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Cultivar and Rootstock Effects on Growth, Yield and Nut Quality of Pistachio under Semi-Arid Conditions of South Mediterranean

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Abstract: Pistachio (*Pistacia vera* L.) cultivation under rainfed conditions of the South Mediterranean has not been studied in depth. Under changing climate conditions, knowledge of cultivar and rootstock performances allows for the optimal use of genetic resources to improve yield and nut quality. This study aimed to evaluate growth, yield, and fruit characteristics of 'Mateur' and 'Achouri' pistachio cultivars grafted on *P. vera* and *P. atlantica* rootstocks grown in northeastern Tunisia. The research was based on three years worth of monitoring of growth, yield and fruit quality. Results showed that annual bio-climatic features had significant effects on all studied parameters. The 'Mateur' cultivar showed higher vigor and fruit yield than 'Achouri'. Fruit production was higher in *P. atlantica* rootstock for 'Mateur' but similar in both studied rootstocks for 'Achouri'. Kernel fat contents (40.7–46.8%) and fatty acid profiles were low or not affected by cultivar, rootstock and their combination. Oleic acid (C18:1) was the major fatty acid (68.94–69.22%) in kernel oil. The unsaturated/saturated fatty acid and oleic/linoleic acid ratios indicated that nuts obtained had high quality. The lower performances of 'Achouri' cultivar in the studied conditions may be related to low acclimation ability of this cultivar. These conditions, however, seem to be suitable for both studied rootstocks.

Keywords: *Pistacia vera*; yields; fruit characteristics; pistachio oil; rainfed conditions

1. Introduction

Pistachio nut species, belonging to the *Anacardiaceae* family, are native to arid zones of Central and West Asia and are spread throughout the Mediterranean Basin. Pistachio kernels are a nutritive nutrient which can be included in a healthy diet to prevent heart diseases [1]. Pistachios have high energetic content with sensorial characteristics highly appreciated by consumers and are a good source of minerals, vitamins, fatty acids (linoleic, linolenic and oleic acids) and phenolic compounds [2–8].

With climate evolution, the Mediterranean Basin is expected to become 20% warmer than the global average with less and more variable precipitations [9]. This leads to the loss of genetic diversity, a reduction in yield and high vulnerability of plants to pests and diseases. Agricultural productivity is more affected when crops are grown under rainfed conditions or with low water supply, often, of low quality. In this situation, a water saving strategy is adopted for more efficient use of the available water for agriculture. Due to its tolerance to drought and its low water requirements, the cultivation of pistachio (*Pistacia vera* L.) has aroused great interest among farmers [10]. In addition, farmers are very interested in its cultivation under rainfed conditions to enhance the value of arid and semi-arid areas and maximize profits [11,12].

The main pistachio-producer countries are Iran, USA, Turkey, Syria, Italy, Greece and Tunisia. Tunisia is the main producer country in the southern part of the Mediterranean Basin, with a total annual production in 2020 of 4662 t, covering an area of 30,196 ha [13]. Most of the plantations are spread in the southern and the central parts of the country with arid and semi-arid climate and no more than 300 mm of average annual rainfall. These regions are among the areas most affected by water stress and temperature rise in the last decades [14–16]. Moreover, the durability of this crop is threatened due to low genetic diversity, with the 'Mateur' cultivar and *P. vera* rootstock being the most used. Selecting adapted and efficient plant material and determining the areas most suitable for this crop are among proposed strategies for the sustainability of this crop in Tunisia [15].

The rootstock influences growth, fruit production and quality of many fruit species including pistachio [7,17–20]. The scion–rootstock interaction may lead to variable responses linked to genetic and physiologic factors and, also, to soil–rootstock and root–soil microbiom interactions [21]. Rootstock has particular importance in pistachio orchards as grafting is the main technique used for its propagation. In traditional orchards, native *Pistacia* species are used as rootstocks (*P. atlantica*, *P. terebinthus*, *P. vera*, *P. integerrima*, *P. khinjuk*, *P. palaestina*, etc.). Recently, selected vigorous and stress-tolerant rootstocks were used in modern orchards to improve crop adaptation and agronomic performance [22–25]. As the diversification of cultivars and rootstocks can be a good tool for enhancing crop adaptation and productivity, recent researches have paid attention to the physiological and agronomic evaluation of pistachio rootstocks and scion–rootstock interactions under different growing conditions and their effects on agro-food parameters [1,11,22,26–31]. It was found that the responses were not homogeneous, and were sometimes contradictory, depending on the different experimental conditions and the stem–rootstock combination. Considering these variable responses, supplemental knowledge of scion–rootstock response under specific orchard managements and environmental conditions may help for an optimal use of available genetic resources with low water supply. Despite the large extension of non-irrigated pistachio orchards in the Mediterranean, only a few studies have been performed in such conditions to assess crop yield and nut quality.

The aim of this work was to study the agronomic performance of four pistachio scion–rootstock combinations grown under rainfed conditions in northeastern Tunisia. The evaluation focused on the effects of the cultivar, the rootstock and their interaction on plant growth, yield and physical and biochemical nut characteristics.

2. Material and Methods

2.1. Experimental Orchard and Growing Conditions

This study was carried out under rainfed conditions in the northeast of Tunisia in the Mornag experimental research unit (36°38′ N–10°16′ E) of the National Institute of Agronomic Research of Tunisia (INRAT). This region belongs to the upper semi-arid bioclimatic stage characterized by mild winters and dry and hot summers. Monitoring was undertaken during three consecutive years, from 2014 to 2016. The total annual rainfall was 352.5 in 2014, 468.9 in 2015 and 482.1 mm in 2016. Almost 80% of the total precipitations occurred from October to March. The monthly average minima and maxima temperatures varied between 7 °C and 35 °C. The coldest and hottest months were, respectively, December to February and July and August. The soil of the orchard was highly calcareous (26.3% total $CaCO_3$) with a silty loam texture. The soil pH and the electrical conductivity (EC) were 7.4 and 1 mS/cm, respectively. The orchard management followed usual standards of pruning, fertilization and tillage. The cultural management practices were those conventionally used for this crop under these growing conditions. Those practices consisted of tillage (mechanical plowing and weed control), N-P-K fertilization spread over the soil, winter pruning and pest and disease control.

2.2. Plant Material

Experiments were performed on twenty-two-year-old trees of 'Mateur' and 'Achouri' pistachio cultivars grafted on *P. vera* and *P. atlantica* rootstocks. Grafting was realized at the second year after rootstock planting. The tree spacing in the orchard was 7 × 8 m. Male trees were placed in entire rows between each three female rows. For each treatment (scion–rootstock combination), at least five trees of comparable size and vigor were chosen for the monitoring.

2.3. Tree Vigor, Yield and Yield Efficiency

For the determination of scion-trunk-cross-sectional area (TCSA), the tree-trunk perimeter was measured at about 30 cm above the graft point when trees have reached the full dormancy (December). TCSA below the graft point was not determined because of the low position of grafting points. Fruit clusters were harvested manually at full maturity occurring in late August. The fruit is considered ripened when the hull becomes easily separated from the shell. For each tree, fruits were separated from clusters and weighed. Tree yield efficiency (g/cm^2) was calculated by dividing the fruit yield by the TCSA.

2.4. Physical Traits of Fruits

Fresh weights of fruit and nut as well as dry weights of nut and kernel were measured for 3 lots of 100 fruits per tree. Nut dehiscence rate was determined. The nut and kernel length (L), width (W) and thickness (T) were measured with a digital caliper for 25 fruits per tree following IPGRI descriptors for *Pistacia vera* L. [32]. Sphericity (ϕ) of fruits, nuts and kernels was calculated according to Equations (1) and (2), with Dg being the geometric diameter:

$$\phi = Dg/L * 100 \quad (1)$$

$$Dg = (L * W * T)^{1/3} \quad (2)$$

2.5. Kernel-Oil Content and Fatty-Acid Composition

The fat content of pistachio kernels, harvested in 2014, was extracted using hexane as solvent. A one-gram sample of grounded kernels was mixed with 3 mL of n-hexane. The mixture was sonicated in an ultrasonic bath (Model 3000512, JP Selecta S.A., Barcelona, Spain) with a constant frequency of 40 kHz at room temperature for 3 h before being centrifuged at 15,000 rpm for 10 min. The fat portion was recuperated by n-hexane evaporation using a stream of nitrogen. Fatty-acid methyl esters (FAMEs) were prepared according to the method described by Carbonell-Barrachina et al. [6] using identical chromatography set-up and conditions. Identification of FAMEs was carried out on 50 mg of extracting oil by comparison with authentic standards from Sigma-Aldrich. This analysis was run in triplicate, and results were expressed as percent of the total area.

Kernel oil extraction in 2015 and 2016 was performed using hexane as solvent and a VELP SCIENTIFICA soxhlet apparatus. Dried kernels were ground, weighed and introduced in soxhlet cartridges before immersion in hexane for 72 min at 130 °C, solvent washing for 20 min and finally solvent recover for 30 min. After complete evaporation of the solvent, the buckets containing the oil were weighed. The percent of fat content (FC) relative to dry matter was calculated.

2.6. Statistical Analyses

Data were subjected to one-way analysis of variance (ANOVA) using SPSS 20.0 software (Manugistics, Inc., Rockville, MD, USA). Duncan multiple-range test was used to compare the means. Differences were considered statistically significant at $p \leq 0.05$.

3. Results

3.1. Tree Vigor, Yield and Yield Efficiency

The TCSA showed no significant variation according to year and rootstock (Table 1). The cultivar and the scion–rootstock interaction, however, significantly affected tree vigor with higher trunk growth on *P. atlantica* and *P. vera* rootstocks for, respectively, 'Mateur' and 'Achouri' cultivars.

Table 1. Trunk-cross-sectional area (TCSA), average tree yield and yield efficiency (YE). Values (n = 5 to 8) followed by the same letter, within the same column, were not significantly different; NS: not significant; * Significant ($p \leq 0.05$).

	TCSA (cm^2)	**Yield (kg tree^{-1})**	**YE (g cm^{-2})**
ANOVA			
Year	NS	*	*
Cultivar	*	*	*
Rootstock	NS	NS	NS
Cultivar/Rootstock			
'Mateur'/*P. vera*	304.8 b ± 59.6	7.3 b ± 5.6	27.4 a ± 19.8
'Mateur'/*P. atlantica*	437.3 a ± 73.9	10.1 a ± 7.1	23.8 a ± 18.0
'Achouri'/*P. vera*	327.9 b ± 100.5	3 c ± 3.6	11.3 b ± 13.2
'Achouri'/*P. atlantica*	248.8 c ± 69.2	3.5 c ± 3.6	13.8 b ± 13.7

Average tree yield showed significant annual variation (Table 1). The highest yields were recorded in 2014 and 2016, while 2015 was marked by a significantly lower tree production, indicating 'off' year features. 'Mateur' was 2.6-fold more productive than 'Achouri' with a significantly higher yield for *P. atlantica* rootstock. No effect of rootstock was recorded for 'Achouri' with this parameter. Tree production (Figure 1) showed no significant effect of rootstock for both cultivars except a significantly higher yield of 'Mateur' on *P. atlantica* rootstock in 2016. Inter-annual variation of fruit yield differed with cultivar. 'Mateur' exhibited 'on' year behavior in 2014 and 2016. 'Achouri' only exhibited an 'on' year in 2014, while 2015 and 2016 were consecutively 'off' years. In the 'off' year (2015), the 'Mateur' production was, respectively, 55.8% and 71.2% lower than those of the 'on' years (2014 and 2016). 'Achouri' exhibited a yield reduction of 85.9% and 70.5%, respectively, in the 'off' years (2015 and 2016) in comparison with the 'on' year (2014). Yield efficiency of trees (Table 1) varied according to the year and the cultivar but was not influenced by the rootstock. 'Mateur' YE was about two-fold that of 'Achouri'.

3.2. Fruit Physical Traits

Data of Table 2 show significant effects of year and cultivar on fruit weight and nut dehiscence rate, but no effect of rootstock. Nut fresh and dry weights in 2014 and 2015 were significantly higher than in 2016, while nut dehiscence rate was significantly lower in 2014 than in 2015 and 2016 (data not shown). Fruit weight and almost all fruit size and shape parameters showed significant variation from year to year, with higher values in 2015 (Tables 2 and 3). Fruits and nuts of 'Mateur' were significantly heavier, longer, wider and thicker than those of 'Achouri'. The same was the case concerning the length and the width of 'Mateur' kernel. The average thickness of the 'Achouri' kernel, however, was significantly higher than that of 'Mateur'. A minor effect due to rootstock was recorded for these parameters. The thickness of fruits, the length and the width of nuts, and the thickness of kernels had more variation according to rootstock with significantly higher values on *P. vera* rootstock. The scion–rootstock combination data revealed few significant differences. The 'Mateur' cultivar produced shorter nuts and thinner kernels on *P. atlantica* rootstock. Fruit sphericity (ϕ) varied significantly from year to year with higher values in 2016.

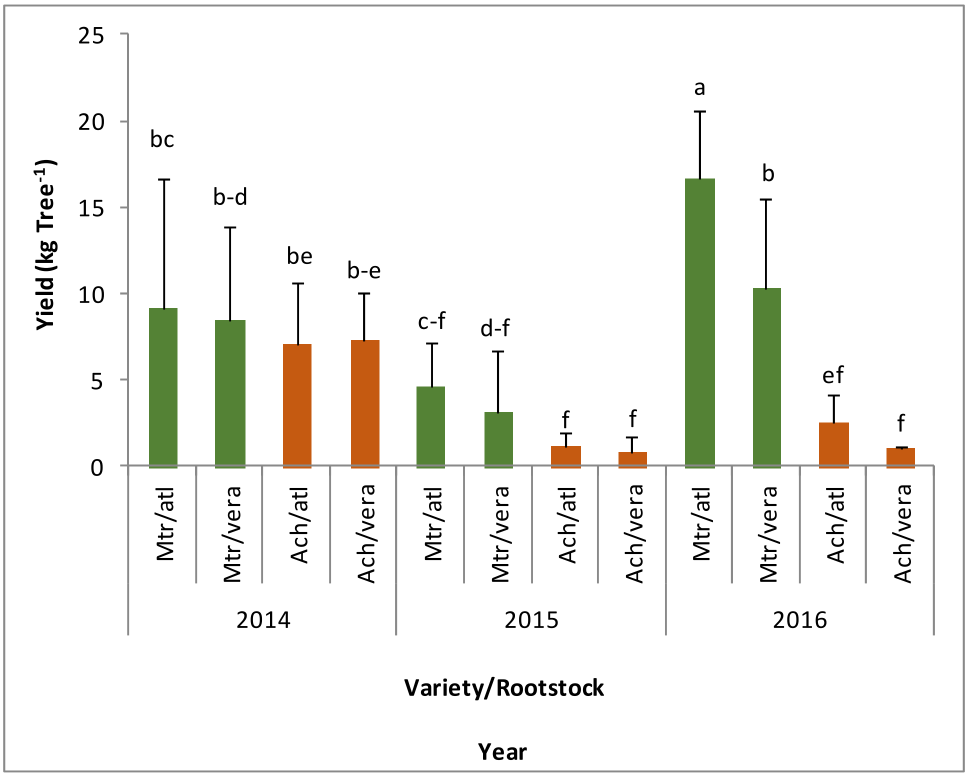

Figure 1. Effect of cultivar–rootstock interaction on annual fruit yield of pistachio. Mtr: Mateur; Ach: Achouri; atl: *P. atlantica*; vera: *P. vera*; Columns with the same letter are not significantly different (ANOVA, $p \leq 0.05$).

Table 2. Mean weights (g) of fresh fruit (FFW) and nut (NFW), dry weights of nut (NDW) and kernel (KDW), and nut dehiscence rate (DR) in percent (%).

Treatment	FFW	N FW	NDW	KDW	DR
ANOVA					
Year	*	*	*	NS	*
Cultivar	*	*	*	*	*
Rootstock	NS	NS	NS	NS	NS
Cultivar * Rootstock	*	*	*	*	*
Cultivar/Rootstock					
‘Mateur’/*P. vera*	209.6 a ± 30.8	124.4 a ± 14.8	88.6 a ± 12.4	52.2 a ± 17.9	53.0 b ± 52.4
‘Mateur’/*P. atlantica*	215.0 a ± 33.52	121.3 a ± 18.8	91.4 a ± 28.0	44.3 ab ± 10.1	63.5 ab ± 30.7
‘Achouri’/*P. vera*	173.2 b ± 30.52	94.6 b ± 23.9	74.1 b ± 19.8	31.0 c ± 10.4	83.4 a ± 19.9
‘Achouri’/*P. atlantica*	177.1 b ± 44.68	101.9 b ± 26.8	74.9 ab ± 17.4	39.0 bc ± 12.6	82.6 a ± 19.5

Values (mean of three lots of 100 fruits per tree) followed by the same letter, within the same column, are not significantly different ($p \leq 0.05$); Kernel weight values and corresponding statistical analysis were for 2015 and 2016 only; NS: not significant; * Significant.

3.3. Kernel Oil Content and Fatty-Acid Profile

The oil content of pistachio kernels ranged between 40.7% and 46.8% (Table 4). No significant variation was found according to year, cultivar, rootstock and scion–rootstock combination. However, a clear tendency of increasing kernel oil content on *P. atlantica* rootstock can be observed for both studied cultivars.

Table 3. Length, width, thickness (mm) and sphericity of fruit, nut and kernel. Values (mean of at least 25 fruits per tree) followed by the same letter, within the same column, are not significantly different ($p \leq 0.05$); NS: not significant; * Significant; ϕ: Sphericity.

	Fruit				**Nut**				**Kernel**			
Treatment	**Length**	**Width**	**Thickness**	**ϕ**	**Length**	**Width**	**Thickness**	**ϕ**	**Length**	**Width**	**Thickness**	**ϕ**
ANOVA												
Year	*	*	*	*	*	*	*	*	*	*	*	*
Cultivar	*	*	*	NS	*	*	*	NS	*	NS	*	NS
Rootstock	NS	NS	*	NS	*	*	NS	NS	NS	NS	*	NS
'Mateur'/*P. vera*	24.7 b ± 2.1	13.4 a ± 1.4	12.4 a ± 1.4	64.8 a	21.3 a ± 1.6	11.8 a ± 1.0	10.0 b ± 0.9	65.2 a	16.3 a ± 2.7	8.4 a ± 2.0	8.0 a ± 0.9	62.8 ab
'Mateur'/P. atlantica	24.8 a ± 2.1	13.6 a ± 1.5	12.3 a ± 1.2	64.6 a	20.3 b ± 1.4	11.8 a ± 0.9	10.4 a ± 0.9	66.6 a	16.3 a ± 1.4	8.5 a ± 3.6	7.8 b ± 0.6	62.8 ab
'Achouri'/*P. vera*	23.4 a ± 2.12	12.5 b ± 1.4	11.6 b ± 1.3	64.4 a	20.1 c ± 1.3	11.0 b ± 0.8	10.0 b ± 1.1	65.0 a	15.5 b ± 1.3	8.5 a ± 6.7	7.7 b ± 0.8	63.5 a
'Achouri'/*P. atlantica*	23.2 b ± 2.2	12.6 b ± 5.1	11.6 b ± 1.2	64.7 a	20.1 c ± 1.5	10.9 c ± 0.9	10.5 b ± 2.1	65.2 a	15.8 b ± 1.7	8.0 a ± 1.0	7.7 b ± 0.7	62.5 b

Table 4. Fat content and fatty-acid profile of pistachio kernels.

Treatment	**Fat Content (%)**	**C16:0**	**C16:1**	**C18:0**	**C18:1**	**C18:2**	**C18:3**	**C20:0**	**C20:1**	**O/L**	**UFAs/SFAs**
ANOVA											
Year	NS	*	*	*	*	NS	NS	NS	NS	NS	NS
Cultivar	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rootstock	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
'Mateur'/*P. vera*	43.2 a ± 4.7	9.88 a	0.78 a	1.83 b	68.94 a	18.03 a	0.27 a	0.16 ab	0.38 a	4.4 a	7.8 a
'Mateur'/*P. atlantica*	45.7 a ± 7.5	9.98 a	0.79 a	2.12 a	70.22 a	16.70 a	0.29 a	0.17 a	0.38 a	4.5 a	7.5 a
'Achouri'/*P. vera*	40.7 a ± 4.5	9.99 a	0.79 a	2.01 ab	69.41 a	17.28 a	0.26 a	0.14 b	0.35 a	4.4 a	7.6 a
'Achouri'/*P. atlantica*	46.8 a ± 4.8	9.81 a	0.74 a	2.04 ab	69.26 a	17.64 a	0.28 a	0.15 ab	0.37 a	3.8 a	7.8 a

Fat content values, Oleic/Linoleic acid ratio (O/L) and Unsaturated/Saturated fatty-acid ratio (UFAs/SFAs) for 2015 and 2016 only; Fatty acids: C16:0: Palmitic acid; C16:1: Palmitoleic acid; C18:0: Stearic acid; C18:1: Oleic acid; C18:2: Linoleic acid; C18:3: Linolenic acid; C20:0: Arachidic acid; and C20:1: Gadoleic acid; Values followed by the same letter, within the same column, are not significantly different ($p < 0.05$); NS: not significant ($p < 0.05$); * Significant ($p \leq 0.05$).

Eight fatty acids were found in pistachio kernels (Table 4): palmitic acid (C16:0), palmitoleic acid (C16:1), stearic acid (C18:0), oleic acid (C18:1), linoleic acid (C18:2), linoleic acid (C18:3), arachidic acid (C20:0) and gadoleic acid (C20:1). Variations on the composition of fatty acids were observed according to the year, especially palmitic, palmitoleic, stearic and oleic acids. Linolenic, arachidic and gadoleic acids were more stable and in minor proportions (0.14–0.38%). In all samples, unsaturated (UFAs) and saturated fatty acids (SFAs) showed little variation and ranged between 88.1% and 88.7% and 11.5% and 12.3%, respectively. The UFA–SFA ratios were between 7.5 and 7.8. The mono-saturated oleic acid was the major fatty acid with little variation (67.62% to 70.41%). Linoleic acid content varied from 16.7% to 18.7%. The oleic/linoleic acid ratios were between 3.8 and 4.5. Obtained results showed no effect of cultivar or rootstock on kernel fatty acid profile for all the experimental periods. The scion–rootstock combination, however, influenced the stearic acid profile for the 'Mateur' cultivar with significantly higher amounts on *P. atlantica* rootstock.

4. Discussion

4.1. Tree Vigor, Yield and Yield Efficiency

The scion–rootstock interaction has been demonstrated to have a significant impact on growth and yield of pistachio [26,31,33,34]. The results of this study clearly established this effect. 'Mateur' with higher vigor (TCSA) exhibited higher yield performance than 'Achouri'. The rootstock had no significant effect on TCSA, yield and yield efficiency.

Data of average tree yield of 'Mateur' cultivar in this study were consistent with those claimed by Oukabli [35] in rainy conditions (9.7 kg tree^{-1}). In the drought conditions of Sfax (southeast Tunisia), the average yield of this cultivar was 2.5 kg/tree [36]. The lower performance of 'Achouri' suggested low acclimation capacity to the tested bio-climatic conditions. Lacasta et al. [22,26] reported higher yield production of 'Achouri' compared to 'Mateur' under the rainfed conditions of central Spain. Rootstock had a significant effect on 'Mateur' fruit yield with higher performance for *P. atlantica* rootstock. These results were consistent with those of Carbonell-Barrachina et al. [6] on the Kerman variety that produced significantly higher yield on *P. atlantica* than on *P. integerrima* and *P. terebinthus* rootstocks. Similarly, Lacasta et al. [22] reported higher productivity of eight cultivars including 'Achouri' (8.4 kg/tree) on *P. atlantica* rootstock compared to *P. terebinthus*, *P. vera* and *P. integerrima*. This was not the case in our study for the 'Achouri' cultivar with any rootstock effect noted. The lower tree growth and productivity of the 'Achouri' cultivar compared to 'Mateur' may be explained by the lesser adaptive capacity of this cultivar to Mornag rainfed conditions.

An alternate bearing is a common trait of pistachio [37,38]. This phenomenon is accentuated by warm climate and rainfed conditions. Its intensity may vary according to the cultivar. Yield variation between the 'off' and the 'on' year can reach three- to five-fold for the Kerman pistachio variety [6]. In the case of this study, this variation did not reach two-fold. Before building up results from a longer monitoring period, these results cannot give exhaustive information on the alternate bearing intensity of studied cultivars.

4.2. Physical Traits of Fruits

The physical characteristics of fruits can be influenced by cultivar, rootstock and bioclimatic features [39–42]. Data of 'Mateur' dry weight in shell nuts in this study are comparable to those obtained by Vargas et al. [43] in the climatic conditions of the northern Mediterranean (IRTA-Mas Bové—Spain). Those of 'Achouri' were, however, lower (74.5 g) than those obtained by these authors (100 g).

Shell splitting is an attractive trait of pistachio nuts that determines the choice of variety in the market. Its occurrence depends on the growth of kernel and nutshell [44]. Factors that enhance kernel size concerning shell size, such as irrigation management and crop load, are thought to promote shell splitting [22]. Climatic conditions in rainfed orchards could have a relevant impact on the seasonal growth of trees and consequently fruit quality. This may, partly, explain the annual variation of DR in this study, which was lower in 2014 than in 2015 and 2016. Shell splitting is closely linked to the cultivar [39]. In this study, significant differences of DR were shown between 'Mateur' and 'Achouri' cultivars. The nut split rate was significantly higher for 'Achouri' than for 'Mateur'. This was in accordance with Vargas et al. [35] in terms of variation, but the DR values in our experiments were higher (82.9% vs. 66% for 'Achouri' and 58.5% vs. 43% for 'Mateur'). It was reported that the DR of 'Achouri' nuts ranged between 55 and 90% [43,45]. For both studied cultivars, no effect of rootstock was observed on fruit weight and DR. Similarly, the 'Bianca' pistachio cultivar showed no variation of DR with rootstock [33]. Other pistachio cultivars, however, have been reported to exhibit significant differences in nut splitting rate according to the rootstock [41,46].

Fruit size and shape are important parameters that are considered in marketing and in post-harvest processing, such as design and setting of equipment [47]. Fruit sizes of 'Mateur' and 'Achouri' in this study were comparable to those of Vargas et al. [43]. Sphericity of fruits, nuts and kernels of both studied cultivars varied from 60.2% to 66.7%, indicating an elongated shape. The most ovoid-shaped Iranian pistachios (Akbari, Badami, Kalle-Ghuchi, Momtaz and Ohadi) were reported to range between 68.2% and 79.8% [47]. Overall, the year of harvest and, to a lesser degree, the cultivar had the most important effects on fruit size and shape of pistachio in this study. The influence of rootstock on these parameters was lower despite a tendency of 'Mateur' and 'Achouri' cultivars to produce smaller fruits on *P. atlantica* rootstock. The 'Achouri' cultivar produced significantly lower spherical kernels on *P. atlantica* rootstock.

4.3. Fat Content and Fatty-Acid Profile

Kernel fat content of pistachio samples varied from 45.25% in 2015 to 42.92% in 2016 (Table 4). No significant variation was recorded between the two studied cultivars and rootstocks as well as their interactions. Fat content values recorded here are similar to those reported by Carbonell-Barrachina et al. [6] for the Kerman pistachio cultivar but lower than those obtained for other pistachio cultivars [4,5]. The fatty-acid composition of kernel samples of studied pistachio cultivars varied significantly over years, but not according to cultivar, rootstock or cultivar–rootstock interaction in our experimental conditions. Significant variation in fatty-acid profile with rootstock was found for immature pistachio kernels [48]. Noguera-Artiaga et al. [30] found no significant variation with rootstock of these components except for the polyunsaturated α-Linolenic acid (C18:3). The content of oleic acid (67.62–70.41%), the major mono-unsaturated fatty acid in pistachio kernel samples, had similar percentages as previously found in Italian (70.1–71.5%), Turkish (53.16–72.63%) and Iranian (51.8–71.23%) kernels [4,5,49]. Similarly, data of linoleic acid contents (16.7–18.7%) were in agreement with those reported for Iranian (17.36–35.16%) and Turkish (16.58 and 35.40%) varieties [48,49]. The comparison of fatty-acid composition of 'Mateur' cultivar with that reported by Chahed et al. [3] in the southern area of Tunisia (Sfax) revealed higher palmitic, palmitoleic, stearic and oleic acids in Sfax than in the Mornag (northern) area. Conversely, higher and equal rates of linoleic and linolenic acids were found in Mornag compared to Sfax (7.6% and 0.2% for linoleic and linolenic acids, respectively). Similar geographical variations were reported by Chahed et al. [3] in oil composition of pistachio kernels originating in 'Mateur' and Sfax areas. This may be attributed to the effect of plant water status on pistachio nut quality [6,12]. The quality index based on the oleic/linoleic (O/L) acid ratio is commonly used for fat-quality assessment to predict chemical stability and shelf life of the oil [1]. The higher this ratio, the greater the stability of the oil. None of the studied parameters here had an effect on this index. Recorded values (3.8–4.5) were comparable to Greek and Italian cultivars (3.9–5.9) but higher than those reported by Tsantili et al. [4] and Esteki et al. [1] for Iranian pistachio cultivars (1.9–3.7). The total rates of unsaturated (UFAs) and saturated fatty acids (SFAs) as well as the UFA/SFA ratio results were in agreement with other pistachio research findings [4,5,48]. The nut pistachio quality of these cultivar–rootstock combinations may contribute to compensating for the reduced financial impact of relatively low-productivity orchards under these rainfed conditions.

5. Conclusions

This work showed high annual variation for the studied parameter for 'Mateur' and 'Achouri' pistachio cultivars grown under rainfed conditions of the Mornag semi-arid climate. Seasonal climatic features were shown to play a major role in plant growth, yield and quality in these growing conditions. The low productivity of 'Achouri' compared to 'Mateur' seems to be linked to less adaptation capacity. All studied parameters appeared to be dependent on cultivar–rootstock combination except for the fatty-acid profile of kernel oil. Technological traits of kernel oils revealed a high quality product that should be valorized to promote higher farmer incomes in this region. Obtained results support the alternative use of *P. atlantica* rootstock in Tunisian pistachio orchards to increase biodiversity and crop adaptation. Pistachio is a great alternative for farmers in the Mediterranean Basin given its low environmental impact and the appreciation of its fruits by consumers.

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