

Pomological and physical attributes of pistachio (*Pistacia vera* L.) varieties grown in west-central Tunisia

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Abstract - Pomological attributes and geometric properties of four pistachio cultivars (Mateur, Elguetar, Kerman, Ohadi) grown in the orchard of the Regional Center of Agriculture Research Sidi Bouzid Tunisia, were studied. This work aims to select suitable cultivars for these environmental conditions and determine important physical properties useful for the design of various separating, handling, storing and drying equipment. Agronomical traits such as production, trunk cross sectional area, yield efficiency, number of grapes/tree, number of fruits/grapes, number of fruits /100g, kernels weight, kernel dry weight /nut and dry weight ratio were evaluated. Physical properties of pistachio kernel such as length, width, thickness, arithmetic diameter, geometric diameter, sphericity and surface area, were determined. Our results showed higher yield for Mateur cultivar than the others cultivars. Ohadi showed higher fruit dimensions, arithmetic diameter, geometric diameter and sphericity, on the other hand this variety showed lower level of splits fruits (52%) and a higher level of blanks rate (26%). The choice of the most adapted and effective pistachio varieties in terms of vigour, production and geometric properties in the studied area are as follows: the first is the Mateur variety followed by Ohadi and Kerman and the last cultivar is Elguetar.

Keywords: pistachio, nut, kernel, geometric properties

1. Introduction

Pistachio [*Pistacia Vera*, Anacardiaceae], is an edible seed from the pistachio tree grown broadly in hot-dry regions of the Middle East, Mediterranean, and America (Moslehi et al. 2015 and references therein). The world production of pistachio is around 917,000 tons with a cultivated area of around 496,500 ha (FAOSTAT 2015) and the main world producers of pistachio nuts are Iran, USA, Turkey, Syria and China.

In Tunisia, pistachio production reached 2500 tons in 2015 (Ministère de l'Agriculture et des Ressources Hydrauliques 2015). The Tunisian cultivars Mateur and Elguetar are adapted to low altitudes and can perform well also in temperate zones near the coast. The Mateur variety, which resembles the Syrian variety Achoury (Jacquy 1973), included three main genotypes: male precocious 25A, male late 40A and femelle 11 D (Ghorbel and Kchouk 1996) and is the only widely employed variety in the country (Ghorbel and Kchouk 1998). Others Iranian and Syrian varieties were introduced in the country. The Ohadi variety is one of the major pistachio cultivars grown in Iran and produces attractive nuts that are slightly smaller than Kerman nuts. Kerman, a California developed cultivar, was selected from seed lot P.I. 86372 in 1936 (collected by W.E. Whitehouse - 1929) and released for trial by the USDA Plant Introduction Station, Chico CA in 1957 (Parfitt 1997). Currently there are 44,000 ha planted with pistachio, corresponding to about 2730 million trees. Irrigated areas cover about 2000 ha while non-irrigated orchards consist of 42,000 ha. Pistachio trees represent about 11% of the country's total area planted with stone fruit trees (excluding date, palm and olive trees). The most important pistachio producing zones are Kasserine, Sidi Bouzid, Gafsa, Sfax and Kairouan. The area of Kasserine contributes with 29% to the natural pistachio production, Sidi Bouzid (22%) and Gafsa (17%). However, production and profitability are still relatively low due to drought, late bearing and uncontrolled pollination.

In recent years, there has been much debate on the issue of mechanized production, because exporting corps lacking of the required standards and quality would not be very profitable (Rezvan et al. 2015). Thus, the knowledge of some important physical properties such as shape, size, volume, surface area, grain weights, density, porosity, angle of repose, of different grains is necessary for the design of



various harvesting, handling, drying, cleaning, separating, packing, storing, and processing of agricultural products (Heidarbeigi et al. 2008; Mohsenin 1980). Aviara et al. (1999) noted that the moisture-dependent characteristics of the physical properties of agricultural products have an effect on the adjustment and performance of processing machines. Hsu et al. (1991) studied the physical and thermal properties of Kerman cultivar of pistachio nut. They investigated some of the moisture-dependent gravimetric properties (bulk density and specific gravity) of this variety. Kashaninejad et al. (2005) also investigated some moisture-dependent physical properties of dried pistachio nut and its kernel for Ohadi variety.

At the Agriculture Research Center of Sidi Bouzid, a collection of pistachio cultivars adapted to Mediterranean conditions is under process. Thus, the present study aims to evaluate (i) pomological traits (production, trunk cross sectional area, cumulative yield, yield efficiency, weight of 100 kernels, number of nuts and kernels in 100g) and (ii) their geometric properties (length, width, thickness, geometric and arithmetic mean diameter, sphericity and surface area) useful for designing handling and processing equipment.

2. Materials and methods

2.1. Plant material

The experiment orchard (2 ha) was located in the experimental station of the Agriculture Research Center (CRRA, Sidi Bouzid) in Central Tunisia. The production area is characterized by a semiarid Mediterranean climate with an annual rainfall of 200 mm irregularly distributed over the growing season, a reference evapo-transpiration (ET_o) of more than 1300 mm and heavy and calcareous soil, with 30.5% total calcium carbonate, 8.8% active lime, water pH 7.7, and a clay-sandy texture. Ten-year-old pistachio trees, on *P. Vera* rootstock, of two Tunisian cultivars Mateur and Elguetar and two Iranian varieties Kerman and Ohadi were studied. Trees were trained to the standard open vase system and planted at a spacing of 6×4 m. Trees were grown under standard conditions of irrigation, fertilization, pruning, pollination and pest and disease control. The surveyed trees were selected for uniform trunk and canopy size. The measures relating to fruit dimensions and morphological and quality parameters of the fruit and kernels were carried out on a sample of 100 fruits taken at random from trees.

2.2. Growth measurement

Trunk girths were measured during the dormant season at 30 cm above the graft union, and the trunk cross-sectional area (TCSA) was calculated. Cumulative yield per tree and yield efficiency (cumulative yield in kilograms per final TCSA) of each scion–stock were computed from the harvest data.

2.3. Production, fruit sampling and evaluation of pomological traits

Harvesting date and annual yield were evaluated in each independent variety. Fruits were handpicked at commercial maturity and assessed by peel fruit color which varies from light-yellow to deep green and fruit dehiscence. Fruits were considered ripe in the tree when their growth had ceased, exhibited orange-red ground color, and the hull was dehiscent. Yield (kg/tree) was determined and a representative fruit sample (100 fruits) was taken for pomological evaluations. The number of grapes per tree and the fruits number per grape were recorded. Pomological evaluation was done according to the pistachio descriptors of International Plant Genetic Resources Institute (IPGR) (Anonymous, 1997). Nut and kernel characteristics such as: the mean fruit weight, 100 kernel weight (g), kernel dry weight/nut and dry weight x 100 (kernel percentages) were calculated using an electronic balance of 0.001 g sensitivity. Split nuts (%), blank production (%), infested nuts and number of nuts in 100 g, were evaluated.

2.4. Geometric properties

To determine the average size of the nut and kernel, a sample of 100 nuts was randomly picked and their three major dimensions, namely length, width and thickness, were measured using a digital caliper having a resolution of 0.01 mm. The average diameter of these nuts was calculated by using arithmetic and geometric mean of the three axial dimensions. The arithmetic mean diameter, D_a , and

geometric mean diameter, Dg, of the nut were calculated by using the following relationships (Olajide et al 2000; Galedar et al 2008):

$$Da = (L+W+T)/3, (1) \text{ and}$$

$$Dg = (LWT)^{1/3} (2)$$

where: Da: arithmetic mean diameter (mm), Dg: geometric mean diameter (mm), L: length (mm), W: width (mm), T: thickness (mm).

The sphericity (%) was calculated by using the following relationship [10]:

$$\Phi (\%) = (LWT)^{1/3} / L. (3)$$

The surface area of pistachio nuts was found by analogy with a sphere of the same geometric mean diameter. In obtaining the surface area, S (mm²), of the samples, the equation given by McCabe et al. (1986) was used as:

$$S = \pi Dg^2 (4)$$

3. Results and discussion

3.1. Tree vigour and yield characteristics

The greatest TCSA was shown with Ohadi whereas the lowest TCSA was shown on Kerman (Table 1). There was no significant difference in cumulative yield among Ohadi, Elguetar and Kerman. Mateur presented significant difference with the three others varieties. The best yield efficiency was found on Kerman but it did not significantly differ from Mateur. In contrast, the lowest yield efficiency was found on 'Ohadi' although it did not differ from Elguetar. This is probably due to their low vigour and so low TCSA. The cumulative yield was greatest on Mateur, and it differ statistically from the three others cultivars.

Table 1. Trunk cross-sectional area (TCSA), cumulative production and yield efficiency of the studied pistachio varieties.

Cultivar	TCSA (cm ²)	Cumulative yield (kg tree ⁻¹)	Yield efficiency (kg cm ⁻²)
Mateur	47.51	7.81	0.16
Elguetar	43.00	3.34	0.07
Ohadi	70.84	3.85	0.05
Kerman	23.74	4.36	0.18

TCSA: trunk cross- sectional area. Mean separation within columns by Duncan's multiple range tests at (p≤ 0.05).

3.2. Production

Harvest date varied from seventeen august for Mateur, Kerman and Elguetar varieties to twelve september for Ohadi variety. Yield per tree is a useful parameter for the choice of the plant variety (Table 2). The results show that Mateur variety is the most productive one with 4.1 kg/ tree. The least productive variety is Elguetar with average of 1.4 kg/ tree. Kerman and Ohadi varieties produce 2.1 kg/ tree. Ghrab et al. (2005) reported that Ohadi cultivar was more productive (4.84 kg/tree) than the local cultivar Mateur (2.53 kg/tree) during the fifteen years of study. During some consecutive years, a low production is observed for both cultivars instead of a cycle of "on" and "off" yield.

Table 2. Agronomic fruit quality traits of the four pistachio varieties (Mateur, Kerman, Elguetar, Ohadi).

Variety	Mateur	Kerman	Elguetar	Ohadi
Number of Grapes/tree	140	60	48	96
Number of fruits/grape	35	21	19	13
Number of fruits /100g	49	55	114	56
Average yield/tree (kg)	4.1 ± 0.1 ^a	2.1 ± 0.3 ^b	1.4 ± 0.2 ^c	2.1 ± 0.1 ^b
Mean grape weight (g)	29.48 ± 0.3 ^a	35.33 ± 0.2 ^b	29.19 ± 0.1 ^a	21.96 ± 0.3 ^c
Weight of 100 fruits (g)	223.1 ± 0.1 ^a	218.3 ± 0.2 ^a	117.2 ± 0.1 ^b	214.3 ± 0.3 ^a
Fruit weight (in hull) (g)	2.23 ± 0.2 ^a	2.18 ± 0.3 ^a	1.17 ± 0.1 ^b	2.14 ± 0.3 ^a

3.3. Dry weight of 100 fruits and 100 kernels

The dry weight of 100 nuts and kernels is another interesting commercial parameter for comparison between varieties. Kerman variety gives the greater 100 nuts weight 87g, followed by Ohadi variety (73g), Mateur (70 g) and Elguetar only 37 g. For the 100 kernels, the Ohadi variety gives the greater

value (62g) followed by Kerman (53g), Mateur (51g) and Elguetar (26g). The analysis of variance of the two parameters revealed a highly significant difference between the samples which can use as criteria for comparing the four varieties.

3.4. Number of fruits in 100g

In terms of yield, the number of fruit per 100g is an adequate parameter and the results recapitulated in Table 2 allow a comparison between the four varieties. The Elguetar variety presents 114 fruits in 100g as highest value; while Mateur variety gives the lowest number, 49. These values are closely related to the dimensions previously described namely length, width and diameter of the fruit. Kerman and Ohadi varieties have respectively 55 and 56 seeds since they recorded the same dry weight of 100 fruits. The analysis of variance of three-dimension revealed a highly significant difference between varieties. Ak (1992) stated that 100 nut weights were found as 102.10 g and 125.00 g in Ohadi cultivar in Ceylanpinar and Gaziantep, respectively. Besides, nut weight values were changed according to the years. 100 kernel weights in Ohadi x P. Vera combination were determined as 63.00 g and 47.00 g in 1989 and 1990, respectively (Ak 1992). Also, these characteristics may be influenced by differences in fruit set percentages.

3.5. The fruit weight

This is a decisive parameter in the selection of varieties in terms of economic importance. The obtained and recapitulated measurements in Table 3 show that Ohadi variety has the greater kernel DW/nut DW, this variety has the lightest epicarp compared to other varieties. The average kernel weight was 0.71 g for 'Ohadi', followed by Kerman (0.67g), Mateur (0.60g) and Elguetar (0.34g). Kernels dry weight and dry weight fruit ratio gives idea on the economic profitability of the four varieties. The Ohadi variety showed the highest kernel DW/nut DW ratio this is an important criterion for the commercialization of this variety.

Table 3. Mean fruit weight for 'Mateur', 'Kerman', 'Elguetar' and 'Ohadi' cultivars

Cultivar	Mateur	Kerman	Elguetar	Ohadi
In hull FW	1.94	1.81	0.87	1.78
In shell FW	1.10	1.23	0.62	1.29
Kernels FW	0.60	0.67	0.34	0.71
In hull DW	0.82	1.0	0.49	0.86
In shell DW	0.70	0.87	0.37	0.73
Kernels DW	0.51	0.53	0.26	0.57
% kernel DW/nut DW	72.85	60.91	70.27	84.93

DW= Dry Weight, FW= Fresh Weight

3.6. Physical parameters

The obtained results revealed that Ohadi variety gets the highest dimensions, 18.37 mm for length and 11.76 mm for width (Table 4; Figure 1). The 'Ohadi' fruit was thicker, larger and longer than the three others varieties whereas the kernel of Elguetar variety has the lowest dimensions (length 14.24 mm, width 8.08 mm and thickness 6.67 mm). These dimension differences can be explained either by the genetic background, the age of the trees or the climatic conditions of the planting zone. These characteristics confirm results observed by other authors working with 'Ohadi' (Seyfettin et al 1998) and 'Mateur' (Vargas et al 1997).

Table 4. Physical characteristics of kernels for 'Mateur', 'Kerman' 'Elguetar' and 'Ohadi' cultivars.

Cultivar	Mateur	Kerman	Elguetar	Ohadi
Length (mm)	17.78	18.22	14.24	18.37
Width (mm)	10.13	9.62	8.08	11.76
Thickness (mm)	8.84	7.94	6.67	10.86
Thickness / Length	0.49	0.43	0.46	0.59
Da	12.25	11.92	9.66	13.66
Dg	11.39	10.89	8.95	12.94
Sphericity (%)	0.64	0.59	0.62	0.70
Surface area (mm ²)	407.35	372.37	251.52	525.77

Da= arithmetic diameter; Dg= geometric diameter

The ratio thickness/ length of the fruit is an important indicator for economic selection. Our results showed that the Ohadi variety presents the highest ratio (0.59) while Kerman variety showed the lowest (0.43). Ghrab et al. 2005 reported that, concerning the fruit characteristics, the Ohadi cultivar produced fruit with a higher weight and a larger size.

The average dimensions, sphericity and surface area of pistachio kernels are given in Table 4. The arithmetic mean and the geometric mean can be used to determine the average diameters of kernels. Similar results were found in the Mateur, Kerman, and Ohadi varieties whereas Elguetar showed the smallest dimensions. The values of sphericity were calculated individually with Eq. (3) by using the data on geometric mean diameter and the major axis of the wild pistachio kernel, and the results obtained are presented in Table 4. The sphericity of the pistachio kernel varied from 59% in Kerman to 70% for Ohadi. The variation of the surface area of the kernels varieties is plotted in Table 4. These results indicate that the surface area varied from 251 mm² in the Elguetar variety to 525 mm² in the Ohadi variety. In general, results of physical study showed that by increasing the moisture content from 5 to 20%, the average length, width, thickness, geometric mean diameter, sphericity and unit mass of unsplit pistachio nuts increased linearly (Maghsoudi et al 2012).

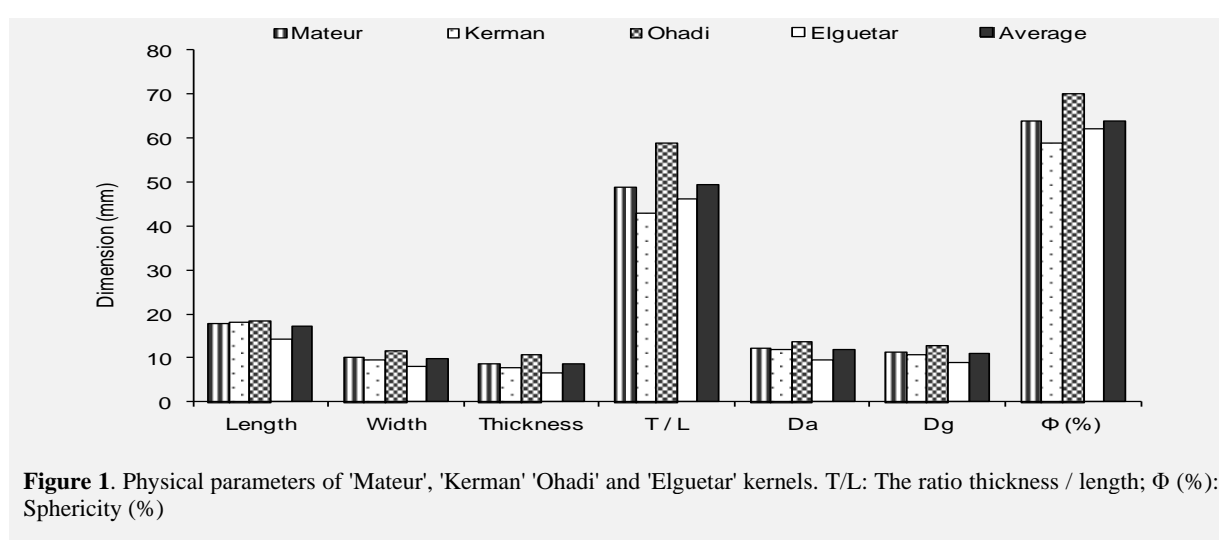
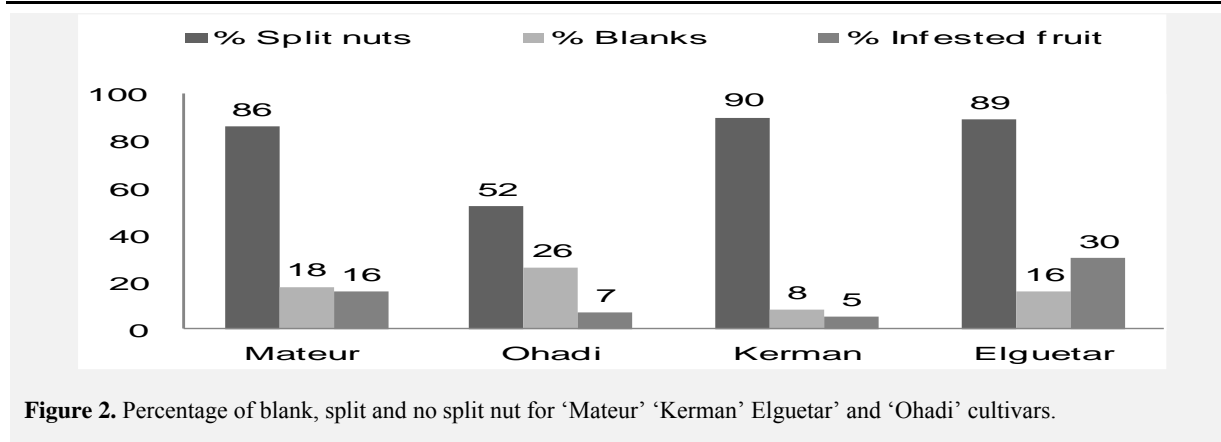


Figure 1. Physical parameters of 'Mateur', 'Kerman', 'Ohadi' and 'Elguetar' kernels. T/L: The ratio thickness / length; Φ (%): Sphericity (%)

3.7. Fruits dehiscence rate

The percentage of dehiscent fruits plays an important role in the marketing of pistachios; in fact, many consumers appreciate the benefits of open pistachio nuts to those with closed shells. This fruit quality trait can vary among varieties and among samples from the same variety depending on genetic and environment factors. Kerman variety records the highest rate of fruit dehiscence (90%), followed by Elguetar variety (89%), Mateur variety (86%) and Ohadi variety (52%) (Figure 2). Pistachio dehiscence is a physical phenomenon resulting from outward pressure from the developing kernel on the shell (Polito and Pinney 1999). Crane and Iwakiri (1981) reported that endocarp dehiscence is a biochemical phenomenon associated with seed growth and development. Regarding the production of seedless fruits, Ohadi showed the greatest rate of blanks (26%) followed by Mateur (18%) and Elguetar (16%). The production of blanks is a common trait to several cultivars of *Pistacia* species. Embryo abortion in pistachio has been variously attributed to lack of pollination, poor nutrition, rainfall during anthesis and to water deficit during seed development (Crane and Iwakiri 1981). Kader et al. (1982) reported that shell staining is an indicator of development, pathogen, and insect problems prior to harvest. Post-fertilisation aberrations in pistachio have been reported to result in low seed set, with a high rate of embryo abortion leading to seedless (blank) or small seeded (semi-blank) fruits (Grundwag and Fahn 1969). Blank development also occurs later in the season and has been explained as the result of the inability of the tree to provide sufficient assimilate to complete development of its entire crop. Inadequate boron and water stress are also indicated as causes of blank formation (Freeman and Ferguson 1995).



4. Conclusion

The obtained results permit to show significant differences between the four studied varieties in regard to their agronomic attributes such as the vigour, the productivity and fruit and kernels characteristics. The choice of the most adapted and effective pistachio varieties in terms of vigour and production in the study area are as follows: the first is the Mateur variety followed by Ohadi and the last is Elguetar.

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5. References

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