Leaf nutrient status of some grafted-pear rootstocks influenced by different soil types

Mitra Mirabdulbaghi (Mirabdulbaghi, M)
Horticultural Science Research Institute (HSRI), Karaj, Iran.

Abstract

Aim of study: Determining leaf nutrient status of some grafted-pear rootstocks grown under different calcareous soil types.

Area of study: The Horticultural Research Station of Kamalabad, Karaj, Iran.

Material and methods: Leaf mineral element concentrations were determined in 2015, 2016, 2017, and 2018. Leaf sampling was carried out about 90 days after full bloom. The N-content was estimated by the Kjeldahl method. Total concentration of calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), and boron (B) were also determined by the atomic absorption spectrophotometry, and phosphorus (P) and potassium (K) were analyzed using the flame photometry. The deviation from optimum percentage (DOP) and its correlation with the ΣDOP of macro- and micro-nutrients were used to determine the nutritional status of the studied plants.

Main results: In clay loamy soil pyrodwarf rootstock, which was grafted with 'William Duchess' scion, presented a more suitable balanced nutritional index than other rootstocks/scion combinations. The OHF69 rootstock grafted with 'Daregazi' offered better balanced nutritional values in fairy lime silt-loamy soil, whereas the pyrodwarf rootstock grafted with 'Louise Bonne' scion in less lime silt-loamy soil was found to have higher values than other studied rootstocks/scion combinations in terms of nutrient concentration.

Research highlights: The study determined effective solutions to the field problems of calcium carbonate equivalent which distinctly affect the soil properties related to plant growth. It also revealed the most suitable pear rootstock/scion combinations in different calcareous soil types for orchard establishment in arid and semi-arid regions.

Additional key words: calcium carbonate equivalent; deviation from optimum percentage; ΣDOP index

Abbreviations used: DAFB (days after full bloom); DOP (deviation from optimum percentage index); EC (electrical conductivity); OC (organic matter); SP (saturation percentage); TNV (total neutralizing value).

Authors' contributions: MM conceived, designed, performed the study, analyzed the data, and wrote the manuscript.

Citation: Mitramirabdulbaghi, M (2020). Leaf nutrient status of some grafted-pear rootstocks influenced by different soil types. Spanish Journal of Agricultural Research, Volume 18, Issue 3, e0903. https://doi.org/10.5424/sjar/2020183-15481

Supplementary material: (Table S1) accompanies the paper on SJAR’s website

Received: 18 Jul 2019. Accepted: 30 Jun 2020.

Copyright © 2020 INIA. This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International (CC-by 4.0) License.

Introduction

Pear rootstocks may come from several species of Pyrus or a different genus. Depending on environmental conditions, the response of each pear rootstock and scion combinations is different (Iktinci et al., 2014). While semi-dwarf growing Pyrodwarf and OHF69 rootstocks are generally well-adapted to the high lime content soils, their responses vary drastically according to pear scion/variety rootstocks combinations (Bosa et al., 2014). Calcareous soils are widely spread in arid and semi-arid regions, which have been estimated to comprise over one-third of the world’s land surface area (Taalab et al., 2019). Reported by the Iranian Ministry of Agriculture (2013), the calcareous soils constitute up to 60% of the total area of Iran. The presence of calcium carbonate (CaCO₃) in the parent material and the accumulation of lime are crucial factors that identify calcareous soils. This is recognized conveniently by the effervescence (fizzing) when these soils are treated with diluted acid. The pH of these soils is usually above 7.0 and may be as high as 8.5 and when contain sodium carbonate, their pH may exceed 9.0. In some soils, CaCO₃ can also concentrate into very hard layers, termed as...
'caliche', which is impermeable to water and plant roots (Taalab et al., 2019).

Iran is located in the arid and semi-arid region of the world, like some other countries such as Pakistan, Indus Basin, Iraq, Jordan, and Lebanon in the Near East and also Portugal, Spain, Italy and Greece in southern Europe. A large proportion of the cultivated lands in this country consists of calcareous soils (FAO, 1977). Such soils have high levels of calcium carbonate equivalent and pH that all together contribute to growth reduction, lower yield, nutrient deficiencies, and leaf-chlorosis (Gharaei, 2009; Dilmaghani et al., 2012). According to the recent statistics, an area of 2.632 ha in Iran is under pear culture with an average annual total production of up to 80.576 tones (FAO, 2017). This average of production, however, is still low since the majority of planted pear trees are located in provinces with high lime soils such as Tehran, Alborz, and Isfahan. These soils are calcareous and contain high pH and calcium carbonate equivalent. In addition, the amount of lime soils in these regions is another issue of concern. Although the nutritional status of pear trees is adversely affected by 14% of soil lime, amount of lime in these regions varies in a range of 10 to 14% (Ikinci et al., 2014).

From the point of leaf nutrient status, the Deviation from the Optimum Percentage (DOP) method is an interpretation method to compare nutrient concentrations with the references using a percentage expression (Montañés et al., 1993; Lucena, 1997). This method quantifies the difference between a single nutrient concentration and its reference value, offering the advantage of ranking the requirements or limitations from the most negative to the highest positive nutrient index (Montañés et al., 1993). Furthermore, the sum of the absolute value of the different DOP indexes (Σ DOPi) is a general index which represents the complete nutritional balance of the plant and the severity of an anomalous situation. In this study, the behavior of OHF69, pyrodwarf, and one pear seedling rootstock grafted with 'Daregazi', 'Louise Bonne,' and 'William Duchess' scions is determined in three different soil types (less lime silt-loamy, with 12.9% calcium carbonate equivalent; fairy lime silt-loamy, with 12.9% calcium carbonate equivalent; and clay loamy, with 14.6% calcium carbonate equivalent) in the Alborz province over four years (2015, 2016, 2017, and 2018) using leaf nutritional status and the DOP and ΣDOP indexes about 90 days following full blossom.

Material and methods

Plant materials

The 'Daregazi', 'Louise Bonne' and 'William Duchess' scions were chip-budded at 10 cm height of one-year-old of three rootstocks (OHF69, pyrodwarf and a seedling of Pyrus communis, obtained from local wild pear genotype) in 2013. Then, they were grown under nursery of Cold and Temperate Fruits Research Center. In winter of 2014, the plant materials were transferred to the experimental orchard located at the Kamalabad Research Station, Karaj, Iran and then, were grown under three different soil types (Table 1) over four years (2015 – 2018).

Geographical location and the weather conditions

The Horticulture Research Station of Kamalabad is located in Karaj, Alborz, Iran (50° 52’ East latitude, 35° 52’ north latitude) with 1320 m height above mean sea level, average annual temperature of 14°C, and the average rainfall of 254.5 mm per year.

Soil treatments

The soil of Horticultural Research Station of Kamalabad consists of four soil series: soil series 1=Xeric Torrithents, less loamy, mixed (calcareous) thermic; soil series 2=Xeric haplocalcids, fairy loamy, mixed, thermic; soil series 3=Xerifluventic haplocalcids, clay loamy, mixed, thermic; soil series 4=Xeric haplocambids, fine, mixed,

---

Table 1. Physico-chemical analyses and mineral substance content of the soil of an experimental orchard

| Soil type | Ava. K-soil | Ava. P-soil | Soil pH | EC | Soil particle (mm) | SP | OC | N-Soil | TNV |
|-----------|-------------|-------------|---------|----|-------------------|----|-----|--------|-----|
| A         | 740         | 5           | 8       | 0.8| Sand 2.005        | 17 | 39  | 0.60  | 0.07| 10.5   |
| B         | 580         | 17.4        | 8.1     | 1.9| Silt 0.05-0.002   | 55 | 38  | 0.30  | 0.12| 12.9   |
| C         | 570         | 10          | 7.9     | 1.9| Clay <0.002       | 44 | 38  | 0.18  | 0.05| 14.6   |

[1] Soil types: A, less lime silt-loamy (with 10.5% calcium carbonate equivalent), B, fairy lime silt-loamy (with 12.9% calcium carbonate equivalent) and C, clay loamy (with 14.6% calcium carbonate equivalent). [2] EC= Electrical conductivity. [3] SP= Saturation percentage. [4] OC= Organic matter. [5] TNV= Total neutralizing value (soil lime)
Leaf nutrient status of some grafted-pear rootstocks influenced by different soil types

thermic. These soil series contain different soil lime levels, according to detailed excavation reports by Fallahi (1998). The soil physicochemical analysis (Walky & Black, 1934; Drouneou, 1942; Isaac & Kerber, 1971; Olsen & Sommers, 1982) was analyzed prior to the orchard establishment. Surface soil (0-30cm) variables were tested to clarify the percentages of Total Neutralizing Value (TNV), total N, pH, available K and P (me L⁻¹) and physical parameters such as the percents of silt, sand, clay, and saturation percentage (SP) as well as organic matter content (Table 1).

**Experimental design**

The field experiment was conducted on a split-factorial arrangement based on the randomized complete blocks design (RCBD) with three replications. Measurements were performed at 90 DAFB over four growing seasons including 2015, 2016, 2017, and 2018. Three field-collected soil types were considered as the main plots and three grafted-pear rootstocks were assigned in the sub-plots. 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 with the OHF69, pyrodwarf rootstocks were spaced at 3 m × 1 m intervals, the plants grafted with the seedling were spaced at 3m × 3m, headed at 80 cm and trained according to the modified leader system.

**Cultural treatments**

A computerized drip irrigation system was applied twice per week from May to October using a class-A pan according to the regional recommendations. Each treatment (grafted-pear rootstocks in each studied soil series) received the same amount of water in each growing season. All trees were also fertilized with essential minerals using the same fertigation method. Weed, disease, and pest controlling were carried out using the protocols commonly used for commercial production.

**Analysis of leaf macro- and micro-nutrient composition**

The concentrations of leaf mineral elements were determined at 90 DAFB in 2015, 2016, 2017, and 2018. The samples (10 leaves per plant) were collected from young expanded leaves of all grafted pear rootstocks. The nitrogen content was estimated by the Kjeldahl method. The Ca, Mg, Fe, Zn, and B were determined using an atomic absorption spectrophotometry {Association of Official Analytical Chemists (AOAC) 2016}. Phosphorous (P) was analyzed by the molybdenum method using a Jenway 6305UV–VIS. Potassium (K) was also analyzed by the flame photometry using a Jenway PFP7 flame photometer (Jenway, Essex, UK). The DOP indexes of macro- and micro-nutrients were used to determine nutritional status of fruit trees: normal (DOP=0), deficiency (DOP < 0) and excess (DOP > 0) (Montañés et al., 1993). The DOP index was calculated from the leaf analysis in July of each year by the following mathematical equation:

\[
DOP = \frac{C - 100}{C_{ref}} - 100
\]

where \(C\) is the measured nutrient content in the sample, and \(C_{ref}\) is the major nutrient content considered as optimum, which both values are given on a dry matter basis. The \(C_{ref}\) was taken from optimum values, proposed by Bergmann (1992) for nutrients (Table 2). The \(\Sigma DOP\) for four studied years was obtained by adding the values of the DOP index irrespective of the sign. The larger \(\Sigma DOP\) was the intensity of imbalances among nutrients.

The SAS and SPSS statistical software were used to calculate the surveyed data. The relationships between \(\Sigma DOP\) and DOP indexes of each evaluated soil type over four studied years were also evaluated by the Spearman correlations.

**Results and discussion**

Responses of leaf macro- and micro-nutrient composition of some grafted-pear rootstocks grown under different calcareous soil types over four years (2015, 2016, 2017, and 2018)

Calcareous soils contain high levels of CaCO₃ which affect soil properties related to plant growth such as soil water content and the availability of plant nutrients.

| Critical level |
|----------------|
| Macro-nutrients (%) |
| N   | 2.2 |
| P   | 0.15 |
| K   | 1.2 |
| Mg  | 0.2 |
| Ca  | 1.2 |
| Micro-nutrient (mg/kg) |
| B   | 20 |
| Fe  | 250 |
| Zn  | 20 |
(Elgabaly, 1973). They are common in the world’s arid areas (FAO, 2016) occupying more than 30% of the total earth’s surface, the majority of which are located in the Near East and the southern Europe (FAO, 1977). Their CaCO3 content also varies from just detectable up to 95% (Marschner, 1995). Two-thirds of Iran is arid with Calcic Yermosols and strongly calcareous Haplic Yermosols and also Calcic Xerosols, thus affecting more than 60% of the soil (Dewan & Famouri, 1964). Such soils are identified by the presence of the mineral CaCO3 or lime in the parent materials and the accumulation of lime. The pH of these soils is usually above 7.0 and can be as high as 8.5. Several land evaluation studies for different crops in Iran demonstrated that soil aridity, salinity, and high carbonate content in soils are among the most serious limiting factors in arid and semi-arid lands (Moghim, 2002; Garkani, negadmasi et al., 2009). Variation in leaf nutrient status of pear rootstock/scion combination can be ascribed to the different types of soils applied (Lewko et al., 2004; Elkins et al., 2011, 2012; Bell et al., 2012; Elkins, 2012; Milošević & Milošević, 2016). Reported by Jacobs & Cook (2003) and Bosa et al. (2014), physiological aspects, growth parameters, and some leaf nutrient content of pear trees are negatively regulated by high pH and lime-rich clay loamy, although the response varies according to pear scion/defrosted combinations. In the present study, the effects of three soil types collected from the different soil series of Horticultural Research Station of Kamalabad, Karaj, Iran at the depth of 0-30 cm exhibited significantly different responses of leaf nutrient status in the scion/rootstocks combinations. Moreover, statistical analysis indicated that the factors including year, soil type, and grafted-rootstock, alone and in combination, exhibited significant effects on leaf mineral content (Table 3). These results have also been confirmed by Stassen & North (2005), Erdal et al. (2008) and Marschner (2012), who proved many factors affecting the nutritional status of a plant, which can be classified to three main groups such as soil, environment, and plant factors.

**Leaf mineral nutrients and DOP index**

To determine the best pear scion/rootstocks combinations for different soil types, the DOP and ΣDOP indexes were measured from leaf mineral elements at 90 DAFB. The following observations by the aforementioned indexes were recorded during the 4 years course of experimentation.

**Deviation from optimum percentage (DOP index) and ΣDOP index**

Based on the DOP index, all studied leaf nutrient contents were either lower or higher than optimum level. The grafted pear rootstocks grown under different soil types in all studied years, except for DOPp level {in pear seedling and OHF69 rootstocks in grafting with 'Louise Bonne' in soil type C (lime rich clay loamy), and in pyrodwarf rootstock grafted with 'Louise Bonne' in soil type B (fairy lime silt-loamy)}, the DOPp level {in OHF69 rootstocks in grafting with 'Louise Bonne', pear seedling rootstocks grafted with 'William Duchess' in soil type C (lime rich clay loamy) in 2016}, the DOPMg level {in pyrodwarf and pear seedling rootstocks grafted with 'William Duchess' in soil type B (fairy lime silt-loamy)}, the DOPCa level {in pear seedling rootstocks grafted with 'William Duchess' in soil type A (less lime silt-loamy)}, the DOPn level {'William Duchess' in soil type B (fairy lime silt-loamy), and finally, the DOPK level {OHF69 rootstocks grafted with 'Louise Bonne' in soil type C (lime rich clay loamy)} in 2018 with a DOP value close to the normal level (Table S1 [suppl.]).

This situation can be explained by the verity that scions may differ in nutrient content due to differential nutrient absorption and/or translocation (Milošević et al., 2013). Table S1 [suppl.] has also indicated significant differences among soil types within the same grafted-pear rootstocks for nutritional balance or ΣDOP index. The high variability of ΣDOP index shown by the leaf nutrient content has already been reported by Zarrouk et al. (2005), Milošević et al. (2014), and Milošević & Milošević (2011b, c). In addition, Milošević & Milošević (2011a, 2015, and 2016) clarified different behavior of pear, apple, and plum cultivars on various rootstocks relates to leaf macro- and micronutrients content.

**Spearman correlations analyses**

Mean values of all studied grafted pear rootstocks over four years (2015, 2016, 2017, and 2018) were used for Spearman correlation analysis between ΣDOP and DOP indexes (Table 4), and each evaluated nutrient of different soil types was classified as follows:

- Highly positive (0.45 ≤ r < 0.90) with the DOPn, DOPCa, and DOPMg, the index for soil type A (less lime silt-loamy soil with 10% calcium carbonate equivalent).
- Highly negative (-0.45 ≤ r < 0.90) with the DOPp index for soil type A (less lime silt-loamy soil with 10% calcium carbonate equivalent).
- Highly positive (0.45 ≤ r < 0.90) with the DOPp and DOPCa, the index for soil type B (in fairy lime silt-loamy soil with 12% calcium carbonate equivalent).
- Moderately positive (0.337 ≤ r < 0.45) with the DOPMg index.
- Moderately negative (-0.337 ≤ r < 0.45) with DOPp for soil type B (in fairy lime silt-loamy soil with 12% calcium carbonate equivalent).
Leaf nutrient status of some grafted-pear rootstocks influenced by different soil types

Highly positive (0.45 ≤ r < 0.90) with the DOP$_{P}$ and DOP$_{Mg}$, the index for soil type C (clay loamy soil with 14% calcium carbonate equivalent).

Moderately positive (0.337 ≤ r < 0.45) with the DOP$_{B}$ and DOP$_{N}$ index for soil type C (clay loamy soil with 14% calcium carbonate equivalent).

Working on conilon coffee crop, Fonseca et al. (2018) obtained positively high and significant Spearman correlations (p ≤ 0.05) between ΣDOP and the DOP indexes of Mn; moderately positive with B; moderately negative for DOP index of P, K, S, and Zn. Our results differed for every single studied soil type. According to the results from to the Spearman correlation, the nutritional imbalance occurred due to the excess of P and Ca, Mg and Zn deficiency in the leaves of the evaluated pear rootstock/scion combinations, whereas the OHF69 rootstock grafted with 'Daregazi' scion, followed by OHF69 rootstock grafted with 'Daregazi' were more efficient in soil type B. The best balanced nutritional values in the C-type soil (clay loamy (with 14% calcium carbonate equivalent)) were found in the pyrodwarf rootstock grafted with 'William Duchess' scion, followed by OHF69 rootstock grafted with 'Daregazi'. Veloso et al. (1995) noted the difficulty of studying the effects of different nutrient toxicity alone, mostly due to interactions with other elements. These interactions can be responsible for the diversity of symptoms and different degrees of growth reduction in different species and cultivars (Foy et al., 1978). The Spearman correlation analyses proved the strong relation between the element levels in leaves. This information is very important to find the most suitable pear rootstock/scion in combinations with different calcareous soils for orchard establishment in the arid and semi-arid regions across the world, like some countries in the Near East (Pakistan, Indus Basin, Iran, Iraq, Jordan, and Lebanon), and also for countries of southern Europe, such as Portugal, Spain, Italy, and Greece.

Table 3. Combined analysis of variance for the leaf nutrition concentration of studied grafted-pear rootstocks grown under different soil types in four studied years (2015, 2016, 2017, and 2018)

| Source                      | DF  | N (%) | P (%)   | K (%)   | Ca (%)  | Mg (%)  | B (ppm) | Fe (ppm) | Zn (%) |
|-----------------------------|-----|-------|---------|---------|---------|---------|---------|---------|--------|
| Soil type                   | 2   | 3.97**| 0.37**  | 1.38**  | 0.05**  | 0.16**  | 28.83** | 1184.72**| 46.53**|
| Year                        | 3   | 43.82**| 10.89** | 9.81**  | 2.81**  | 1.58**  | 12847.82**| 485399.95**| 2951.12**|
| Soil type*Year              | 6   | 0.57**| 0.16**  | 0.62**  | 0.06**  | 0.10**  | 14.163** | 24076.37**| 74.05**|
| Block*Soil type*Year        | 24  | 0.01**| 0.02**  | 0.01**  | 0.3**   | 0.06**  | 0.16**  | 91.12**  | 0.72**  |
| A (rootstock)               | 2   | 2.88**| 0.19**  | 0.74**  | 1.39**  | 0.03**  | 354.55** | 21949.01**| 31.24**  |
| Soil type*A                 | 4   | 0.46**| 0.16**  | 3.28**  | 0.52**  | 0.06**  | 21.97**  | 13701.39**| 161.72** |
| Year*A                     | 6   | 2.09**| 0.70**  | 2.24**  | 0.26**  | 0.11**  | 101.27** | 99955.68**| 248.20** |
| Place*Year*A               | 12  | 0.67**| 0.17**  | 1.60**  | 0.03**  | 0.17**  | 23.92**  | 6582.00** | 103.41** |
| A*Block (Block*year)       | 48  | 0.01**| 0.003w  | 0.02w   | 0.01**  | 0.04**  | 0.17w   | 91.57ns  | 0.75w   |
| B                           | 2   | 1.48**| 0.81**  | 4.42**  | 1.21**  | 0.87**  | 346.08** | 20877.71**| 652.98** |
| A*B                         | 4   | 4.40**| 0.28**  | 5.67**  | 0.91**  | 0.74**  | 378.06** | 24257.18**| 232.55** |
| Year*B                     | 6   | 4.61**| 0.19**  | 2.392** | 0.07**  | 0.41**  | 226.49** | 28523.42**| 134.94** |
| Place*B                    | 4   | 0.33**| 0.47**  | 1.42**  | 1.51**  | 0.42**  | 94.36**  | 5978.79** | 288.37** |
| Place*Year*B               | 12  | 0.23**| 0.16**  | 0.52**  | 0.1**   | 0.06**  | 19.66**  | 3190.68** | 55.62**  |
| Year*A*B                   | 12  | 2.36**| 0.25**  | 3.71**  | 0.43**  | 0.29**  | 106.62** | 104494.31**| 179.88** |
| Place*A*B                  | 8   | 1.09**| 0.18**  | 1.39**  | 0.14**  | 0.31**  | 25.63**  | 11082.98**| 138.94** |
| Place*Year*A*B            | 24  | 0.44**| 0.16**  | 0.42**  | 0.15**  | 0.09**  | 21.21**  | 10096.90**| 31.00**  |
| CV (%)                      | 3.18 | 14.12 | 0.83    | 10.99   | 36.29   | 2.04    | 4.09    | 3.38    |

p*≤0.05; p**≤0.001, respectively; ns, no significant (F-probability).
Table 4. Spearman correlation analysis between ΣDOP and DOP indexes of each evaluated soil type. Values are the mean of all studied grafted-pear rootstocks over five years (2015, 2016, 2017, and 2018).

| Soil   | N  | p   | k | Ca  | Mg  | B   | Fe   | Zn   | ΣDOP |
|--------|----|-----|---|-----|-----|-----|------|------|------|
| Soil A | 0.24 | 0.717** | -0.159 | 0.545** | 0.669** | 0.185 | 0.185 | -0.435** | 1  |
| ΣDOP   | 0.161 | 0.917** | -0.337* | 0.478** | 0.414* | 0.249 | 0.179 | -0.21  | 1  |
| Soil C | 0.410* | 0.806** | 0.247 | 0.135 | 0.504** | 0.398* | 0.072 | 0.135 | 1  |

[1] ΣDOP: sum of the absolute value of the different DOP indexes. *,**: p ≤ 0.05, p ≤ 0.001, respectively (F-probabilities)

This paper presents creative data concerning the content of eight micro- and macro-elements in leaves of 'Daregazi', 'Louise Bonne' and 'William Duchess' scions grafted with OHF69, pyrodwarf, or a seedling of Pyrus communis which were grown in three different soil types (less lime silt-loamy, fairly lime silt-loamy and lime-rich clay loamy) over five years (2015, 2016, 2017, and 2018). Among all studied rootstocks, the pyrodwarf rootstock showed a more adequate level of mineral nutrients in the loamy soil. However, among all studied scions, 'Louise Bonne' scion showed a more adequate level of mineral nutrients in the loamy soil. Pyrodwarf rootstock grafted with 'William Duchess' scion exhibited a relatively more suitable balanced nutritional index than other rootstocks/scion combinations in clay loamy soil with 14% calcium carbonate equivalent. Our results also revealed that the seedling rootstock grafted with 'Louise Bonne' resulted in superior balanced nutritional values in the fairy lime silt-loamy soil with 12% calcium carbonate equivalent. The pyrodwarf rootstock grafted with 'Louise Bonne' scion was more efficient in less lime silt-loamy soil with 10% calcium carbonate equivalent. This rootstock when grafted with 'Louise Bonne' scion showed the lowest ΣDOP (290.33) and the greatest intensity of balance among nutrients than other rootstocks/scion combinations in less lime silt-loamy soil. In comparison to other rootstocks/scion combinations in fairy lime silt-loamy soil, the OHF69 rootstock in grafting with 'Daregazi' showed the highest ΣDOP (398.44) and the lowest intensity of balance among nutrients.

References

Bell R, Elkins, R, Einhorni T, 2012. The current state of pear rootstock research: progress and priorities (Abstract). HortScience 47 (9) (suppl): S100.

Bergmann W, 1991. Nutritional disorders of plants. Gustav Fischer Verlag, Jena, Germany. 332 pp.

Bosa K, Jadczykobjaz E, Kalaji M, Majewska M, Allakhverdiev SI, 2014. Evaluating the effect of rootstocks and potassium level on photosynthetic productivity and yield of pear trees. Russ J Plant Physiol 61 (2): 231-237. https://doi.org/10.1134/S1021443714020022

Dewan ML, Famouri J, 1964. The soils of Iran. FAO, Rome, Italy.

Dilmaghani MR, Hemmaty S, Naseri L, 2012. Effects of sulfur application on soil pH and uptake of phosphorus, iron, and zinc in apple trees. J Plant Physiol Breed 2 (1): 1-10.

Drouneou J, 1942. Dosage rapid, du calcaire actif des sols. Annals Agron 12: 441-50.

Elgabaly MM, 1973. Reclamation and management of the calcareous soils of Egypt. Report of the FAO/UNDP Regional Seminar on Reclamation and Management of Calcareous Soils, Cairo, Egypt, 27 Nov-2 Dec 1972. FAO Soils Bull 21: 123-127.

Elkins RB, Castagnolis S, Embree C, Parra-Quezada R, Robinson TL, Smith TJ, Ingelas CA, 2011. Evaluation of potential rootstocks to improve pear tree precocity and productivity. Acta Hort 909: 183-194. https://doi.org/10.17660/ActaHortic.2011.909.19

Elkins R, 2012. Evaluation of potential new size controlling rootstocks for European pear. 2011 California Pear Research Report, California Pear Advisory Board, pp: 104-113.

Elkins R, Bell R, Einhorni T, 2012. Needs assessment for future U.S. pear rootstock research directions based on the current state of pear production and rootstock research. J Am Pomol Soc 66 (3): 153-163.

Erdal I, Askin MA, Kucukyumuk Z, Yildirim F, Yildirim A, 2008. Rootstock has an important role in iron nutrition of apple trees. World J Agric Res 4 (2): 173-177.

Fallahi S, 1998. Detailed studies of the soil of the horticulture experience station of Kamalabad of Karaj / Iran. Soil and Water Research Institute, Tehran. Iran. [In Persian]. http://www.swri.ir/homepage.aspx?site=DouranPortal&tabid=1&lang=fa-IR

Fonseca A, Lima L, Jesus M, Silva S, 2018. Spatial variability of deviation from the optimum percentage in Conilon coffee. J Exp Agric Int 23 (5): 1-11. https://doi.org/10.9734/JEAI/2018/41817

Foy CD, Chaney RL, White MC, 1978. The physiology of metal toxicity in plants. Annu Rev Plant Physiol Lan-
Leaf nutrient status of some grafted-pear rootstocks influenced by different soil types

Milošević T, Milošević N, Glišić I, 2013. Agronomic properties and nutritional status of plum trees (Prunus domestica L.) influenced by different cultivars. J Soil Sci Plant Nutr 13 (3): 706-714. https://doi.org/10.4067/S0718-9512010300500056

Milošević T, Milošević N, Glišić I, Nikolić R, Milivojević J, 2014. Early tree growth, productivity, fruit quality, and leaf nutrients content of sweet cherry grown in a high-density planting system. Hort Sci (Prague) 42: 1-12. https://doi.org/10.17221/119/2014-HORTSCI

Milošević T, Milošević N, 2015. Apple fruit quality, yield, and leaf macro-nutrient content as affected by fertilizer treatment. J Soil Sci Plant Nutr 15 (1): 76-83.

Milošević T, Milošević N, 2016. Estimation of nutrient status in pear using leaf mineral composition and deviation from the optimum percentage index. Acta Sci Pol Hortorum Cultus 15 (5): 45-55.

Moghim AH, 2002. Semi-detailed soil survey and classification in Ashkara plain, Iran. Soil & Water Research Institute, Ministry of Agriculture, Tehran, Iran. http://www.swri.ir/homepage.aspx?site=DouranPortal&tabid=1&lang=fa-IR

Montañés L, Heras L, Abadia J, Sanz M, 1993. Plant analysis interpretation based on a new index: deviation from optimum percentage (DOP). J Plant Nutr 16: 1289-1308. https://doi.org/10.1080/01904169309364613

Olsen RA, Sømmers LE, 1982. Phosphorus. In: Methods of Soil Analysis, Part 2; Page AL, Miller RH & Kenney DR (eds.), pp: 403-30. SSSA, Madison, WI, USA.

Taalab AS, Ageeb GW, Hanan SS, Mahmoud SA, 2019. Some characteristics of calcareous soils. A review. Middle-East J Agric Res 8 (1): 96-105.

Veloso CAC, Muraoka T, Malavolta E, Carvalho JG, 1995. Effect of manganese on mineral nutrition and growth of black pepper (Piper nigrum, L.). Scientia Agricola 52 (2): 376-383. https://doi.org/10.1590/S0103-9016199500200028

Walky A, Black J, 1934. An examination of the digital method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Sci 37: 29-38. https://doi.org/10.1097/00010694-193401000-00003

Zarrouk O, Gogorcena Y, Gómez-Aparisi J, Betrán JA, Moreno MA, 2005. Influence of almond × peach hybrids rootstocks on flower and leaf mineral concentration, yield, and vigor of two peach cultivars. Sci Hortic 106: 502-514. https://doi.org/10.1016/j.scienta.2005.04.011