

Article

Characterization of Oleaster-Leafed Pear (*Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia*) Fruits in Turkey

Halil Ibrahim Sagbas ¹, Gulce Ilhan ¹, Sezai Ercisli ¹, Muhammad Akbar Anjum ² and Vojtěch Holubec ^{3,*}

¹ Department of Horticulture, Agricultural Faculty, Ataturk University, 25240 Erzurum, Turkey; hibrahimsagbas@gmail.com (H.I.S.); gulceilhan07@gmail.com (G.I.); sercisli@gmail.com (S.E.)

² Department of Horticulture, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, 60800 Multan, Pakistan; akbaranjum@bzu.edu.pk

³ Department of Gene Bank, Crop Research Institute, Drnovská 507, Prague 6—Ruzyně, 161 06 Prague, Czech Republic

* Correspondence: holubec@vurv.cz; Tel.: +420-233-022-497

Abstract: Oleaster-leafed pear (*Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia*) fruits are used for food and dietary supplements in Turkey, and seedlings are used as rootstock for pear cultivars. Information on the effect of genotypes on oleaster-leafed pear fruit characteristics is needed in order to optimize production of quality food and dietary supplements. The characteristics of oleaster-leafed pear fruits relative to genetic background were evaluated from 16 wild grown oleaster-leafed pear genotypes at eastern Turkey. Genotype influenced ripening dates, fruit weight, fruit length/width ratio, fruit pedicel length, fruit flesh texture, fruit firmness, the number of seeds per fruit, soluble solid content, titratable acidity, total phenolic content, total flavonoid content and antioxidant activity. Analysis of the data obtained from 16 oleaster-leafed pear genotypes demonstrated a highly significant influence of genotype on fruit characteristics. The genotypes G12, G13 and G9 had the highest fruit weight (19.22, 18.54 and 18.30 g) and G9 the highest total phenolic content (122 mg gallic acid equivalent/100 g fresh fruit). The genotypes G3, G5, G11 and G13 had the slightly sandy fruit flesh texture and those genotypes may be good selections for processing and producing health oleaster-leafed pear products.

Keywords: *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia*; fruit characteristics; wild edible fruit; biochemical content



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1. Introduction

Oleaster-leafed pear (*Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia*) is one of the most widely known wild grown pear species, which is a member of the Rosaceae family. It is small to medium-sized tree and native to central, eastern and southern Anatolia region in Turkey including cities such as Amasya, Ankara, Antalya, Artvin, Bolu, Erzincan, Erzurum, Gumushane, Kahramanmaras, Kastamonu, Kayseri, Konya, Kutahya, Mersin, Mus, Nigde, Sivas, and Van [1]. Trees occur in a scattered distribution pattern as single individuals or in small groups in different parts of Turkey and Europe. Oleaster-leafed pear is extremely light-demanding and has weak competitive abilities. As a result, the tree exists mostly at the edge of forests, in farmland hedges or on very extreme, marginal sites such as very dry or wet spots [2]. The goats are live in *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* growing areas but there are no impact on the populations of *Pyrus*. This is an important aspect for the population conservation.

Pyrus elaeagrifolia Pall. subsp. *elaegrifolia* is a significant plant genetic resource, which deserves to be preserved with appropriate in situ conservation strategies, as done for other crop wild relatives in the Mediterranean area [3]. Using sustainable criteria for pasture planning in order to preserve the natural habitat [4].

In Turkey, plant scientists identified crop wild relatives (CWRs) as a target group for conservation over last 20 years ago and accelerating rates of species extinctions were

identified at that time as threats to the genetic base of Turkey's agriculture, and effort and resources were expended during the following decades to collect CWRs and maintain them both in ex situ (off-site) and in-situ (on-site) conservation programs [2,5].

The local names for wild edible pears vary from place to place, and include *Ahlat*, *Aklap*, *Alfat*, *Argun*, *Banda*, *Corduk*, *Cotur*, *Covur*, *Kerte*, *Panta* and *Zingit* [2]. After ripening and harvesting, the aromatic fruit becomes soft and edible [5]. It is widely consumed as preserves and occasionally pickled and dried. The fruit is also used in Turkish folk medicine, primarily in the treatment of diarrhea and detoxification of poisonous snake bites [1]. Oleaster-leafed pear (*Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia*) has long played an important role in traditional Turkish cuisine, especially in the countryside, even despite the presence of common cultivated pear cultivars belong to *P. communis* L., which are more attractive and profitable.

Oleaster-leafed pear (*Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia*) trees flower between April and May and the fruits mature in October and November. Oleaster-leafed pear trees are small and, unlike cultivated pears, have round shape. Because oleaster-leafed pear fruits are very hard even when ripe, farmers usually leave them in hay for several weeks. Oleaster-leafed pears are almost always eaten in some processed form—in fresh, raw form, they are too hard and acidic to be enjoyable. They can be dried, cooked, fermented, or marinated in vinegar. Oleaster-leafed pears are even used to prepare alcoholic beverages and, in rural areas the seeds were roasted and then toasted (it is called *Kavut* locally), and used as a substitute for tea or coffee.

Seedlings are used as rootstocks for commercial pear cultivars due to good compatible characteristics with commercial pears. However scions of cultivars (*Pyrus communis* L.) grafted on *Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia* grow vigorously similar to pear seedlings causing a long juvenile period [6] and also seedling display high genetic variation [7] indicating traditional use of fruits are more important than rootstock value.

The plant has xerophytes features with deep roots and resistance to cold up to $-30\text{ }^{\circ}\text{C}$ [8] as well. The deep roots have ability to uptake more Fe and Zn from soils to avoid chlorosis. The plant can be grown on high pH soils where not suitable for growing many *Pyrus* species and thus oleaster-leafed pears adapted very well to calcareous, salty and arid conditions [9,10]. Thus *Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia* is one of the gene sources used to improve rootstock tolerance to drought and chlorosis [8]. The plant is not only native to Turkey but also to Albania, Bulgaria, Romania, and Crimea.

Today, despite this long gastronomic history, the use of oleaster-leafed pears is disappearing for various reasons. For example, cultivated pears do not need to be processed before being eaten. In addition, urban migration means that people are forgetting about oleaster-leafed pears and the associated recipes and preparation techniques.

The sandy fruits are pseudocarp with 3–4 cm diameter spherical-pear like shape. Non-hairy fruits are initially green and then turn into yellow-brown [2,5,11,12].

The knowledge of characterization of oleaster-leafed pear genotypes (*Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia*) based on phenological, morphological and biochemical parameters is scarce in literature. Thus this study will help to understand knowledge related to phenological, morphological and biochemical traits of relatively a large number of diverse *Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia* genotypes collected from eastern Anatolia region of Turkey. These results provide a theoretical and scientific basis for the selection and breeding of different wild *Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia* genotypes.

2. Materials and Methods

2.1. Plant Material

Fruits of 16 wild grown oleaster-leafed pear trees naturally grown in rural areas of Askale districts belong to Erzurum province in eastern Turkey were sampled in 2018 year (Figure 1).



Figure 1. Sampling locations of 16 *Pyrus elaeagnifolia* Pall. subsp. *elaegnifolia* genotypes.

The selected 16 genotypes were diverse each other in terms of fruit and tree characteristics and all genotypes had attractive fruits, high yield capacity and free of pests and diseases characteristics.

For phenological observation fruit-ripening time (harvest date) was determined. For morphological evaluation, fruit weight (g), fruit length/width index, fruit pedicle length (mm), fruit firmness (kg/cm^2), the number of seeds per fruit and fruit flesh texture were determined. For biochemical parameters, Soluble Solid Content (SSC), titratable acidity, vitamin C, total phenolic content, total flavonoid content and antioxidant activity (FRAP, Ferric Reducing Antioxidant Power and DPPH, 2,2-diphenyl-1-picrylhydrazyl assays) were analyzed. A total of 50 fruits per genotype were used for measurements and analysis. Fruit weight (g) was measured with a digital scale sensitive to 0.01 g (Scaltec SPB31, Denver Instrument Company, Arvada, CO, USA). Fruit firmness was determined with non-destructive Acoustic Firmness Sensor (Model DTF, Aweta B.V., Pijnacker, The Netherlands) expressed as kg/cm^2 . The shape was determined by dividing fruit length by fruit width. A trained panel of five experts evaluated the fruit flesh texture and evaluated as highly sandy, sandy and slightly sandy for each genotype. Pedicel length, fruit length and width were determined by digital caliper.

Soluble Solid Content (SSC) were determined by extracting and mixing one drop of juice from the each fruit into a digital refractometer (Model RA-250HE, Kyoto Electronics Manufacturing Co. Ltd., Tokyo, Japan) at 22 °C. Vitamin C (Ascorbic acid) was quantified with the reflectometer set by using RQFlex (RQFlex 20, Merck Company, Darmstadt, Germany) and expressed as $\text{mg}/100$ g. Fruit extracts were taken in a magnetic stirrer with water. The extract was then filtered and subjected to potentiometric acid-base titration with adjusted NaOH solution. Titration acidity of wild pear samples was expressed in g mallic acid equivalent/100 g sample.

Total phenolics of samples were determined by Folin Ciocalteu reactive and reading the absorbance of colorful solution at 765 nm wavelength and expressed in mg gallic acid equivalent/100 g sample in fresh weight base [13]. For total flavonoids content, 3.5 mL of methanol was added over 800 μL of fresh fruit extract. Then, 100 μL both 10% ammonium acetate and 1 M ammonium nitrate were added and left to incubate 40 min. After incubation

of the samples, the absorbance values at 517 nm were determined on the spectrophotometer. Obtained values were expressed as mg catechin equivalent (CE)/100 g [14].

Total antioxidant activity was determined by FRAP (Ferric Reducing Antioxidant Power) and DPPH (1,1-diphenyl-2-picryl-hydrazil) assays. For FRAP assay, 120 µL samples were supplemented initially with 0.2 M of PO_4^{3-} to get a volume of 1.25 mL and then with 1.25 mL 1% $\text{K}_3\text{Fe}(\text{CN})_6$. Resultant mixture was vortexed and incubated at 50 °C for 1 h. Incubated samples were supplemented with 1.25 mL 10% TCA and 0.25 mL 0.1% FeCl_3 . Then, absorbance values at 700 nm were determined on the spectrophotometer. Obtained values were expressed as mmol trolox equivalent/kg [15]. For DPPH assay, 0.26 mM DPPH (1,1-diphenyl-2-picryl-hydrazil) solution was prepared for DPPH analysis. 2700 µL of ethyl alcohol and 1 mL of DPPH solution were added to 300 µL of fruit extract and vortexed. Then, 30 min kept in dark. After incubation of the samples, the absorbance values at 517 nm were determined on the spectrophotometer. Obtained values were expressed as mmol trolox equivalent/kg [16].

2.2. Statistical Analysis

To verify statistical significance, means of four independent repetition were calculated on morphological and biochemical parameters. One-way analysis of variance (ANOVA) were performed using SPSS (20.0), followed by LSD test to assess differences between group means. p values of < 0.05 were considered to be significant. In R software, the principal component analysis was used for all variables with the ggplot2 and factor extra packages. Pearson correlation coefficient was used to determine correlation matrix among bioactive parameters.

3. Results and Discussion

3.1. Morphological Characterization

In this study, *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* fruits were characterized in terms of morphological and biochemical properties. Table 1 shows the qualitative and quantitative morphological data of genotypes. Significant morphological variation was observed among the oleaster-leaved pear genotypes studied. According to the statistical comparison, the harvest dates were found between 24 October and 10 November. Yilmaz et al. [17] a wide variation on ripening date of *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes (from 11 October to 10 November) in middle Anatolia in Turkey.

The fruit weight of the genotypes G12 (19.22 g), G13 (18.54 g) and G9 (18.30 g) were found non significant each other but they significantly differed from G16 (9.22 g), G14 (8.95 g), G8 (7.68 g) and G7 (5.73 g) ($p < 0.05$). Similar high variations on fruit weight were obtained in *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes by Yilmaz et al. [17] as 4.71–27.09 g and Gerçekcioglu et al. [18] as 16–22 g, respectively. Kececi et al. [19] also reported higher fruit weight variation between 18.05–55.50 g among *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes sampled from Hakkari region in eastern Turkey.

The number of seeds ranged from 5.40 (G4) to 8.84 (G10). For fruit pedicel length, the genotype G6 (21.11 mm) and G14 (20.06 mm) was found significantly different than the other genotypes ($p < 0.05$). Fruit length/width were found between 0.82 (G3) and 1.12 (G9). Yilmaz et al. [17] and Gerçekcioglu et al. [18] found a great variation on pedicel length that varied from 6.89–24.23 mm and 18.0–25.0 mm, respectively on oleaster-leaved pear genotypes. Same researchers reported fruit length/width ratio of oleaster-leaved pear genotypes between 0.67–1.09 and 0.77–0.96, respectively. Kececi et al. [19] also reported high variation on fruit length/width ratio (0.90–1.23) among *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes sampled from Hakkari region in eastern Turkey. Also, fruit firmness were compared, the genotype G5 (9.63 kg/cm²), G14 (9.04 kg/cm²), and G8 (8.85 kg/cm²) was found significantly higher than the other genotypes (Table 1). Gerçekcioglu et al. [18] reports a great variation on the number of seeds per fruit and fruit firmness between 4.0–8.0 and 4.0–10.0 kg/cm² among oleaster-leaved pears fruits, respectively. Kececi et al. [19] reported high variation on the number of seeds per fruit between 6.0–9.0 among *Pyrus*

elaeagrifolia Pall. subsp. *elaeagrifolia* genotypes sampled from Hakkari region in eastern Turkey. All above studies supports our findings. Studies on morphological and biochemical characteristics of oleaster-leaved pear (*Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia*) genotypes were very limited in literature as indicated above. This highlights the importance of present study.

Table 1. Phenological and morphological characteristics of *Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia* genotypes.

Genotype Names	Codes	Harvest Date	Fruit Weight (g)	The Number of Seeds	Pedicel Length (mm)	Fruit Length/Width	Fruit Firmness (kg/cm ²)	Fruit Flesh Texture
ASKALE1	G1	1 Nov	10.54 bc	6.63 b	14.44 b	0.90 c	7.44 c	Sandy
ASKALE2	G2	3 Nov	14.40 b	5.96 bc	12.70 bc	0.94 bc	5.11 de	Highly Sandy
ASKALE3	G3	28 Oct	15.11 ab	6.40 bc	13.22 bc	0.82 d	5.89 de	Slightly Sandy
ASKALE4	G4	31 Oct	11.35 bc	5.40 c	14.67 b	0.98 bc	8.10 b	Sandy
ASKALE5	G5	8 Nov	13.28 b	8.10 ab	10.30 bc	1.04 ab	9.63 a	Slightly Sandy
ASKALE6	G6	24 Oct	12.04 bc	6.70 b	21.11 a	0.86 cd	7.76 bc	Sandy
ASKALE7	G7	27 Oct	5.73 cd	5.73 bc	10.60 bc	1.01 b	6.51 cd	Highly Sandy
ASKALE8	G8	28 Oct	7.68 c	7.67 ab	19.90 a	0.93 bc	8.85 a	Sandy
ASKALE9	G9	10 Nov	18.30 a	5.55 bc	11.20 bc	1.12 a	4.78 e	Sandy
ASKALE10	G10	26 Oct	14.12 b	8.84 a	13.03 bc	0.85 cd	6.90 cd	Highly Sandy
ASKALE11	G11	28 Oct	11.38 bc	6.33 bc	6.80 c	0.94 bc	4.18 e	Slightly Sandy
ASKALE12	G12	5 Nov	19.22 a	7.13 ab	11.80 bc	0.94 bc	8.22 b	Sandy
ASKALE13	G13	25 Oct	18.54 a	7.20 ab	9.27 bc	0.97 bc	6.56 cd	Slightly Sandy
ASKALE14	G14	26 Oct	8.95 c	8.39 a	20.06 a	1.06 ab	9.04 a	Sandy
ASKALE15	G15	1 Nov	12.56 bc	7.41 ab	12.10 bc	0.90 c	6.10 d	Highly Sandy
ASKALE16	G16	25 Oct	9.22 c	6.00 bc	12.00 bc	0.88 cd	5.44 de	Sandy

Same letters in same column indicate statistically significant differences ($p < 0.05$) among the genotypes.

The percentage of slightly sandy in fruits was determined to be 25% of genotypes, 25% of genotypes as highly sandy and 50% of genotypes as sandy (Table 1). Yilmaz et al. [17] and reported that among 43 *Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia* genotypes, 20 genotypes had sandy fruit (47%), 12 genotypes had highly sandy (28%) and 11 genotypes had slightly sandy fruits (25%), which in accordance with our results.

3.2. Biochemical Characterization

As indicated before studies on morphological and biochemical characteristics of oleaster-leaved pear (*Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia*) genotypes were very limited in literature. This highlights the importance of present study and vitamin C and antioxidant capacity first time determined in this plant in literature.

The results of analyses performed for vitamin C were not significant among genotypes analyzed. However, all other biochemical variables (SSC, titratable acidity, total phenolic and antioxidant capacity) analyzed in genotypes were significant (Tables 2 and 3), demonstrating that genotypes differed in biochemical characteristics.

The quality of oleaster-leaved pear fruits can be evaluated in terms of sensory factors. It is known that the characteristic taste of fruit is determined largely by the content of sugars and organic acids [20]. Furthermore, the sugar–acid ratio is considered particularly useful as an index of acceptability in many fruits [19]. The SSC, acidity, sugar/acid ratio and other nutrients in fruit are important indicators for evaluating fruit quality and flavour; high levels of SSC, acidity and sugar/acid ratio in fruits indicate better flavor [21,22]. Each genotype assayed in this study showed different levels of SSC and titratable acidity (Table 2). The levels of SSC in different oleaster-leaved pears from the 16 *Pyrus elaeagrifolia* Pall. subsp. *elaeagrifolia* genotypes ranged from 12.30 to 21.40%. The highest SSC was observed in G9 (21.40%), and the lowest was found in G6 (12.30%). There were no significant differences among G2 and G12 (19.40 and 19.60%, respectively) and G7 and G11 (15.80 and 15.40%, respectively). Titratable acidity of genotypes were found between 0.82 (G7) and 1.38 (G5)%. The genotypes G5, G9, G12 and G15 showed higher

SSC and titratable acidity content. Previously Yilmaz et al. [15] recorded quite variable SSC and titratable acidity between 12.0–20.0% and 0.20–1.40% in fruits of 43 wild grown *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes that indicate similarities with our results. Gerçekcioglu et al. [16] revealed SSC content of 10 *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes were in range of 13.0–18.0%. Kececi et al. [19] also found high variation on SSC and titratable acidity content in fruits of *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes sampled from Hakkari region in eastern Turkey were between 11.1–16.3% and 2.0–4.0%, respectively. Our results of SSC and titratable acidity were comparable to above studies. Plant genotype, environmental conditions, affect biochemical content in horticultural plants [20,22,23]

Table 2. Biochemical characteristics of *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes.

Genotype Names	Codes	SSC (%)	Titratable Acidity (%)	Vitamin C (mg/100 g)
ASKALE1	G1	17.80 c	1.00 c	9.6 ^{NS}
ASKALE2	G2	19.40 b	1.16 bc	11.0
ASKALE3	G3	16.10 cd	1.06 c	8.4
ASKALE4	G4	17.50 c	1.10 bc	10.2
ASKALE5	G5	20.80 a	1.38 a	7.1
ASKALE6	G6	12.30 ef	0.74 de	8.0
ASKALE7	G7	15.80 d	0.82 d	11.2
ASKALE8	G8	16.60 cd	0.90 d	10.6
ASKALE9	G9	21.40 a	1.22 b	7.6
ASKALE10	G10	14.00 de	0.65 e	9.9
ASKALE11	G11	15.40 d	0.96 cd	11.4
ASKALE12	G12	19.60 b	1.16 bc	8.1
ASKALE13	G13	15.00 de	0.99 cd	8.8
ASKALE14	G14	13.80 e	0.71 de	9.4
ASKALE15	G15	19.00 bc	1.04 c	7.7
ASKALE16	G16	15.20 de	1.02 c	8.4

Same letters in same column indicate statistically significant differences ($p < 0.05$) among the genotype.

Table 3. Bioactive characteristics of *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes.

Genotype Names	Codes	Total Phenolic (mg GAE/100 g)	Total Flavonoid (mg CE/100 g)	DPPH (mmol/kg)	FRAP (mmol/kg)
ASKALE1	G1	102 cd	18.55 ab	0.96 c	4.70 bc
ASKALE2	G2	106 c	21.03 ab	0.93 c	5.05 ab
ASKALE3	G3	85 f	12.08 c	0.76 e	3.78 bc
ASKALE4	G4	96 de	15.50 b	0.93 c	3.94 bc
ASKALE5	G5	114 b	18.84 ab	1.04 b	5.70 ab
ASKALE6	G6	112 b	18.37 ab	1.08 b	5.11 ab
ASKALE7	G7	99 d	18.68 ab	0.91 cd	4.45 bc
ASKALE8	G8	91 ef	12.47 bc	0.79 de	3.56 bc
ASKALE9	G9	122 a	15.73 ab	1.15 a	5.85 a
ASKALE10	G10	82 g	15.04 bc	0.70 f	3.39 c
ASKALE11	G11	86 f	12.42 bc	0.62 g	3.70 bc
ASKALE12	G12	110 b	21.11 a	1.02 b	4.96 b
ASKALE13	G13	72 h	12.88 bc	0.60 g	3.43 bc
ASKALE14	G14	93 e	15.25 bc	0.86 d	4.20 bc
ASKALE15	G15	98 d	15.44 bc	0.84 d	4.33 bc
ASKALE16	G16	84 g	12.17 bc	0.70 f	3.77 bc

Same letters in same column indicate statistically significant differences ($p < 0.05$) among the genotypes.

The results show that total phenolic content (TPC) was significantly different among the *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes, ranging from 72 to 122 mg GAE/100 g FW (Table 3). The TPC of G5, G6 and G12 was not significantly different. The highest TPC was found in G9 (122 mg GAE/100 g), and followed by G5 (114 mg

GAE/100 g), G6 (112 mg GAE/100 mg) and G12 (110 mg GAE/100 g), respectively. The great differences in TPC among studied genotypes of *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* suggest that it is possible to select genotypes with the highest concentration of these compounds, and as a consequence, more beneficial properties. Galvis-Sanchez et al. [24] reported that pear flesh have total phenolic content between 123–200 GAE/100 g. Marinova et al. [25] found that pears include total phenolic content between 91–125 mg GAE/100 g. Liaudanskas et al. [26] showed total phenolic content among pear cultivars between 51–111 mg GAE/100 g. Karakaya et al. [27] reported that 27 clones of local ‘Alisar’ pear genotypes grown in Turkey had total phenolic content between 72–147 mg GAE/100 g. In Bosnia & Herzegovina, the total phenolics content were reported between the ranges 307–717 mg GAE/100 g for pear genotypes [28]. In eastern Turkey local pear genotypes showed total phenolic content between 112–230 mg GAE/100 g [29] and 126–215 mg GAE/100 g [30]. In Northeast Bosnia & Herzegovina a wide variation on total phenolic content (15–190 mg GAE/100 g) were reported among a large number of indigenous European pear (*Pyrus communis*) cultivars [31].

Total flavonoid content were found between 12.08–21.11 mg CE/100 g indicating G10 genotype had the lowest value and G9 genotype had the highest value (Table 3). Karakaya et al. [27] reported that 27 clones of local ‘Alisar’ pear genotypes grown in Turkey had total flavonoid content between 3.05–8.48 ng CE/100 g that is indicating lower values than our result. The total flavonoids content was determined between 32–38 mg CE/100 g for pear cultivars grown in Ankara [32]. Duric et al. [28] reported total flavonoids content between 43–120 mg CE/100 g for pear genotypes from Bosnia and Herzegovina. In present research, values of total flavonoids in the wild pear clones were lower than those of other researches. The content of phenolics and flavonoids and antioxidant activity in the pear fruit might be affected by many factors such as genetic structure (variety or genotype), growing ecology, soil characteristics, harvest season and maturity stage of fruit [28,29,33].

The antioxidant capacity was measured in the 16 *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes using the DPPH radical-scavenging assay, as shown in Table 3. Each genotype expressed different levels of antioxidant capacity. The antioxidant capacity among the various *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* was significantly different, ranging from 0.60 mmol/kg to 1.15 mmol/kg, as determined by the DPPH assay. The genotypes G9, G6, G5 and G12 had significantly ($p < 0.05$) higher antioxidant capacities than the rest of the genotypes, as determined by the DPPH assay. There are no reported studies on the antioxidant capacity of *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* fruits.

In FRAP, antioxidant capacity assay, 16 *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes had antioxidant capacity between 3.39–5.85 mmol/kg, indicating G10 genotype had the lowest and G9 genotype had the highest antioxidant capacity (Table 3).

Both FRAP and DPPH scavenging activity in wild oleaster-leaved pear genotypes indicating their higher antioxidative potential which might help to reduce oxidative stress.

Previous studies conducted on different wild edible fruits showed a great variability among genotypes belongs to different species due to open pollinated nature and rich gene combinations of them [34–38]. Wild edible fruits are also reported to have high adaptability capacity for different environment conditions [39–42]. Variability within a species as the basis for successful adaptation to changing conditions of the environment during its long life cycle, which in the long run is important for the survival of the species, i.e., variability ensures adaptability of populations to changes in the environment over generations [43,44].

There are no reported studies on the antioxidant capacity of *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* fruits indicating the importance of present study. Our results also indicate quite differences among wild grown *Pyrus* genotypes in terms of antioxidant capacity. This is also indicate importance to use the most diverse genotypes in future breeding activity. The antioxidant potential of commonly consumed fruit has been rated in the order of plum > kiwi > apple > pear [33]. Previous studies indicated that wild edible fruits are very rich in terms of bioactive substances that has antioxidant effect [45–51].

Distribution of oleaster-leaved pear genotypes according to agro-morphological characteristics are given in Figure 2. Genotypes clearly differed each other in PCA-Biplot analysis.

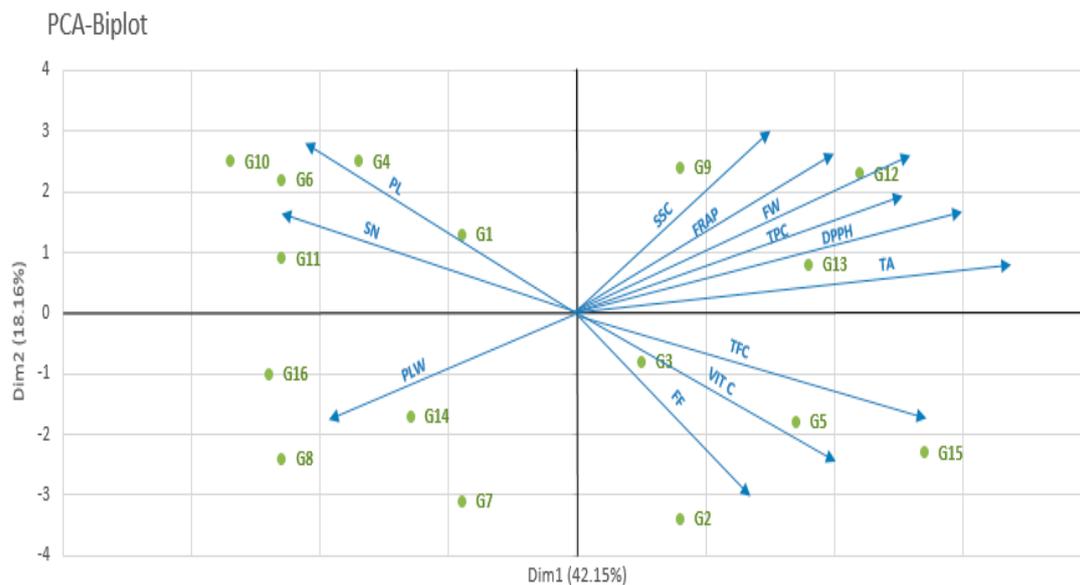


Figure 2. Distribution of oleaster-leaved pear genotypes according to agro-morphological characteristics. FW: Fruit weight; SN: Seed number; PL: Pedicel length; FLW: Fruit length/width; FF: Fruit firmness; SSC: Soluble solid content; TA: Titratable acidity; Vit.C: Vitamin C; TPC: Total phenolic content; TFC: Total flavonoid content; FRAP: Ferric Reducing Antioxidant Power; DPPH: 1,1-diphenyl-2-picryl-hydrazil.

3.3. Correlation among Fruit Bioactive Compounds in Wild Pears

As indicated in Table 4, based on DPPH and FRAP assays, significant positive correlations ($p < 0.001$) were computed between total phenolics and antioxidant activity ($r = 0.656^{***}$ and $r = 0.774^{***}$), respectively. Moderate positive relationship ($r = 0.407^{**}$) was found between total phenolics and total flavonoids (Table 4). In addition DPPH and FRAP assays revealed a significant positive correlation each other ($r = 0.695^{***}$). Both antioxidant assays showed moderate positive relationships with total flavonoid ($r = 0.337^*$ and 0.489^{**}), respectively. Abacı et al. [29] reported a positive correlation ($r = 0.758^*$) between total phenolic and DPPH. Azzini et al. [52] computed a high positive correlation between total phenolics and FRAP ($r = 0.874^{***}$) in pears. There are many antioxidant compounds that might contribute to total antioxidant capacity; however, it is clear that TPC are responsible for the observed antioxidant capacity in this study due to high correlation between them. Liaudanskas et al. [25] showed that antioxidant capacity were between 42–60 μmol of trolox equivalents/g dry weight base in pear cultivars and highly correlated with TPC. Galvis-Sanchez et al. [22] reported that the antioxidant capacity in pear fruits was correlated with the content of chlorogenic acid ($r = 0.46$), while ascorbic acid made only a small contribution to the total antioxidant capacity of the fruit.

Table 4. Correlation matrix for fruit bioactive compounds of of *Pyrus elaeagrifolia* Pall. subsp. *elaegrifolia* genotypes.

	Total Phenolics	DPPH	FRAP
DPPH	0.656 ***	-	-
FRAP	0.774 ***	0.695 ***	-
Total Flavonoids	0.407 **	0.337 *	0.489 **

Pearson r values indicate significant correlations (* $p < 0.05$; ** $p < 0.005$; *** $p < 0.001$).

4. Conclusions

Thirty oleaster-leaved genotypes compared for morphological, biochemical and antioxidant potential showed high diversity, which can be further used in breeding activity. Due to the fact that there are not enough studies regarding oleaster-leaved pear indicating importance of this study. The genotypes varied for morphological and biochemical characteristics, which expands the variation. Especially, harvest dates, fruit weight, fruit firmness, total phenolic content and antioxidant capacity strongly varied among genotypes. Even within a small number of genotypes, the variation could be concluded as important for future studies. In oleaster-leaved genotypes, G9, G12 and G3 had high fruit weight values; G9 and G2 also had high total phenolic, total flavonoid content and antioxidant activity. The results indicate potential use of fruits of wild *Pyrus* in bio-industrial applications, which remains unexplored so far. The results are also highlighted that special attention must be paid to proper management of wild edible oleaster-leaved populations located in eastern Turkey in order to preserve this important wild relatives of cultivated *Pyrus* species in terms of both abundance and genetic diversity.

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