabi' at the beginning of the growth stage on the 2nd truss the rootstock had a stronger affected on the index of FFW and it was significantly increased than in CT (Fig. 3C), but in the next growth periods there no found differences.

Fruits picked in GR plants from 5th and 10th truss of 'TY Red 250' were characterized with a high index of weight compared to CT (Fig. 3B). In general, with aging of tomato plants in the end of study (15th truss) were determined significantly reduction of the index of FFW in comparison with fruits picked in the beginning of the growth stage (2nd truss), where it was decreased on 46.9-43.2% in 'Dokia', on 49.0-44.9% in 'TY Red 250', and on 45.8-59.0 % in 'Pilabi', respectively in CT and GR plants.

Investigation of the effect grafting on the fruit size showed that depends on the growth stages of cultivars was varied. With aging of plants there no observed the significantly reduction of the FL values among cultivars in both treatments. It should be noted that in tomato cultivars 'Dokia', 'TY Red 250' and 'Pilabi' grafted on the 'Spider' rootstock, the FL values were higher in 5th and 15th truss (Fig. 3D), 5th and 10th (Fig. 3E), and only in 2nd truss (Fig. 3F) than in CT plants, respectively.

The effect of grafting technique on the FD in CT and GR plants was not significantly different for 'Dokia' and 'Pilabi' during all growth period (Fig. 3G and I), except for 'TY Red 250' (Fig. 3H). As mentioned above in the measurement of FL, the grafting significantly increased the FD in the fruits of cv. 'TY Red 250' located in the 5th and 15th truss.

Almost the same pattern was found in estimation of the FPT in CT and GR plants of tomatoes 'Dokia' and 'Pilabi', where no identified significantly affect of the rootstock on the index of FPT during all growth stages(Fig. 4A and C), except 'TY Red 250', where in fruits harvested only from 10th truss of GR plants were observed higher values (Fig. 4B). On the whole, in the end of study (15thtruss) compared to the 2nd truss the index of FPT in 'Dokia', 'TY Red 250' and 'Pilabi' reduced on 16.9-19.1%, on 25.2-24.3% and on 29.9-33.3%, respectively between CT and GR plants

Measurement of the FH showed also the reduction it in both treatments with aging of plants but there was persisted varietal

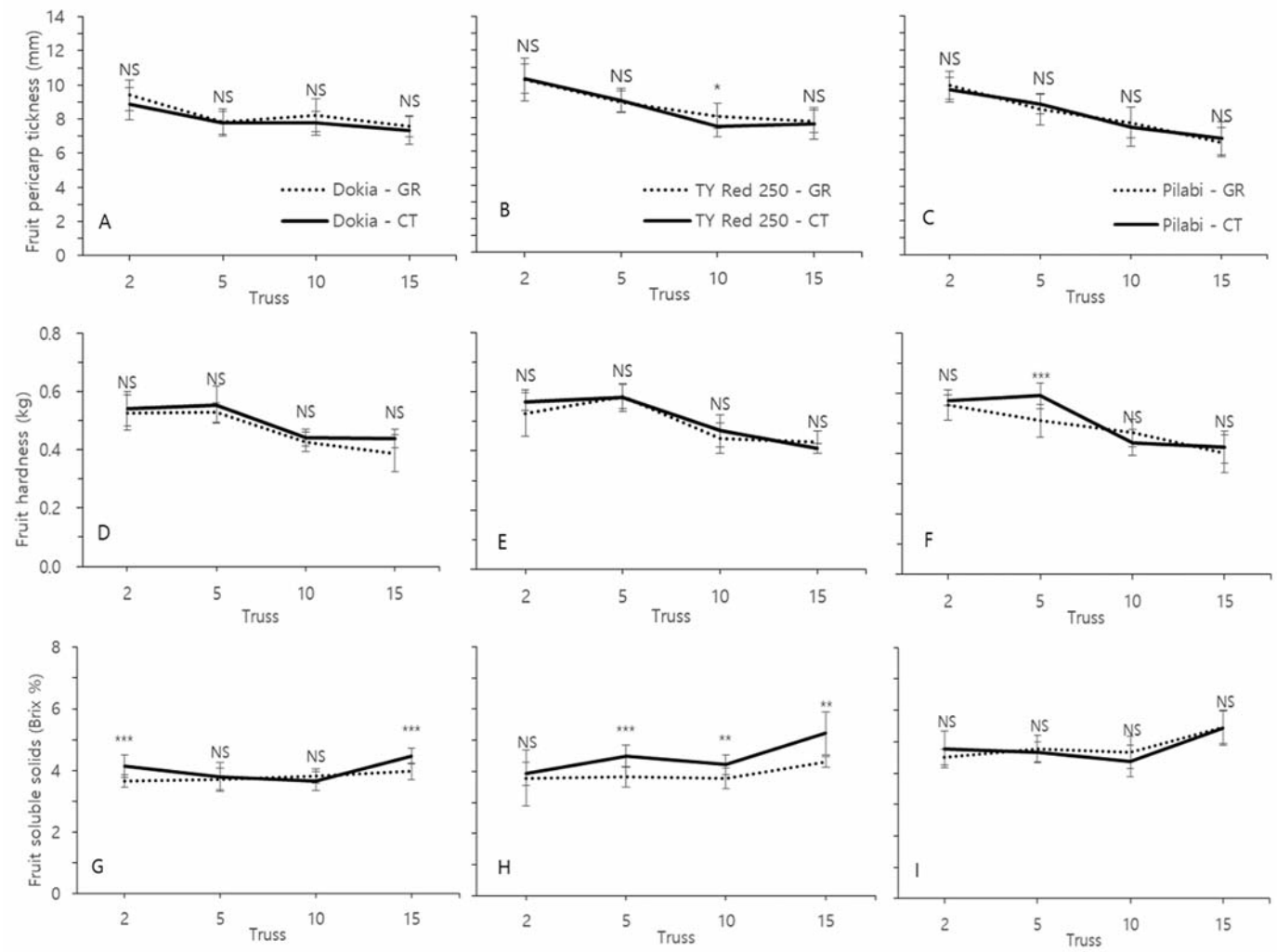


Figure 4. Changing of the fruit pericarp thickness, hardness and soluble solids parameters in tomato cultivars 'Dokia', 'TYRed 250' and 'Pilabi' between grafted and non-grafted plants, in fruits collected from 2nd, 5th, 10th and 15thtrusses. Significant differences were evaluated with Student's t-test (p≤0.05, p≤0.01 and p≤0.001) and denoted by *, ** and ***. NS indicates not significant and bars indicate ±SD (n=12)

differences. Textural firmness traits of fruits picked from plants of 'Dokia' and 'TY Red 250' regardless of treatments was not remarkable varied during all experiment period (Fig. 4D and E), except tomato 'Pilabi' (Fig. 4F). In general, in the end of study (15thtruss) compared to the 2ndtruss the index of FH reduced on 18.5-26.4% in 'Dokia'between CT and GR plants, on 28.1-18.9% in 'TY Red 250', and on 31.0-25.0% in 'Pilabi', respectively.

The fruit soluble solids concentrations were slightly increased among CT and GR plants with rising the ambient temperature, but there were persisted varietal differences. Thus, in fruits of 'Dokia' was observed degradation of FSS index in GR plants in the beginning (2nd truss) and in the end of evaluation (15th truss) than in CT (Fig. 4G), while the fruits of 'TY Red 250' from GR plants accumulated high index of FSS from 5thto 15thtruss than plants from CT (Fig. 4H). Meanwhile, in fruits of 'Pilabi' no observed significant differences in accumulation of the FSS between CT and GR treatments during all growth period (Fig. 4I). On the whole, comparison of the increasing the values in FSS from 2ndtruss to 15thtruss showed that it was grew up on 9.8-8.1% in 'Dokia'between CT and GR plants, on 33.3-13.2% in 'TY Red 250', and on 12.5-22.2% in 'Pilabi', respectively.

Discussion

On the basis of the results obtained from this study, the rootstock effect on the vegetative and reproductive traits varied according to the features of the each genotype (scion). Several studies have shown that the growth, yield and fruit parameters of tomato may be affected by their genetic potential, environmental and cultivation technologic factors including the grafting [2-5,9,11,13]. The present research demonstrated that the effect of the grafting are different and depending on the cultivar and growth period can be varied [17,18]. Thus, the rootstock negatively affects the PH in tomato plants 'Dokia' but positively in cv. 'TY Red 250', while in CT and GR plants of 'Pilabi' showed no differences (Fig. 1).

Almost the same pattern was found in study the SD among tomatoes, where the grafting significantly reduced the index of SD in the mid of the growth stages in plants of 'Dokia' (Fig. 1), whereas other tomato cultivars did not show any variation during growth period. This is consistent with previous reports, where using grafting technique may positive or negative effect on growth rate and stem diameter in tomatoes [17-19].

Regardless of the cultivars and treatments the SD values were significantly decreased with aging of plants and like that pattern was identified in measurement of the vegetative traits LL, LW and in reproductive FFW, FD, FPT and FH. Presumablythis might be due to mainly from the misbalance in metabolites and osmotic balance [13-16,19]. Additionally, our results demonstrate that the leaf parameters for the scion practically was not significantly affected by rootstock [18,21],whereas this contrarywith a other reports where the rootstock increased the leaf area [19,22].

Nevertheless, little is known about the effect of tomato rootstock on flowering. Investigation of the effect rootstock on the beginningflowering time among tomatoes showed different response of the cultivars in combination with grafting and non-grafting, where the significant reduction in the days to flowering were identified in plants grafted onto rootstock 'Spider' in all studied tomatoes (Table 1). However, in the next growth period the differences between CT and GR plants were reduced, and in the end of experiment there no significant differences in the days to flowering among all cultivars and treatmentswere observed [21].

Grafted and non-grafted plants were characterized by a similar FYT during all cultivation period, except in GR plants 'TY Red 250' which produced a higher yield per truss in 1st, 5-7th(Fig 2B).However, the FYT depending on the cultivars regardless of the treatments showed significantly reduction from 10-12th trusses, when the daily temperature in July and Augustwas sufficiently higher over 30°C. While, as well as, the high sub-optimal temperatures tended to significantly effect on floral organs development and reduced the fruit set ratio among tomato cultivars, regardless of heat tolerant rate [23-26]. On the whole, index of FYT and FYP was increased significantly in grafted plants of 'TY Red 250' (Fig 2B), whereas no significant differences were observed in 'Dokia' and 'Pilabi' from CT and GR plants (Fig. 2A and B). The differences observed in evaluation of the productivity probably reported recently, where grafting may increase [1,8,21,27,28], decrease [2,27,29] or either did not affect [30,31]of the yield in tomatoes and associated with physiological compatibility between scion and rootstock with response to the cultivation conditions [4,18,32,33].

Meanwhile, the grafting technique had a strong effect on the FFW in 'TY Red 250' (Fig. 3B), while in contrast this result, FFW no significantly affected by a rootstock in tomatoes 'Dokia' and 'Pilabi' (Fig. 3A and C). Similar different results in tomatoes were obtained in reports [2,14,18,21,28]. Moreover, almost the same differences in measurement of the fruit quality were observed in FL and FD, where depends on the scion and rootstock it was varied during growth period. It should be noted, with aging of the tomato plants and ambient temperature the fruit quality parameters such as FFW, FL, FD, FPTand FHwere slightly decreased, except the index of FSS. Additionally, previous results show that the fruit size of vegetable crops are often influenced [3,18,21,34] or unaffected [35-37] by grafting combination.

There no identified significant difference in measurement of the FPT among CT and GR plants, except in fruits of 'TY Red 250' harvested from 10th truss (Fig. 4B). The investigated rootstock also no significantly affected the FH, except in fruits of tomato 'Pilabi' from 5th truss (Fig. 4F).

However, the results of the current investigations concerning fruit soluble solids rate showed the ambient temperature a stronger effect on the tomatoes, where it was slightly increased among all cultivars (Fig. 4G-I). Especially, FSS were significantly increased in CT fruits of 'TY Red 250' with rising the daily temperature, whereas in grafted plants it showed the contrary pattern. While, in fruits of 'Dokia' this trend were identified in the beginning and the end of the investigation. Such as genotypic differential responses in accumulation of the FSS in grafted and non-grafted tomato plants were observed recently [1,18,21,28].

Conclusions

In general, we can conclude that using rootstock may affect positively or negatively the growth rate of tomato cultivars, but cultivating continuously of tomato plants may contribute significantly reduction in values of the agronomical traits such as SD, LL, LW, FFW, FD, FPT and FHD, while the index of FSS in all cultivars regardless of treatments with the rising of the ambient temperature was slightly increased. The optimal cultivation period for tomato cultivars grafted and non-grafted was limited until 10 truss. Since, decreasing the

vegetative traits values with aging of plants might be the main obstacle to the development of fruits and to a decrease in yield. We assume that with aging of plants regardless of treatments the plants of tomato will find it difficult to absorb the nutrients and water which may destroy the osmotic balance and on the whole lead to a physiological imbalance.Tomato rootstock "Spider" had a positive effect on the yield per truss and plant and the improvement of FFW, FL and FD traits in 'TY Red 250', but negatively affected the index of FSS. While, in 'Dokia' and 'Pilabi' tomatoes no observed sufficient differences in the improvement of the quality parameters by rootstock.

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