Physiological Aspects, Leaf-nutrient Content and Growth Parameters of some Grafted-pear Rootstocks Grown under Different Soil Types

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Summary

Low average production is an important problem in pear trees in calcareous soils of Iran, which make over 60% of Iranian soils. Therefore, the objective of this study was to study the effects of three soil types with different levels of soil lime on physiological aspects, leaf-nutrient content, and growth parameters of some grafted-pear rootstocks. The field experiment was based on a split factorial layout in a randomized complete block design with three replications and was carried out in Horticulture Research Station during the two growing seasons, 2015 and 2016. Three field-collected soil types were used as the main plots: less lime silt-loamy, fairly lime silt-loamy and lime rich clay loamy and three grafted-pear rootstocks (OHF69, Pyrodwarf and seedling rootstock) grafted with 'Daregazi', 'Louise Bonne' and 'William Duchess' scions were assigned in sub-plots. Based on the combined analysis, all interactions among soil types and grafted-pear rootstocks were significant for all studied parameters (except of SPAD-Value and leaf area in 2015 study and chlorophyll fluorescence parameters including FO and FV/FM in 2016 study). The results of this research showed different responses according to studied various scion/rootstocks combinations in soil type treatments. In the present work, the best graft combination for lime rich clay loamy (silt 30%, sand 40%, clay 28% and lime 14.6%) soils is OHF69 rootstock grafted with 'Louise Bonne' in each two years of study (2015 and 2016).

Key words

soil type, levels of soil lime, grafted-pear rootstocks

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Introduction

Iran is located in the arid and semi-arid region of the world. Furthermore, a large proportion of the cultivated lands in the country consist of calcareous soils. Such soils have high levels of calcium and pH that cause growth reduction, lower yield, nutrient deficiencies and leaf-chlorosis (Dilmaghani *et al*., 2012; Gharaie, 2009). According to recent statistics, an area of 14,502 hectares in Iran is under pear culture with an average annual production of about 145,123 tones (FAO, 2011). This average production is also low; because of most planted pear trees are located in high lime soils (such as Tehran, Isfahan, Alborz etc.). The soils of these regions are calcareous in nature. High pH and carbonate levels are common characteristics of these soils. In addition the amount of lime soils in these regions is variable in a range between 10 to 44%. Physiological aspects of pear trees are negative affected by 14% of soil lime. The response varies according to pear scion/various rootstocks combinations (Jacobs & Cook, 2003; Bosa *et al*., 2014). These relationships are important from a horticultural point of view, because they provide a basis for selecting the best graft combination for particular environmental conditions. The lack of knowledge of the compatibility of grafted-pear rootstocks with different soil conditions in Iran is considered a major problem in Iranian horticulture. Therefore, the aim of this study was to assess the differential response of individual pear scion/rootstocks to three different soil types (less lime silt-loamy; fairly lime silt-loamy, and lime rich clay loamy) in terms of growth, leaf morpho–physiology and leaf nutrition concentration traits when grown under field conditions with different soil lime levels.

Material and methods

Plant material, soil treatments and experimental design

'Daregazi', 'Louise Bonne' and 'William Duchess' scions were chip-budded at a height of 10 cm on 1-year-old three rootstocks (OHF69, Pyrodwarf and a seedling of *Pyrus communis*, obtained from local wild pear genotype), were planted in three different soil types of horticulture research station of Kamalabad/Karaj in January 2015. The trial for evaluation of different grafted-pear rootstocks was set up on a three soil types (less lime silt-loamy, lime, fairly silt-loamy and lime rich clay loamy), in the experience station of Kamalabad, in Karaj province, Iran. Soil of horticultural experience station of Kamalabad consisted of four soil series (soil series 1=Xeric Torriorthents, mixed (calcareous) thermic; soil series 2=Xeric haplocalcids, mixed, thermic; soil series 3=Xerifluventic haplocalcids, mixed, thermic; soil series 4=Xeric haplocampids, fine, mixed, thermic) (Table I). These soil series at depth of 0-30 cm consisted of different soil lime levels, according to detailed excavation reports by Fallahi (1998). The selected three soils for this trial were from soil series 1, 2 and 3, respectively. Chemical properties of soil at the beginning of experiment were determined following ordinary methods of soil analysis (Walkley & Black, 1934; Drouineau, 1942; Isaac & Kerber, 1971; Olsen & Sommers, 1982). Experiment was laid out in a randomized complete-block design with three blocks for each studied soil trial, individually. Each soil trial consisted of three blocks with three rows. Each row contained 27 grafted-pear rootstocks. Data were collected from the nine central trees in each block, using the remaining trees as guards. The plants grafted on the OHF69 and Pyrodwarf rootstocks were spaced at 3 m x 1 m intervals, and those grafted on the seedling were spaced at 3m x 3m, headed at 80 cm and trained according to the modified leader system.

Irrigation, fertigation, and weed, disease and insect control

Irrigation of the plants was carried out using a computerized drip irrigation system. Irrigation frequency was two times per week from May to October each season of two studied years (2015 and 2016) according to regional recommendations using class-A pan. Each treatment (grafted-pear rootstocks in each studied soil series) received the same total amount of water in each season. All treated trees were similarly fertigated with essential minerals using the fertigation method. Weed, disease, and insect control was managed using the practices that were commonly used for commercial production, and all the treatments were under the identical management.

Data collection on physiological aspects, leaf-nutrient content and growth parameters

In July 2015 and 2016, leaves were sampled from all grafted pear rootstocks. For leaf area, and also leaf-nutrient content, five leaves were sampled per plant. The mean leaf area of individual plant was determined by portable leaf area meter LI – 3000 (Li-Cor, USA). The plant chlorophyll was indirectly measured during the experimental period using a portable SPAD-502 device (Minolta Camera CO, Ltd., Japan) in two young expanded leaves with two readings per leaf. Chlorophyll fluorescence parameters (F0: minimum fluorescence; FM: maximum fluorescence and value of photochemical capacity of photosystem 2 (FV/FM) were measured with a portable Fluorimeter (Plant Efficiency Analyser, PEA, Hansatech Instruments Ltd., England). Prior to the measurements, the leaves were kept in the dark for 30 min using cuvettes. A 5-s light pulse at 400 $\mu mol\ m^{-2}\ s^{-1}$ was used. The nitrogen content was estimated by the Kjeldahl method. Ca, Mg, Fe, Zn and B were determined by atomic absorption spectrophotometry (AOAC, 2016). Phosphorous (P) was analyzed by the molybdovanadate method using a Jenway 6305UV–VIS. Potassium (K) was analyzed by flame photometry using a Jenway PFP7 flame photometer (Jenway, Essex, UK). Plant growth was measured in July 2015 and 2016. The growth variables included shoot diameter and shoot length. Shoot diameter 20 cm

Table 1. Chemico-physical properties of the tested soils

Soil type	Ava.K-soil	Ava.P-soil	Soil pH	EC	Soil particle (mm)			SP	OC	N-soil	Lime	Soil texture
	(mg kg^{-1})			(dS/m)	Sand 2-0.05	Silt 0.05-0.002	Clay <0.002	%				
Soil 1	740	5	8	0.8	17	55	28	39	0.60	0.07	10.5	Silt-loamy
Soil 2	580	17.4	8.1	0.69	20	48	32	38	0.30	0.12	12.9	Silt-loamy
Soil 3	570	10	7.9	1.9	44	30	28	38	0.18	0.05	14.6	Loamy

EC= Electrical conductivity; SP= Saturation percentage; Organic matter=OC; T.N.V= Total neutralizing value (soil lime) above the graft union was measured with digital calipers in July of each studied year (2015 and 2016).

Weather condition

Horticulture Research Station of Kamalabad (Karaj, Iran) is located at 50°52' N longitude and 35°52' E latitude and has a semi-arid climate (cold during the winter and hot and dry in the summer). The climate is characterized by mean annual precipitation of 250 mm and mean annual temperature of 14°C.

Statistical analysis

The statistical evaluation was done by using analysis of variance (ANOVA). SAS statistic computer system was used to calculate the surveyed data and means were evaluated using Duncan's multiple range test at p = 0.05. The relationships between studied parameters were evaluated by Pearson's correlation coefficients at p ≤0.05.

Results

Statistical analysis of data for both studied years indicated that the soil type has significant effect on the behavior of most studied parameters of grafted-pear rootstocks. The interaction between soil type and grafted-pear rootstocks was also significant for all of the tested characteristics, except for leaf chlorophyll content in 2016 and chlorophyll fluorescence parameter (FO) in 2015 (Table 2). The following observations for physiological aspects, leaf-nutrient content and growth parameters of three grafted-pear rootstocks (OHF69, Pyrodwarf and one seedling rootstock) grafted with 'Daregazi', 'Louise Bonne' and 'William Duchess' grown under different soil types were described in detail each year.

Physiological aspects

Leaf chlorophyll content (SPAD-Value)

2015 study. The OHF69 rootstock grafted with 'Daregazi' grown in soil type 1 (less lime silt-loamy) showed the highest value of leaf chlorophyll content (47.33). The lowest value of leaf chlorophyll content (33.35) was observed with the Pyrodwarf rootstock grafted with 'Daregazi' scion grown in soil type 1 (Fig. 1). Results from correlation analysis showed that there were no negative significant coefficient between SPAD values and total neutralizing value (soil lime) in all of studied grafted pear rootstocks in 2015 (Table 3).

2016 study. The Pyrodwarf rootstock grafted with 'Daregazi' grown in soil type 3 (lime rich clay loamy) showed the highest value of leaf chlorophyll content (44.1). The lowest value of leaf chlorophyll content (28.86) was observed with the seedling rootstock grafted with 'Louise Bonne' scion grown in soil type 3 (Fig.1). Results from correlation analysis showed that there was no negative significant correlation between SPAD values and total neutralizing value (soil lime) in all of studied grafted pear rootstocks in 2016 (Table 3).

Table 2. Significance of single and combined effects of factors for the physiological aspects, plant nutrition concentration and growth parameters of studied grafted-pear rootstocks grown under different soil type in two studied years (2015 and 2016)

S.O.V	DF	SPAD-value		Chlorophyll fluorescence parameters						Leaf area (cm²)		Shoot diameter (mm)		Shoot length (cm)	
				F0		FM		FM/FV							
										Sampling time: July					
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Scion (a)	2	6.87ns	177.94**	177.94**	4601.96**	243106.54**	38642.26**	0.0003ns	0.002*	3065.21**	497.43**	149.46**	67.79**	5566.96**	24979.92**
Rootstock (b)	2	72.16**	83.74**	83.74**	21482.24**	365900.91**	176123.93**	0.002**	0.01**	287.70ns	57.00ns	149.50**	109.07**	9847.34**	4664.80**
Soil type (c)	4	118.70**	39.69ns	39.69ns	22831.28**	703595.87**	254157.53**	0.001*	0.003**	1268.23**	608.06**	87.34**	122.99**	736.42**	187.17ns
a*b	2	18.16ns	32.123ns	32.123ns	4502.62**	30699.11ns	65209.47**	0.002**	0.002**	611.40*	615.33**	27.97**	47.19**	2352.19**	2305.79**
a*c	4	56.34**	107.47**	107.47**	6108.16**	245928.5**	79046.02**	0.003**	0.002**	2061**	74.23ns	4.11ns	55.78**	643.31**	7000.09**
b*c	2	72.55**	39.29ns	39.29ns	20261.45**	509111.4*	182360.95**	0.008**	0.01**	2534.10**	186.1**	29.73**	33.07**	1734.42**	1695.46**
a*b*c	4	38.60**	19.58ns	19.58ns	5126.25**	131000.51**	53869.04**	0.002**	0.001ns	221.59ns	284.09**	9.82**	21.87**	1392.01**	505.45*
CV (%)		8.11	14.69	7.36	5.76	14.28	6.54	2.07	2.65	30.25	31.60	14.30	17.26	12.72	12.89

S.O.V	DF	Leaf-nutrient content															
		N		P		K		Ca		Mg		B		Fe		Zn	
		%										M gKg⁻¹					
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Scion (a)	2	1.18*	2.23**	1.13**	0.17**	7.24**	3.04**	0.22**	0.37**	1.31**	0.17*	0.17*	308.40**	922.64**	85.59**	85.59**	104.76*
Rootstock (b)	2	3.588**	2.20**	1.96**	0.29**	6.03**	1.14*	1.34**	0.50**	0.05ns	0.22**	0.22**	147.99**	2780.00**	103.27**	103.27**	340.87**
Soil type (c)	4	2.65**	1.073**	0.78**	0.06**	1.97**	0.85*	0.01**	0.08ns	0.73**	0.06ns	0.06ns	43.45*	215.88**	57.22**	57.22**	83.10*
a*b	2	7.98**	1.28**	0.74**	0.22**	14.58**	1.45**	1.42**	0.08ns	0.63**	0.43**	0.43**	103.05**	2854.95**	77.30**	77.30**	330.36**
a*c	4	0.26ns	0.33**	0.74**	0.13**	0.65**	1.76**	0.41**	0.13*	0.21*	0.27**	0.27**	108.95**	47.06ns	6.52ns	6.52ns	198.45**
b*c	2	1.03*	0.68**	0.60**	0.04**	6.68**	0.90*	0.25**	0.07ns	0.15ns	0.19**	0.19**	55.75**	136.27**	44.56**	44.56**	42.49ns
a*b*c	4	1.68**	0.40**	0.57**	0.09**	1.01**	1.11**	0.32**	0.11*	0.34**	0.08*	0.08*	42.17**	202.97**	44.81**	44.81**	52.004*
CV (%)		20.63	5.64	18.57	31.01	15.17	16.94	21.96	25.82	43.53	33.11	4433	20.38	18.23	13.33	22.75	21.94

SPAD-value= leaf chlorophyll; FO= Minimum fluorescence; FM= maximum fluorescence; FV/FM= value of photochemical capacity of photo system 2; F-probabilities are indicated by symbols: P*≤0.05; P**≤0.001; ns (no significant).

Table 3. The significant linear regression equation* between studied physiological aspects, leaf-nutrient content, growth parameters and total neutralizing value** of each studied grafted-pear rootstocks in two studied years (2015 and 2016)

2015 study		
'Louise Bonne' *Pyrodwarf		
FO=-2074X+416.7	R^2=0.929	P≤0.001
Shoot length=-36.06x+115.5	R^2=0.677	P≤0.001
Shoot diameter=-2.199x+16.44	R^2=0.776	P≤0.001
Leaf-N content=-0.32x+2.23	R^2=0.99	P≤0.001
Leaf-K content=-1.50x+5.55	R^2=0.99	P≤0.001
Leaf-Fe content=-6.93x+38.68	R^2=0.82	P≤0.001
Louise Bonne *seedling		
FM=-0.258.9x+2040	R^2=0.962	P≤0.001
leaf-P content=0.33x+1.54	R^2=0.63	P≤0.05
'William Duchess'*Seedling		
FO=-24.33x+420.7	R^2=0.264	P≤0.05
FM=-211.2x+1983	R^2=0.48	P≤0.05
Shoot diameter=-1.157x+13.83	R^2=0.478	P≤0.05
Leaf-N content=-0.051x+0.53	R^2=0.87	P≤0.001
Leaf-P content=-1.19x+4.05	R^2=0.99	P≤0.001
Leaf-Ca content=-0.021x+0.26	R^2=0.87	P≤0.001
Leaf-Mg content=-0.057x+0.73	R^2=0.93	P≤0.001
Leaf-B content=-0.18x+1.96	R^2=0.99	P≤0.001
Leaf-Fe content=-1.05x+12.53	R^2=0.99	P≤0.001
Leaf-Zn content=-1.50x+18	R^2=0.99	P≤0.001
'William Duchess'*OHF69		
FM=-192.1x+2020	R^2=0.480	P≤0.05
FO=-40.07x+461.5	R^2=0.651	P≤0.001
Leaf-Mg content=-0.51x+1.61	R^2=0.87	P≤0.001
'William Duchess'* Pyrodwarf		
Shoot length=-15.28x+83.98	R^2=0.65	P≤0.001
Leaf-N content=-1.46x+6.10	R^2=0.99	P≤0.001
Leaf-P content=-0.49x+198	R^2=0.99	P≤0.001
Leaf-K content=-1.42x+5.10	R^2=0.75	P≤0.001
Leaf-Ca content=-0.59x+2.65	R^2=0.99	P≤0.001
Leaf-Mg content=-0.05x+006	R^2=0.68	P≤0.001
Leaf-B content=-0.03x+1.05	R^2=0.97	P≤0.001
Leaf-Zn content=-12.36x+410	R^2=0.61	P≤0.05
Leaf-Fe content=-13.17x+51.98	R^2=0.80	P≤0.001
'Daregazi'*Seedling		
Shoot diameter=-1.862x+17.44	R^2=0.508	P≤0.05
'Daregazi'*OHF69		
Shoot length=-15.16x+131.8	R^2=0.52	P≤0.05
Leaf-P content=-0.40x+1.60	R^2=065	P≤0.001
Leaf-Ca content=-0.46x+1.8	R^2=0.52	P≤0.001

2016 study		
'William Duchess'*Seedling		
FV/FM=-0.016x+0.795	R^2=0.961	P≤0.001
Leaf-K content=-0.12x+3.30	R^2=0.69	P≤0.001
Leaf-B content=-0.83x+22.38	R^2=0.87	P≤0.001
Leaf-Fe content=-0.66x+18.42	R^2=0.53	P≤0.001
Leaf-Zn content=-1.04x+3364	R^2=0.87	P≤0.001
'William Duchess'*OHF69		
FM=-88.09Xx1172	R^2=0.439	P≤0.001
Leaf-P content=-0.522x+0.29	R^2=060	P≤0.05
Leaf-K content=-0.30x+3.76	R^2=50	P≤0.05
Leaf-B content=-6.55x+25.41	R^2=0.64	P≤0.05
'William Duchess'* Pyrodwarf		
Leaf-N content=-0.37x+343	R^2=0.92	P≤0.001
Leaf-P content=-0.44x+1.52	R^2=0.91	P≤0.001
Leaf-K content=-037x+3.62	R^2=0.94	P≤0.001
Leaf-Ca content=-0.04x+1.02	R^2=0.68	P≤0.001
Leaf-Mg content=-0.16x+005	R^2=0.75	P≤0.001
Leaf-Fe content=-3.76x+33.8	R^2=0.65	P≤0.001
'Louise Bonne' *seedling		
FV/FM=-0.047x+0.832	R^2=0.940	P≤0.001
leaf-Fe content=2.29x+2.38	R^2=0.47	P≤0.05
'Daregazi'*OHF69		
Shoot length=-46.62x+239.8	R^2=0.909	P≤0.001
'Daregazi'* Pyrodwarf		
Shoot length=-31.51x+165.1	R^2=0.705	P≤0.001
Shoot diameter=-2.720x+16.63	R^2=0.760	P≤0.001
Shoot diameter=-6.266x+29.30	R^2=0.771	P≤0.001
leaf-Zn content=-8.23x+35.84	R^2=0.60	P≤0.05
'Daregazi'*Seedling		
Leaf-Ca content=-0.15x+1.025	R^2=0.92	P≤0.001
Leaf-Mg content=-0.35x+1.51	R^2=0.79	P≤0.001
Leaf-Fe content=-7.95x+35.52	R^2=0.96	P≤0.001
Lleaf-Zn content=-1.80x+18.97	R^2=0.61	P≤0.001

*Number of observation=9; ** x= total neutralizing value (soil lime)

Chlorophyll fluorescence parameters

2015 study. The Pyrodwarf rootstock grafted with 'Daregazi' grown in soil type 2 (fairly lime silt-loamy) showed the highest value of FV/FM (0.79). The lowest value of FV/FM (0.69) was observed with the seedling rootstock grafted with 'Daregazi' scion grown in soil type 2 (Fig. 2). Results from correlation analysis showed that there was no negative significant correlation between chlorophyll fluorescence parameter (FV/FM) and total neutralizing value (soil lime) in all of studied grafted pear rootstocks in 2015. However, chlorophyll fluorescence parameters including FO and FM showed negative and significant correlation with soil lime in 'Louise Bonne'

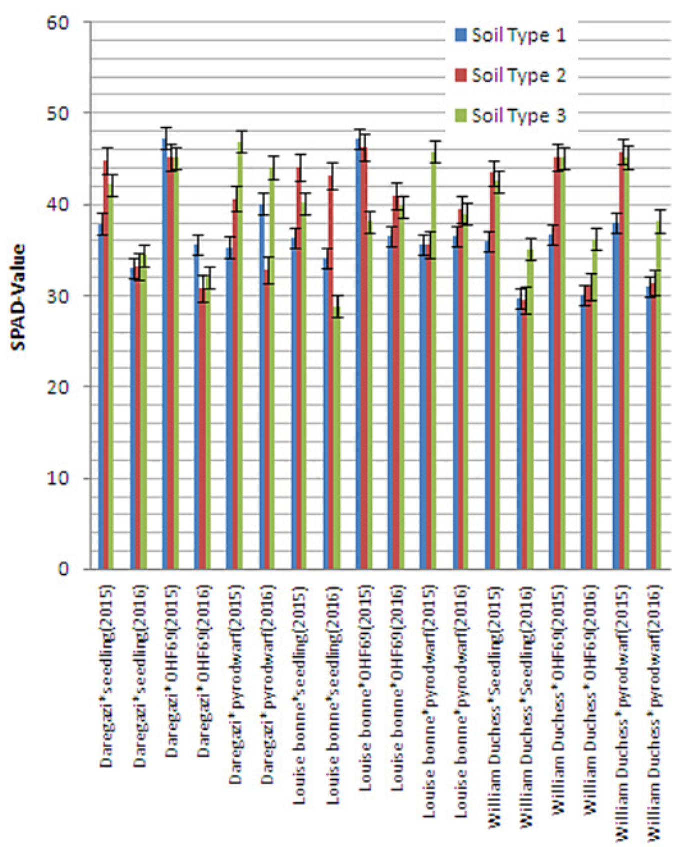

Figure 1. Chlorophyll content (SPAD-Value) of fully expanded leaves of the studied grafted-pear rootstocks (OHF69, Pyrodwarf and seedling rootstock grafted with 'Daregazi', 'Louise Bonne' and 'William Duchess' scions) for different soil types (less lime silt-loamy, lime, fairly silt-loamy and lime rich clay loamy), as estimated by SPAD values in two studied years (2015 and 2016). Vertical bars indicate SE (n=3)

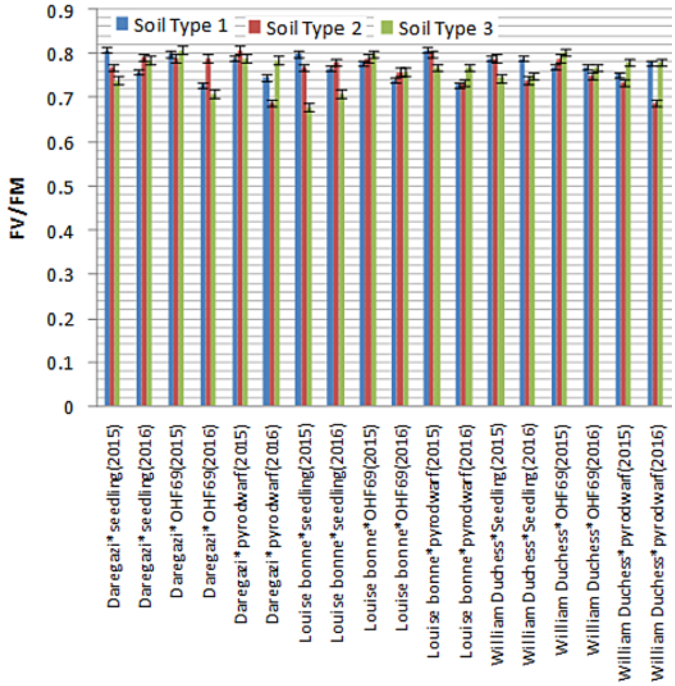

Figure 2. Chlorophyll fluorescence parameter (FV/FM) of fully expanded leaves of the studied grafted-pear rootstocks (OHF69, Pyrodwarf and seedling rootstock grafted with 'Daregazi', 'Louise Bonne' and 'William Duchess' scions) for different soil types in two studied years (2015 and 2016). Vertical bars indicate SE (n=3)

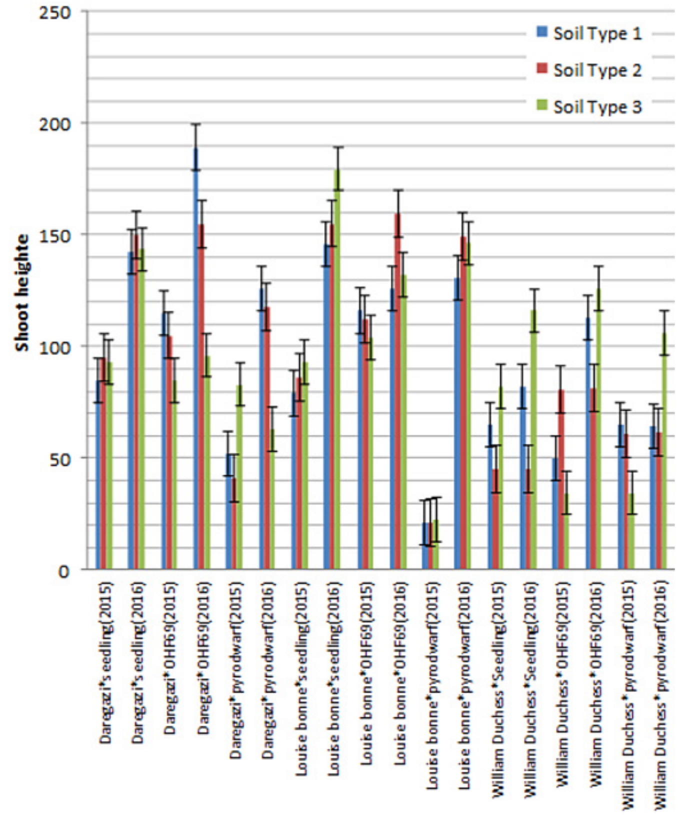

Figure 3. Shoot length of the studied grafted-pear rootstocks (OHF69, Pyrodwarf and seedling rootstock grafted with 'Daregazi', 'Louise Bonne' and 'William Duchess' scions) for different soil types in two studied years (2015 and 2016). Vertical bars indicate SE (n=3)

scion grafted on seedling and Pyrodwarf rootstocks and as well, this behavior was also observed in 'William Duchess' scion grafted on seedling and OHF69 rootstocks (Table 3).

2016 study. The Pyrodwarf rootstock grafted with 'Louise Bonne' grown in soil type 1 (less lime silt-loamy) showed the highest value of FV/FM (0.81). The lowest value of FV/FM (0.69) was observed with the seedling rootstock grafted with 'Louise Bonne' scion grown in soil type 3 (lime rich clay loamy) (Fig. 2). There was negative significant correlation between soil lime and chlorophyll fluorescence parameter (FV/FM) in 'William Duchess' scion grafted on seedling rootstock. Similarly, this behavior was also observed in 'Louise Bonne' scion grafted on seedling rootstock. Chlorophyll fluorescence parameters including FM showed negative and significant correlation with soil lime in 'William Duchess' scion grafted on OHF69 rootstock (Table 3).

Growth parameters

2015 study. The highest (20.13 mm) and lowest value (4.96 mm) of shoot diameter were observed in OHF69 rootstock grafted with 'Louise Bonne' and 'William Duchess' scions grown in soil type 2 (fairly lime silt-loamy) and 3 (lime rich clay loamy), respectively. The highest value of shoot length (116 cm) was observed in OHF69 rootstock grafted with 'Louise Bonne' in soil type 1(less lime silt-loamy). However, the lowest value of shoot length (21 cm) was observed with the Pyrodwarf rootstock grafted with 'Louise Bonne' in soil types 2 and 3 (Figures 3 and 4). Results from correlation analysis showed that there were no negative significant coefficient between growth parameters (including shoot diameter and shoot height) and total neutralizing value (soil lime) in Pyrodwarf rootstock grafted with 'Daregazi', OHF69 rootstock grafted with 'Louise Bonne' and 'William Duchess' and also seedling rootstock grafted with 'Louise Bonne' scion. In Table 3 is shown negative significant coefficient between growth parameters and total neutralizing value in all other observed grafted-pear rootstocks in 2015.

2016 study. The highest (21.33 mm) and lowest value (7.31mm) of shoot diameter were observed in OHF69 rootstock grafted with 'Louise Bonne' and Pyrodwarf rootstock grafted with 'William Duchess' grown in soil type 1 (less lime silt-loamy) and 2 (fairly lime silt-loamy), respectively. The highest value of shoot length (189.25 cm) was observed in OHF69 rootstock grafted with 'Daregazi' in soil type 1. However, the lowest value of shoot length (45.27 cm) was observed with the seedling rootstock grafted with 'William Duchess' in soil types 2 (Figures 3 and 4). Results from correlation analysis showed that there was no negative significant correlation between growth parameters and total neutralizing value in all of studied grafted pear rootstocks, except for OHF69 rootstock grafted with 'Daregazi' and 'Louise Bonne' scions and furthermore Pyrodwarf rootstock grafted with 'Daregazi' in 2016.

Leaf-nutrient content

Observations and evaluations of leaf-nutrient content were made during two studied yeas (2015 and 2016) for each grafted-pear rootstocks as follows:

Seedling rootstock grafted with 'Daregazi'

The results showed that leaf-nutrient content of seedling rootstock grafted with 'Daregazi' was not significantly influenced by studied soil types in 2015 study, except for leaf-Fe and leaf-Zn

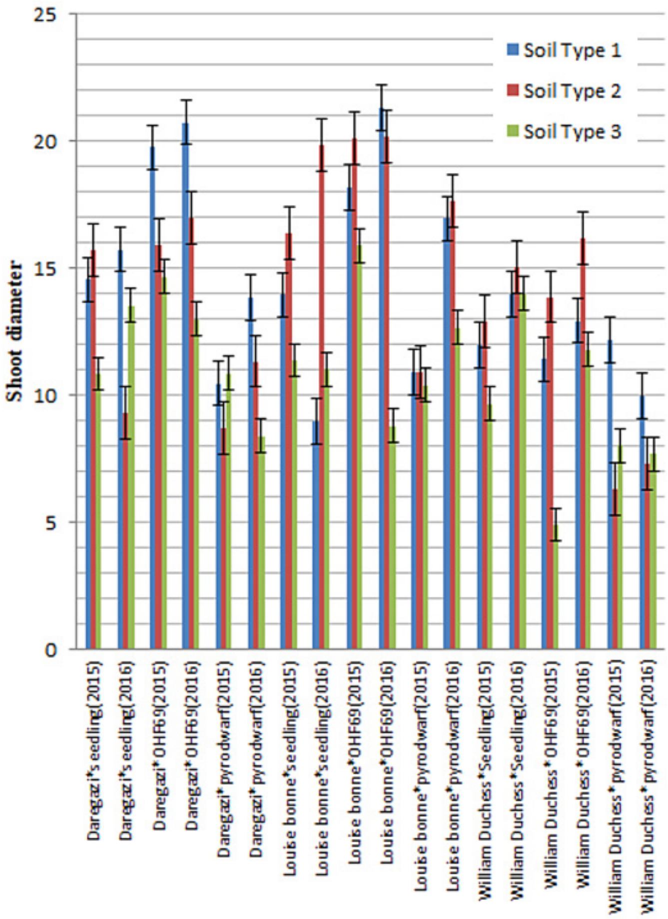

Figure 4. Shoot diameter of the studied grafted-pear rootstocks (OHF69, Pyrodwarf and seedling rootstock grafted with 'Daregazi', 'Louise Bonne' and 'William Duchess' scions) for different soil types in two studied years (2015 and 2016). Vertical bars indicate SE (n=3)

contents. However, it was observed that soil type had a significant effect on all studied leaf-nutrient contents in 2016 study, except for leaf-P content (Table 4). Results from correlation analysis showed that there was no negative significant correlation between studied leaf-nutrient content and total neutralizing value (soil lime) in this grafted pear rootstock in 2015 study. Though, in 2016 study there was a negative correlation between soil lime and leaf-Ca, leaf-Mg, leaf-Fe and leaf-Zn at P≤0.001 (Table 3).

OHF69 rootstock grafted with 'Daregazi'

The results showed that leaf nutrient contents of OHF69 rootstock grafted with 'Daregazi' were not significantly influenced by studied soil types in 2015 study, except for leaf-P, leaf-Fe and leaf-Zn contents. Conversely, it was observed that soil type had a significant effect on all studied leaf-nutrient content in 2016 study, except for leaf-P content (Table 4). Results from correlation analysis showed that there were negative significant correlations between leaf-P, leaf-Ca contents and total neutralizing value (soil lime) for this grafted pear rootstock at P≤0.001 in 2015 study. Also, in 2016 study there was a negative correlation between soil lime and leaf-P content at P≤0.001 (Table 3).

Pyrodwarf rootstock grafted with 'Daregazi'

The results showed that leaf-nutrient contents of Pyrodwarf rootstock grafted with 'Daregazi' were not significantly influenced by studied soil types in 2015 study, except for leaf-K, leaf-Ca and leaf-Mg contents in 2015 study. Likewise, there was no significant difference between leaf nutrient contents on three studied soil types except for leaf-B and leaf-Zn contents in 2016 study (Table 4). Results from correlation analysis showed that there was no negative significant correlation between studied leaf-nutrient content and total neutralizing value (soil lime) in this grafted pear rootstock in 2015 study. Also, in 2016 study there were no negative significant correlation between soil lime and leaf-nutrient content, except for leaf-Zn content (Table 3).

Seedling rootstock grafted with 'Louise Bonne'

The results showed that leaf-nutrient content of seedling rootstock grafted with 'Louise Bonne' was not significantly different between studied soil types in 2015 study, except for leaf-P, leaf-K and leaf Ca-contents. Likewise, there were no significant differences between studied soil types and leaf nutrient content, except for leaf-N, leaf-P, leaf-Ca, and leaf-Zn contents in 2016 study (Table 4). Results from correlation analysis showed that there were no negative significant correlation between studied leaf-nutrient content and total neutralizing value (soil lime) in this grafted pear rootstock in both study years, except for leaf-P content in 2015 study and leaf-Fe content in 2016 study (Table 3).

OHF69 rootstock grafted with 'Louise Bonne'

The results showed that leaf-nutrient content of seedling rootstock grafted with 'Louise Bonne' was not significantly different between studied soil types in both study years, except for leaf-Mg content in 2015 study and leaf-N content in 2016 study (Table 4). Results from correlation analysis showed that there was no negative significant correlation between studied leaf-nutrient content and total neutralizing value (soil lime) for this grafted pear rootstock in both study years (Table 3).

Pyrodwarf rootstock grafted with 'Louise Bonne'

The results showed that leaf-nutrient content of Pyrodwarf rootstock grafted with 'Louise Bonne' was significantly different between studied soil types in 2015 study, except for leaf-Ca and leaf-Mg contents in 2015 study. However, it was observed that soil type had a significant effect on leaf-N, leaf-Mg and leaf-B contents in 2016 study (Table 4). Results from correlation analysis showed that there were negative significant correlations between studied soil lime and leaf-N, leaf-K, and leaf-Fe contents at P≤0.001 in 2015 study. Controversy, there was no negative significant correlation between soil lime and studied leaf-nutrient content in 2016 study (Table 3).

Seedling rootstock grafted with 'William Duchess'

The results showed that leaf-nutrient content of seedling rootstock grafted with 'William Duchess' was significantly different between studied soil types in 2015 study, except for leaf-K and leaf-Zn contents in 2015 study. However, it was observed that soil type had a significant effect on leaf-K, leaf-B, leaf-Fe and leaf-Zn contents in 2016 study (Table 4). Results from correlation analysis showed that there were negative significant correlations between soil lime and all studied leaf-nutrient contents, except for leaf-K content in 2015 study. Moreover, there were negative significant correlations between soil lime and leaf-K, leaf-B, leaf-Zn and leaf-Fe contents in 2016 study (Table 3).

OHF69 rootstock grafted with 'William Duchess'

The results showed that leaf-nutrient content of OHF69 rootstock grafted with 'William Duchess' was not significantly different

Table 4. Mean comparison for leaf nutrient content of studied grafted-pear rootstocks grown under different soil type in two studied years (2015 and 2016)

Soil type	Leaf-nutrient content															
	N		P		K		Ca		Mg		B		Fe		Zn	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
	%DM								mg Kg^{-1}DM							
	Daregazi*seedling															
1	1.76a	0.14b	0.81a	0.18a	2.81a	3.83b	0.82a	0.89a	0.66a	1.26a	6.61a	8.82c	32.93a	26.62a	15.94b	16.35b
2	1.11a	1.66a	1.16a	0.14a	2.63a	4.60a	0.91a	0.73b	0.37a	0.60b	4.08a	13.83b	23.39c	21.54b	13.38c	17.01a
3	1.46a	1.37b	0.99a	0.32a	2.72a	4.88a	0.87a	0.60c	0.55a	0.55b	5.39a	15.14a	28.61b	10.72c	18.31a	12.75c
	Daregazi*OHF69															
1	2.76a	1.90a	0.96a	0.19a	2.80a	2.86ba	0.71a	0.57b	0.7a	0.62a	7.36a	8.61ba	39.15a	16.48a	31.39a	30.90a
2	1.46a	1.73b	0.96a	0.14a	2.72a	4.89a	0.87a	1.45a	0.55a	0.26a	5.41a	3.33b	28.61ba	17.95a	18.31b	24.85a
3	1.18a	1.20c	0.59b	0.13a	2.51a	2.16b	1.34a	1.01ba	0.51a	0.45a	4.52a	12.47a	24.72b	17.83a	7.21c	22.67a
	Daregazi*Pyrodwarf															
1	1.94a	1.73a	0.42a	0.19a	3.03a	3.65a	0.84c	0.85a	1.50a	0.84a	10.23a	17.50a	42.65a	19.66a	18.53a	29.54a
2	1.81a	1.82a	0.5a	0.10a	2b	3.37a	1.01b	1.03a	0.85a	0.82a	12.00a	4.86b	44.00a	12.53a	16.01a	15.53b
3	1.71a	1.42a	0.52a	0.34a	1.48b	3.02a	1.47a	1.01a	0.002b	0.54a	13.77a	16.63a	45.37a	21.31a	14.39a	13.08b
	Louise Bonne *seedling															
1	3.24a	1.640c	1.26a	0.26a	3.21c	3.47a	1.58a	0.50ba	0.89a	0.65a	9.98a	17.63a	19.92a	18.67a	21.42a	13.73c
2	2.55a	2.004a	0.62b	0.11b	3.91b	3.19a	1.09b	0.68a	0.91a	0.56a	10.52a	21.34a	23.42a	14.67a	25.26a	26.16a
3	1.87a	1.80b	0.83ba	0.15ba	4.61a	2.97a	0.58c	0.31b	0.89a	0.25a	11.09a	18.00a	26.93a	14.09a	29.11a	15.12b
	Louise Bonne *OHF69															
1	1.60a	1.42b	0.71a	0.16a	3.02a	3.23a	0.46a	0.72a	0.66ba	0.54a	5.94a	17.49a	33.35a	15.84a	22.02a	26.49a
2	2.03a	2.04a	1.05a	0.14a	2.05a	2.52a	0.74a	0.69a	1.02a	0.94a	18.81a	16.00a	20.87a	17.48a	11.45a	38.45a
3	2.77a	0.63c	1.08a	0.15a	3.52a	3.70a	0.68a	0.50a	0.46b	0.82a	12.67a	19.96a	19.98a	16.58a	12.43a	22.07a
	Louise Bonne *Pyrodwarf															
1	1.91a	1.86a	0.47c	0.18a	4.09a	4.15a	0.65a	1.08a	0.96a	0.21b	7.92a	7.99b	31.73a	18.66a	28.45c	14.75a
2	1.61b	1.82b	0.49b	0.15a	2.59b	2.87a	0.82a	0.75a	0.99a	0.71a	5.21b	17.16a	24.86ba	19.53a	36.48b	22.13a
3	1.28c	1.47c	0.51a	0.22a	1.09c	3.24a	0.99a	0.84a	1.02a	0.63a	2.48c	12.96ba	17.86b	16.79a	44.48a	26.27a
	William Duchesse*Seedling															
1	0.48a	1.77a	2.87a	0.12a	0.18a	3.17a	0.24a	0.76a	0.69a	0.79a	1.79a	21.63a	11.52a	17.96a	16.51a	32.70a
2	0.42b	1.70a	1.66b	0.14a	0.17a	3.07b	0.22b	0.72a	0.63b	0.76a	1.60b	20.56b	10.38b	16.73b	14.88a	31.39b
3	0.38c	1.70a	0.49c	0.12a	0.16a	2.92c	0.20c	0.73a	0.58c	0.73a	1.43c	19.96b	9.43c	16.64b	13.52a	30.63c
	William Duchesse*OHF69															
1	1.58a	1.64a	0.49c	0.24a	3.31c	3.36a	0.68a	0.79a	1.10a	0.52a	4.05a	21.70a	60.39a	17.37b	16.52a	22.24a
2	1.64a	1.51a	0.69b	0.17a	3.82b	3.36a	0.73a	0.63a	0.59b	0.57a	5.17a	6.64c	67.46a	17.74b	16.52a	24.20a
3	2.14a	1.64a	0.91a	0.14a	4.33a	2.76a	0.79a	0.76a	0.09c	0.32a	6.28a	8.60b	74.52a	18.81a	16.51a	24.53a
	William Duchesse*Pyrodwarf															
1	4.64a	3.01a	1.49a	1.00a	3.21a	3.21a	2.06a	0.98a	0.013b	0.14b	1.02a	21.02a	35.01a	29.67a	14.01b	17.67a
2	3.18b	2.80b	1.03b	0.81b	3.21a	2.98b	1.47b	0.95a	0.003c	0.20b	0.99b	18.99a	33.29b	27.03ba	9.16a	16.51a
3	1.72c	2.28c	0.52c	0.12c	0.37b	2.48c	0.89c	0.89b	0.12a	0.46a	0.96c	18.86a	8.67c	22.15b	38.72c	17.82a

Means having the same letter(s) within a column are not significantly different at 5% level between studied soil types in both study years, except for leaf-P, leaf-K, and leaf-Mg contents in 2015 study, and leaf-B, leaf-Fe contents in 2016 study (Table 4). Results from correlation analysis showed that there was negative significant correlation between soil lime and leaf-Mg content in 2015 study. Moreover, there were negative significant correlations between soil lime and leaf-K, leaf-B and leaf-P contents in 2016 study (Table 3).

Pyrodwarf rootstock grafted with 'William Duchess'

The results showed that leaf-nutrient content of Pyrodwarf rootstock grafted with 'William Duchess' was significantly different between studied soil types in both study years, except for leaf-B and leaf-Zn contents in 2016 study (Table 4). Results from correlation analysis showed that there were negative significant correlations between soil lime and all studied leaf-nutrients in both study years, except for leaf-B and leaf-Zn in 2016 study (Table 3).

Discussion

Calcareous soils are common in many arid and semi-arid regions of Iran and they affect more than 60% of the soils. Such soils are identified by the presence of the mineral calcium carbonate ($CaCO_3$ or lime) in the parent material and an accumulation of lime. The soil pH of these soils is usually above 7 and may be as high as 8.5. The lack of knowledge of the compatibility of grafted-pear rootstocks with different soil conditions in Iran is considered a major problem in Iranian horticulture. Several land evaluation studies for different crops in Iran had been reported (Moghimi, 2002; Garkani Negad *et al.,* 2009). These authors agreed that for arid and semiarid lands of Iran, the soil aridity, salinity, and high carbonate content in soils are listed among the most serious limiting factors. In international sources, several authors reported different performances of pear rootstock-scion combinations for certain soil conditions (Lewko *et al*., 2004; Elkins, 2012; Elkins *et al*., 2012; Elkins *et al.,* 2011; Bell *et al*., 2012). Also, Jacobs and Cook (2003) and Bosa *et al.* (2014) reported that physiological aspects, growth parameters and some leaf nutrition content of pear trees are negatively affected by high pH and lime rich clay loamy, although the response varies according to pear scion/various rootstocks combinations. In agreement with above researchers, we have found different responses according to studied various scion/ rootstocks combinations in three soil type treatments. In the present work, responses of OHF69 rootstock grafted with 'Louise Bonne' was better in the lime rich clay loamy (silt 30%, sand 40%, clay 28% and lime 14.6%) than other studied scion/rootstocks combinations. As a result, existing of soil's limiting factors such as higher pH, higher clay content, higher lime soils and also higher electrical conductivity (EC) in soil type 3 (lime rich clay loamy) did not have negative effect on most studied parameters in OHF69 rootstock grafted with 'Louise Bonne' scion. Furthermore, the results showed that soil type had no significant effect on most of studied traits in both years of experiment. Negative correlation between studied parameters and total neutralizing value (soil lime) showed that there were contrasting results year to year for all studied grafted pear rootstocks, except for OHF69 rootstock grafted with 'Louise Bonne' scion. This grafted pear rootstock showed that there were no negative significant correlations between studied traits and total neutralizing value (soil lime) in both study years.

Conclusions

The results of this research showed different responses according to studied scion/ rootstocks combinations (OHF69, Pyrodwarf and seedling rootstock grafted with 'Daregazi', 'Louise Bonne' and 'William Duchess' scions) in three soil type treatments (less lime silt-loamy, fairly lime silt-loamy and lime rich clay loamy). We concluded that use of OHF69 rootstock grafted with 'Louise Bonne scion' is suitable on lime rich clay loamy.

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