

Pomological Properties and Proximate Analysis of Native Chestnut (*Castanea sativa* Mill.) Germplasm from Isparta, Turkey

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Abstract

There are some natural stands of chestnut in Isparta (Turkey) with a great number of different genotypes. Our purpose was to select suitable genotypes combining general quality, large nut size and suitability for chestnut paste. In 2002, native chestnut populations were surveyed with respect to health, tree vigor and nut size. After the accessions with small nut size were eliminated, 32 native chestnut trees were chosen for evaluating morphological, phenological and pomological characters according to UPOV methods during two growing seasons (2003-2004). Most of the accessions ripened in the first half of October. Average nut weight ranged between 10.66 g and 31.73 g (100 and 39 nuts per kg). Shell thickness varied from 0.26 mm to 0.52 mm. The highest kernel weight was 28.22 g, and, the lowest was 9.11 g. Two accessions (D-22 and D-49) had typical chestnut color according to $L^*a^*b^*$ values. Peeling of the testa varied from difficult to moderately easy and testa penetration into the seed was moderate. Thirteen promising accessions (designated D-48, D-5, D-49, D-50, D-26, D-51, D-28, D-30, D-25, D-9, D-18, D-41 and D-10) were selected with the weighted ranking method on the basis of yield, nut and kernel characteristics for conservation of *C. sativa* germplasm and breeding efforts. Chemical analyses were also conducted on these 13 accessions. The range of constituents (dry matter basis) were as follows: ash 1.3 to 2.8 g 100g⁻¹; crude protein 6.57 to 11.05 g 100g⁻¹; starch 26.03 to 35.21 g 100g⁻¹; total sugar 9.17 to 22.48 g 100g⁻¹ and fat 0.62 to 2.81 g 100g⁻¹.

Cultivated chestnut trees belong to the species *Castanea sativa* (Mill.) (European chestnut), *C. dentata* (Borkh.) (American chestnut), *C. mollissima* (Bl.) (Chinese chestnut) and *C. crenata* (Sieb and Zucc.) (Japanese chestnut). *C. sativa* originated in the Mediterranean, and is now cultivated in mild temperate areas of Europe and the subtropics. It also has been planted in the United States, Russia, and in mountainous areas of the tropics, e.g. in Indonesia at 1400 m altitude (37). In contrast to Europe and Asia, North America has never had a large commercial chestnut industry. Although North America had significant production area in the early 1900s, the American chestnut was wiped out by the chestnut blight fungus (*Cryphonectria parasitica* [Murr]). Although the genetic pool of American chestnut has not been lost (38), production has greatly declined (26).

In European countries, chestnuts are categorized into two pomological groups. These

are 'Marrone' (the highest quality types) and 'Chataigne' (classical chestnuts types). Chataigne types are polyembryonic (Fig. 1) and the seed does not separate easily from the fruit. Marrone chestnuts are monoembryonic (Fig. 1), usually bigger than Chataignes, and they are used to produce candied chestnuts, creams, purees, and canned food. Chataigne chestnuts are used for fresh consumption.

Anatolia has been considered as the main center of origin for chestnut (4, 39) Chestnut, called 'Kestane' in Turkish, spread from the Eastern Black Sea region, through the Marmara region and the Aegean to Antalya in the Mediterranean as a native population (13, 33). Regions where chestnuts are indigenous have traditionally been the world's major producing areas of a wide variety of chestnuts, especially Italy, France, Spain, and Portugal in Europe, and China, Japan, Korea and Turkey in Asia (26, 33). Turkish production was 48,000 MT in 2003, which was the

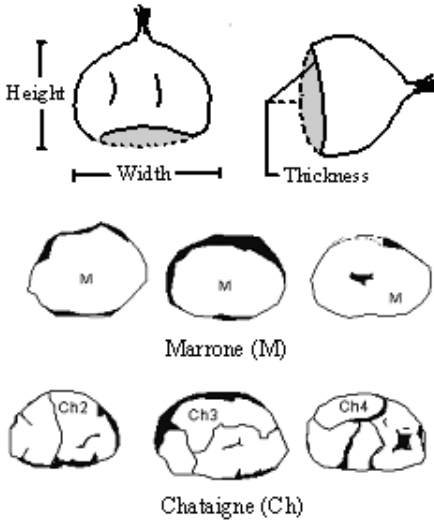


Figure 1. Schematic drawing of fruit dimensions and cross section of Marrone (mono-embryonic) and Chataigne (poly-embryonic) chestnut kernels. Original transformed from Soylu (33).

fourth highest in the world at that time (2).

In Turkey, there are a large number of natural (wild) chestnut trees other than the standard cultivars. We have two main problems: ink disease and chestnut blight. Chestnut stands have been severely destroyed by *Phytophthora cambivora* (ink disease) since the 1950s (14) and by chestnut blight since the 1970s (11). Although chestnut production in Turkey has decreased in the last fifteen years, we have very diverse native chestnut germplasm in different parts of the country. These chestnut trees grow spontaneously in forests with other trees or as solid chestnut stands.

Chestnut represented the principal food and income source of the population for centuries. The nuts are palatable raw, but in Turkey they are usually consumed cooked, often roasted in the shell, boiled, or steamed. The main market products are candied chestnuts, creams and purees (6). Chestnut flour is also used by the confectionery industry to make paste, which in turn becomes a basic ingredient of desserts (9).

In recent years, farmers have taken great interest in planting chestnut orchards in Turkey, especially in Marmara and the West Mediterranean regions, because of its economic importance. In addition, it seems clear that new products and new uses of chestnut can be developed in the event of supply exceeding present demand. In this situation, breeding and selection are of fundamental importance to obtain new and valuable cultivars for superior nut and timber production. In Europe and Asia, where chestnut has been grown for centuries or millennia, the main problems are to select the best varieties from the large available pool of germplasm and eventually to add to the best existing cultivars genes for resistance to major diseases and pests (7). In Turkey, efforts are aimed at obtaining new cultivars with desirable traits or selection from among the better chestnut accessions adapted to local growing conditions. For this purpose, scientific selection work on chestnut was started in 1975. By the end of the 1970s, chestnut genetic resources were under investigation in many parts of Turkey.

The objective of the present study, following previous research carried out in other areas (4, 5, 24, 29, 30), was to characterize quantitative fruit characters of a series of promising accessions from a population growing in Isparta.

Materials and Methods

Research area and sampling. The research was performed on native chestnut trees arisen from seed (*C. sativa* Mill.) in the Yenice and Dere districts of Isparta, situated in the West Mediterranean area of Turkey, during 2002-2004. The research area, consisting of chestnut stands spread over approximately 61 ha, is located south of Isparta city between 37° 44' N, latitude and 30° 32' E longitude (Fig. 2). The chestnut stands, situated at 1090-1170 m altitude in a small valley, are in a transitional region between the Mediterranean and



Figure 2. Location of the chestnut trees evaluated in this study.

Central Anatolia, and have a specific regional microclimate. According to long term average records, annual rainfall is 597 mm, the mean maximum temperature is 18.1 °C, the minimum is 6.1°C, and mean annual temperature is 12°C. The chestnut trees have grown naturally without any cultural practices such as pruning, fertilization, irrigation, etc. Firstly, seedling chestnuts were surveyed, and trees which were weak, had too small a fruit size (< 11 g), or were affected by chestnut blight or ink disease were eliminated in 2002. Then 52 healthy and vigorous trees of bearing age were sampled for the analysis of various traits. At harvest season in 2002, chestnut trees which produced fruits below 11 g were discarded. Fruit samples were collected from 32 accessions for two growing seasons (2003 and 2004). Pomological and morphological characters were measured according to UPOV methods (35) and those of Ayfer and Soyly (4) with some modifications. The selection parameters are presented in Table 1. For characterization of fruits, 25 fruits per sample, randomly chosen from harvested nuts, were evaluated.

Sensory data. For determination of color, the sensory panelists first grouped chestnuts by external color as “typical chestnut color”, “slightly dark”, “light brown” and “dark”. Kernels were classified as “light cream”, “cream” and “dark cream”. Then, shell and kernel color of these grouped chestnuts were

measured according to the CIE (Commission Internationale de l’Eclairage) system with a CR-300 chromameter (Minolta, Osaka, Japan), and the limits (min-max) values of $L^*a^*b^*$ for each color group were determined. The scores for the Weighted Ranked method were based on these limits.

In sensory evaluation, hedonic scales were used. Five panelists (scientists in the Horticulture Department) evaluated the chestnuts for taste. Taste was scored on a 5-point scale (1 = poor and 5 = sweet). Shell hardness was assessed by using the fingers to crack the shell.

Phenological observations. The dates of bud swelling, bud burst, beginning of flowering for female and male flowers, receptivity of pistil, length of receptive period, shedding of male flowers and duration of stamens for each selection were observed according to UPOV (35) and Ayfer and Soyly (4). The dates of harvest and beginning of nut fall were also recorded.

Chemical analyses. Chemical analyses were conducted using accessions selected as most promising. A 25-nut sample of each accession was completely shelled and peeled from the seed coat manually. The peeled kernel samples were broken into little pieces and a portion was dried in a forced-air oven at 65°C for at least 24 h to determine the moisture content and the proximate composition. The remaining portion was stored in a freezer at -80°C until use. Dried samples were ground with a stainless-steel mill (Waring, Torrington, Conn., USA) for analytic procedures. In accordance with AOAC methods (3), moisture was determined by weight loss after heating in an oven at 105°C, ash in a muffle furnace at 550°C for 5 h. Crude protein was calculated from nitrogen, determined by Kjeldahl method, multiplying the value by 6.25 as recommended by Bremner

Table 1. Tree and fruit characteristics evaluated in chestnut accessions, & methods of measurement.

Trait	Character measures and categories
Growth habit	Upright, semi-upright, or spreading according to UPOV
Yield per tree	Weighing with balance
Nut weight (g)	With 0.01 g sensitivity digital balance
Kernel weight (g)	With 0.01 g sensitivity digital balance
Nut size	Number of nuts / kg
Nut width (mm) (Fig. 2)	With a digital micrometer (Mitutoyo, Maharashtra, India)
Nut length (mm) (Fig. 2)	With a digital micrometer
Nut height (mm) (Fig. 2)	With a digital micrometer
Shell color	Using Minolta chromameter (Model CR-300, Minolta). Considered a* b* values
Shell brightness	Using Minolta chromameter (Model CR-300, Minolta). Considered L* values
Shell thickness (mm)	Measured at the center of the two sides of each nut with digital micrometer
Shell hardness	With sensory analysis; as soft, medium or hard
Kernel color	Using Minolta chromameter (Model CR-300, Minolta) Considered L* a* b* values
Testa peeling	With sensory analysis as easy, moderately easy or difficult
Penetration of seed coat into embryo (mm)	Measured testa with a digital micrometer
Pomological group	As Marrone, or Chataigne type according to Soyulu (33) (Figure 1)
Taste	With sensory analysis as sweet, fairly sweet, or poor

(10). Crude fat was analyzed by extraction with petroleum ether in a soxhlet apparatus (Model MX225 Elektro-mag, Istanbul, Turkey). To determine total carbohydrates, starch and total sugars, a modified anthrone method (27) was used. The absorbance at 620 nm of the samples was measured using a Shimadzu 1601 UV spectrophotometer (Tokyo, Japan).

Statistical analysis. Descriptive statistics were computed for quantitative characters. The tree and nut characteristics were evaluated in 2003 and 2004. All statistical analyses were performed using the SPSS computer statistical program (1). The data are presented as the mean \pm standard deviation of three replicates of 25 nuts each over two years.

In order to identify superior selections for 3 different uses (general quality, nut size and chestnut paste), the modified Weighted Rank (WR) method was used (4, 5, 17, 18, 29, 30). The characteristics of each accession evaluated for WR method and their relative scores

for use in total weighted rank scores are presented in Table 2. To obtain the total WR scores, the relative scores were multiplied by each characteristic's score and summed for each chestnut selection.

Results and Discussion

Thirty-two accessions from the chestnut population southwest of Isparta were evaluated. Phenological phases of these accessions are shown in Figure 3. Bud swelling occurred in the second half of April, and the bud burst date ranged from 21 April to 9 May. Bud burst took place approximately 8-14 days after bud swelling. Receptivity of female flowers began in the first week of June, and ended early July. The duration of receptivity was about 9-14 days, depending on the accession. Staminate flowers shed their pollen 1-2 days after the onset of receptivity of pistillate flowers, and lasted about two weeks. The fruits ripened over a 16-day period. The time of ripening was between 9 October (for D-

Table 2. Characteristic ranking, classes and scores of characteristics and relative scores of evaluated characters using the weighted rank method.

Characteristics	Characteristics Classes	Scores	Relative Scores		
			General quality	Nut size	Chestnut paste
Yield	Very good (≥ 18 kg)	10	25	25	25
	Good (12.1-18 kg)	7			
	Medium (6.1-12 kg)	4			
	Low (≤ 6 kg)	1			
Nut size (Number of nuts/kg)	Very large (≤ 55)	10	25	35	10
	Large (56-65)	8			
	Medium (66-85)	6			
	Small (86-100)	3			
	Very small (≥ 100)	1			
Shell color	Typical chestnut color (L*: 29-32, a*: 25-26, b*: 13-16)	10	10	10	0
	Slightly dark (L*: 27-35, a*: 13-21, b*: 9-20)	7			
	Light brown (L*: 30-33, a*: 17-22, b*: 12-22)	4			
	Dark (L*: 26-28, a*: 11-13, b*: 6-7)	1			
	Bright (L*: 32-35)	10			
Shell brightness	Matte (L*: 29-32)	4	5	5	0
	Hairy (L*: 26-29)	1			
	Very thin (≤ 0.42 mm)	7			
Shell thickness	Thin (0.32-0.48 mm)	5	5	5	5
	Slightly thick (0.49-0.60 mm)	3			
	Thick (≥ 6 mm)	1			
	Soft	3			
Shell hardness	Medium	2	5	5	5
	Hard	1			
	Light cream [L*: 81-90, a*: (-2)-(-1), b*:15-23]	10			
Kernel color	Cream [L*: 82-88, a*: (-3)-(-1), b*: 20-26]	7	5	5	15
	Dark cream [L*: 83-87, a*: (-2)-(-4), b*: 25-28]	1			
	Easy	10			
Testa peeling	Moderately easy	5	10	5	20
	Difficult	1			
	Not or slightly (≤ 1.0 mm)	10			
Penetration of testa into embryo (mm)	Rather (2-3 mm)	7	0	0	10
	Deeply (≥ 4 mm)	1			
	Sweet	5			
Taste	Fairly sweet	3	10	5	10
	Poor	1			

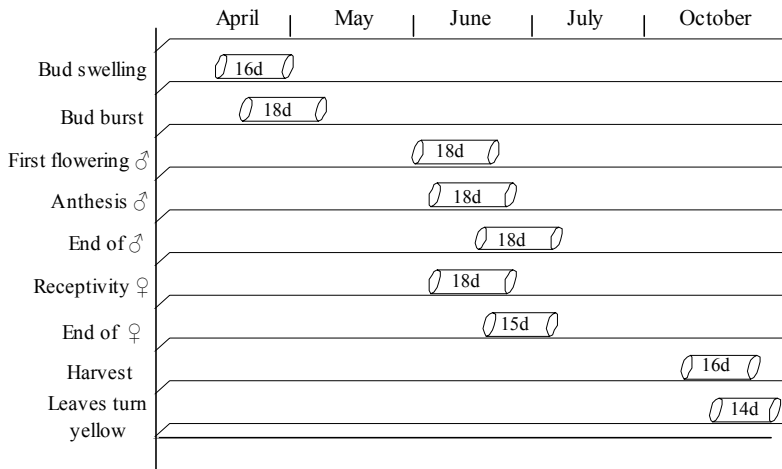


Figure 3. Phenogram of flowering and ripening of chestnut accessions. ♂: male flower, ♀: female flower

21, 22, 23) and 25 October (for D-39). Most accessions were harvested in the first half of October (Figure 3). Our research area, a microclimate, showed close similarity to the Marmara region with respect to phenological phases. However, the harvest period of these accessions was later than in the Marmara region (4). Hence, we did not select any accessions for earliness.

All the chestnut accessions had good morphological characteristics and were free from the major diseases. The accessions were characterized as having large crown size, being very tall, and the growth habit was upright (10 accessions) or spreading (22 accessions). The yield ranged from “low” (D-21, D-50) to “very good” (D-1, D-25, D-26, D-45, D-52) on the scale. The average nut weight of accessions was between 10.7 g (D-12) and 31.7 g (D-18), which is equivalent to between 100 and 39 nuts per kg. With respect to nut size distribution, 11 accessions were evaluated as “very large”, 9 accessions as “large” and only 2 accessions as “small”. The accessions had a range of 29.7 to 45.4 mm for nut width, 28.2 to 36.5 mm for nut length and 17.4 to 27.2 mm for nut height (Figure 1 and Table

3). Average fruit weight reported by other researchers was between 2.8 g and 20.0 g in Turkey and elsewhere (4, 8, 19, 29, 32). The number of nuts per kg varied from 57 to 120 in different studies (25, 30, 34). When the fruit weight and fruit size of our chestnut accessions were compared to previous studies, the results were within the limits, or higher than, those of previous reports.

The physical and organoleptic properties of kernels appear in Table 5. The highest kernel weight (28.2 g) was recorded for accession D-18, and the lowest (9.1 g) for D-12. Shell thickness varied from 0.26 mm to 0.52 mm (Table 4). The shell thickness of our research accessions was slightly thinner than those reported by Ayfer and Soylu (4) or Serdar and Soylu (30), but similar to those of Serdar and Bilgener (31). For shell brightness, the lowest L^* value was obtained from accession D-39 ($L^*= 26.11$), and the highest for D-25 ($L^*= 34.52$). For the shell color of chestnuts, a^* and b^* values varied between 11.84 (D-32) and 26.45 (D-49), and between 6.90 (D-32) and 21.15 (D-46), respectively (Table 4). A higher L^* value indicates greater lightness of kernel color (Table 5). Typical chestnut

Table 3. Tree and nut characteristics of chestnut accessions from Isparta, Turkey. Each value is the average value of 3 replicate samples of 25 nuts and two years (n=6).

Accession	Growth habit	Yield	Nut size (no. of nuts/kg)	Nut Wt. (g)	Nut width (mm)	Nut length (mm)	Nut height (mm)
D-1	Spreading	Very good	68	14.20±2.98	34.14±1.95	30.93±1.44	21.48±3.26
D-4	Upright	Medium	43	22.38±2.61	44.56±2.39	35.26±1.61	24.01±2.68
D-5	Spreading	Good	51	25.02±3.89	38.33±2.40	34.57±3.37	24.50±4.04
D-9	Spreading	Good	63	16.47±2.66	36.63±2.52	33.46±1.60	20.04±2.69
D-10	Upright	Good	52	20.44±4.06	37.17±3.50	33.94±2.85	25.13±2.83
D-11	Spreading	Medium	92	11.42±1.71	31.05±1.60	28.65±1.36	18.59±2.34
D-12	Spreading	Medium	100	10.66±2.91	29.72±3.18	30.45±2.60	18.37±2.72
D-13	Upright	Medium	73	14.12±1.32	34.82±1.44	32.32±1.72	20.25±2.76
D-14	Upright	Good	80	12.45±2.25	32.63±2.07	29.15±4.03	20.29±3.06
D-18	Spreading	Good	39	31.73±5.41	45.41±2.78	36.53±2.23	27.21±2.85
D-21	Spreading	Very small	67	16.83±2.25	35.92±1.78	32.03±1.69	20.57±2.62
D-22	Upright	Medium	82	14.23±3.09	32.04±3.29	28.22±2.22	19.68±3.27
D-23	Spreading	Medium	66	16.63±2.26	35.95±2.57	30.00±2.11	19.67±2.85
D-25	Upright	Very good	61	15.86±1.91	36.57±2.83	36.30±1.51	21.01±1.57
D-26	Spreading	Very good	58	17.20±2.65	38.77±1.63	31.88±2.68	21.04±2.98
D-28	Spreading	Good	46	23.02±2.21	41.08±1.45	36.22±0.72	23.73±1.53
D-30	Spreading	Good	47	21.89±2.67	41.15±2.07	34.15±1.63	22.69±2.15
D-31	Spreading	Medium	64	15.16±1.49	36.05±1.27	33.30±1.94	19.57±1.77
D-32	Upright	Medium	52	19.94±3.70	39.74±1.93	34.32±1.51	22.91±2.73
D-35	Spreading	Medium	63	15.46±2.08	37.63±2.02	31.23±1.34	19.05±1.40
D-37	Spreading	Good	85	11.63±2.66	32.54±2.54	33.17±2.17	17.43±2.03
D-39	Spreading	Medium	69	15.97±2.90	34.97±2.46	32.13±1.96	20.69±2.46
D-41	Spreading	Good	62	16.82±3.07	38.59±2.57	33.18±1.85	20.45±2.52
D-42	Spreading	Good	61	18.13±3.12	37.52±2.90	31.54±1.80	21.33±1.91
D-45	Upright	Very good	69	14.93±2.93	36.07±1.88	33.28±2.22	19.74±3.26
D-46	Upright	Good	61	15.78±2.25	37.27±2.32	34.39±0.94	21.44±1.57
D-47	Spreading	Medium	43	28.05±2.48	43.27±2.20	36.50±1.59	23.86±2.13
D-48	Spreading	Good	51	18.75±2.33	40.28±1.90	32.80±1.95	23.33±2.12
D-49	Spreading	Good	42	23.83±4.07	42.39±2.25	36.54±2.28	24.74±2.00
D-50	Spreading	Very small	41	23.49±3.03	43.92±2.44	34.71±1.80	24.54±1.60
D-51	Spreading	Good	65	15.88±2.03	36.88±1.98	30.79±1.50	20.20±1.98
D-52	Upright	Very good	59	19.30±3.96	39.08±2.25	32.66±1.62	21.87±3.50

kernels had a light cream color, as indicated by the a^* and b^* values. Most chestnuts in Turkey are consumed fresh, so external attractiveness is very important in chestnut marketing. In this respect, the accessions D-22 and D-49 had typical chestnut color considering the $L^*a^*b^*$ values. Peeling of the testa varied from difficult to moderately easy, but most were difficult. In most of the accessions, the testa entered moderately into

the seed, but in two accessions (D-11, D-35) it did not enter the embryo (Table 5). Accessions D-11 and D-32 were the best Marrone types. Twelve accessions were mono-embryonic (Marrones) the rest were poly-embryonic (Chataignes). The taste of the chestnut kernel was rated from sweet to poor.

All research accessions were evaluated with the WR method, and their total WR scores were calculated to select the most

Table 4. Shell characteristics of chestnut accessions. Each value is the average value of 3 replicate samples of 25 nuts and two years (n=6).

Accession	Shell color ^z		Shell brightness ^z	Shell thickness (mm)	Shell hardness	Testa peeling
	a*	b*	L*			
D-1	-17.49±2.90	12.77±2.39	30.07±1.52	0.52±0.22	Medium	Difficult
D-4	-21.18±1.70	18.53±2.74	32.51±2.04	0.43±0.09	Medium	Mod. easy
D-5	-16.87±2.61	10.81±2.31	29.49±1.69	0.32±0.08	Soft	Difficult
D-9	-17.35±1.04	14.65±1.54	29.28±1.33	0.29±0.07	Medium	Difficult
D-10	-16.54±2.95	10.88±2.97	27.24±2.12	0.40±0.09	Medium	Mod. easy
D-11	-16.50±2.44	12.77±2.59	28.19±1.79	0.36±0.07	Soft	Mod. easy
D-12	-14.04±2.33	9.97±2.92	27.00±2.21	0.41±0.12	Medium	Difficult
D-13	-17.31±1.46	13.06±2.65	29.48±1.99	0.34±0.11	Soft	Difficult
D-14	-19.80±1.63	14.36±2.56	28.78±2.16	0.36±0.11	Soft	Difficult
D-18	-16.51±2.72	10.63±2.22	28.83±1.44	0.41±0.08	Hard	Difficult
D-21	-19.28±1.41	15.09±2.35	30.09±1.56	0.39±0.12	Medium	Difficult
D-22	-25.88±1.11	15.86±2.25	31.94±1.54	0.34±0.08	Medium	Difficult
D-23	-15.82±1.69	11.11±2.13	28.94±1.24	0.36±0.11	Medium	Difficult
D-25	-20.78±2.76	19.15±2.89	34.52±2.32	0.34±0.11	Soft	Difficult
D-26	-20.74±1.79	18.03±2.47	32.89±1.63	0.37±0.10	Soft	Difficult
D-28	-14.10±2.74	9.10±2.62	27.60±1.48	0.37±0.05	Hard	Difficult
D-30	-13.91±2.80	9.85±2.59	27.41±2.24	0.26±0.08	Soft	Difficult
D-31	-20.13±1.99	15.51±2.88	31.20±2.01	0.29±0.09	Soft	Difficult
D-32	-11.84±2.90	6.90±1.72	27.49±1.24	0.40±0.09	Soft	Difficult
D-35	-18.74±1.58	14.11±2.66	31.49±1.54	0.31±0.03	Soft	Difficult
D-37	-18.80±1.97	14.36±2.29	29.83±1.25	0.36±0.11	Medium	Difficult
D-39	-12.07±1.92	6.97±1.60	26.11±1.54	0.33±0.09	Soft	Mod. easy
D-41	-19.86±2.16	16.97±2.40	30.28±1.80	0.38±0.11	Soft	Mod. easy
D-42	-14.71±2.39	9.58±2.35	28.51±1.51	0.32±0.10	Medium	Difficult
D-45	-17.77±2.80	19.98±2.70	28.02±2.38	0.33±0.07	Soft	Difficult
D-46	-21.26±1.51	21.15±2.84	32.67±1.85	0.30±0.09	Soft	Difficult
D-47	-20.64±1.99	17.49±2.89	31.52±1.84	0.39±0.08	Medium	Difficult
D-48	-17.97±1.35	12.12±1.95	29.49±1.41	0.37±0.10	Soft	Mod. easy
D-49	-26.45±1.81	12.83±2.09	29.24±1.42	0.42±0.08	Medium	Difficult
D-50	-19.62±2.41	13.01±2.42	27.08±1.95	0.31±0.08	Soft	Difficult
D-51	-13.90±1.55	9.43±1.43	27.24±1.54	0.34±0.10	Soft	Difficult
D-52	-16.18±2.10	11.64±2.95	28.96±1.99	0.37±0.08	Soft	Difficult

^zL* values (lightness): 0 = black, 100 = white; a* values: positive = red, negative = green; b* values: positive = yellow, negative = blue

superior types. According to WR scores, 13 accessions were selected for each selection goal: a) general quality, b) nut size, c) chestnut paste. The selected accessions and their WR scores are given in Table 6. Accession D-48 had the highest WR score, and it was the largest, the best quality and the most ap-

propriate for chestnut paste.

Chemical analyses were also conducted on the selected accessions. Data for the proximate composition are reported in Table 7. The chestnut kernels contained from 38.9 % (D-5) to 49.2 % (D-25) moisture (fresh weight basis). Ash content was between 1.3 and 2.8

Table 5. Kernel characteristics of chestnut accessions. Each value is the average value of 3 replicate samples of 25 nuts and two years (n=6).

Accession	Kernel weight (g)	Kernel color ^z			Testa entry into seed (mm)	Taste
		L*	a*	b*		
D-1	11.80±2.48	86.88±1.89	-2.84±0.40	20.56±2.18	2-3	Poor
D-4	19.15±2.30	83.11±4.93	-2.02±0.94	20.33±2.78	2-3	Poor
D-5	22.09±3.54	82.54±2.91	-2.21±0.53	20.66±1.30	≥ 4	Fairly sweet
D-9	14.62±2.39	84.42±2.72	-2.37±0.40	22.94±2.32	2-3	Poor
D-10	17.83±3.76	86.01±2.35	-2.80±0.67	23.77±2.08	2-3	Fairly sweet
D-11	09.48±1.55	85.41±3.32	-3.62±0.68	27.00±2.90	≥ 0	Fairly sweet
D-12	09.11±2.65	84.44±2.93	-2.89±1.10	26.90±2.09	2-3	Fairly sweet
D-13	12.45±1.20	84.87±3.61	-2.90±0.53	26.14±4.34	≥ 4	Fairly sweet
D-14	10.50±2.03	84.67±1.41	-1.66±0.55	21.13±2.17	2-3	Fairly sweet
D-18	28.22±5.24	83.61±2.71	-4.33±0.90	25.73±2.02	≥ 4	Poor
D-21	15.33±2.34	85.44±2.15	-2.15±0.32	23.03±2.40	2-3	Sweet
D-22	11.89±2.76	86.25±1.79	-2.96±0.12	26.44±1.92	2-3	Fairly sweet
D-23	13.82±2.05	87.44±1.28	-2.82±0.27	22.83±0.26	2-3	Fairly sweet
D-25	13.59±1.70	85.03±3.68	-2.75±0.66	24.22±1.11	2-3	Fairly sweet
D-26	14.76±2.38	84.26±2.25	-1.54±0.84	21.13±2.16	2-3	Sweet
D-28	20.40±1.99	83.81±3.70	-2.51±0.63	21.95±1.88	2-3	Poor
D-30	19.66±2.52	85.85±2.18	-2.78±0.14	26.23±3.31	2-3	Fairly sweet
D-31	12.78±2.88	86.02±2.65	-2.77±0.41	20.48±0.41	2-3	Fairly sweet
D-32	17.53±3.46	83.42±2.30	-2.08±1.05	24.66±2.02	2-3	Fairly sweet
D-35	13.49±2.03	84.57±3.41	-2.15±1.53	26.02±2.99	≥ 0	Poor
D-37	09.95±2.26	85.11±1.69	-2.30±0.38	21.59±0.85	2-3	Fairly sweet
D-39	14.21±2.67	86.31±0.64	-3.15±0.35	23.39±3.39	2-3	Fairly sweet
D-41	14.83±3.40	86.71±2.04	-2.68±0.88	22.05±2.50	2-3	Fairly sweet
D-42	16.35±2.89	87.33±1.18	-3.47±0.54	25.67±2.72	≥ 4	Sweet
D-45	12.90±2.61	82.20±4.43	-1.76±0.86	23.95±2.64	2-3	Fairly sweet
D-46	13.84±2.12	83.45±0.27	-2.22±0.33	22.41±2.19	2-3	Poor
D-47	24.65±2.36	87.49±1.75	-2.39±0.34	20.14±1.76	≥ 4	Sweet
D-48	16.28±2.15	83.54±3.67	-1.60±1.04	21.72±2.07	≥ 4	Fairly sweet
D-49	20.68±3.84	85.82±2.07	-2.52±0.56	21.28±2.59	2-3	Fairly sweet
D-50	20.95±2.69	85.87±3.02	-2.62±0.53	20.03±2.30	2-3	Fairly sweet
D-51	14.03±1.87	86.08±1.28	-2.84±0.60	22.84±2.34	2-3	Fairly sweet
D-52	17.39±3.61	86.26±2.15	-3.11±0.53	27.80±3.36	≥ 4	Fairly sweet

^zL* values (lightness): 0 = black, 100 = white; a* values: positive = red, negative = green; b* values: positive = yellow, negative = blue

g 100 g⁻¹ DM. Chestnuts, unlike many other tree nuts, are low in protein and fat but high in carbohydrate (22, 28). The values for protein content (N*6.25) showed an average of 8.3 g 100 g⁻¹ (dry matter basis), and ranged from 6.6 (D-48) to 11.1 g 100 g⁻¹ (D-25). These values are slightly higher than those reported by McCarthy and Meredith (22), Ferreria-

Cardoso et al. (15), or Üstün et al. (36), but agree with values reported by Desmaison and Adrian (12) and Ferreria-Cardoso et al. (16). For the total carbohydrate content, the average value was 54.4 g 100 g⁻¹ DM, with the minimum value being 45.0 g 100 g⁻¹ (D-25) and the maximum value 59.9 g 100 g⁻¹ (D-51). Carbohydrates represent the major

Table 6. Total weighted rank scores for the elite selected accessions.

Accession	General quality score	Accession	Fruit size score	Accession	Chestnut paste score
D-48	755	D-48	815	D-48	635
D-5	730	D-5	810	D-41	575
D-49	727.5	D-49	807.5	D-5	555
D-50	715	D-50	795	D-26	555
D-26	700	D-28	775	D-50	555
D-51	695	D-30	765	D-49	555
D-28	685	D-18	760	D-25	535
D-30	685	D-51	755	D-51	535
D-25	680	D-26	750	D-28	525
D-9	672.5	D-9	742.5	D-10	515
D-18	670	D-25	740	D-9	512,5
D-41	670	D-41	720	D-30	465
D-10	595	D-10	665	D-18	435

Table 7. Basic proximate composition of chestnut kernels from selected accessions (g 100 g⁻¹ dry weight).

Accession	Moisture content ²	Ash	Protein	Total Carbohydrates	Total Sugar	Starch	Fat
D-5	38.90±1.90	1.4±0.00	8.04±0.17	50.32±0.55	10.04±0.32	35.21±6.94	0.92±0.05
D-9	43.82±0.00	1.6±0.01	8.83±0.06	54.03±1.96	19.04±0.44	29.45±6.31	0.91±0.13
D-10	44.68±1.70	1.3±0.01	7.43±0.16	53.10±0.33	17.32±2.31	30.45±9.53	1.97±0.87
D-18	42.18±2.96	2.5±0.01	9.24±0.75	55.38±0.38	17.23±0.28	32.58±7.21	1.48±0.15
D-25	49.20±0.58	2.4±0.04	11.05±0.67	44.96±2.02	9.17±1.24	31.15±5.78	0.96±0.22
D-26	44.69±1.82	2.2±0.01	9.57±0.59	58.19±0.76	18.08±1.95	34.24±5.59	1.81±0.60
D-28	44.37±5.53	2.2±0.01	8.01±0.10	57.08±2.46	22.34±0.56	28.86±6.42	0.62±0.22
D-30	43.70±1.43	2.1±0.02	6.94±0.11	52.87±0.65	21.60±0.56	26.03±8.62	1.83±0.41
D-41	43.81±2.67	2.2±0.01	8.06±0.34	56.46±2.89	21.43±0.80	29.17±4.58	1.22±0.01
D-48	46.93±0.84	2.2±0.01	6.57±0.01	53.18±0.55	19.09±2.99	28.81±5.02	2.81±0.57
D-49	46.29±1.02	2.0±0.10	9.30±0.21	56.65±1.86	22.48±2.27	28.64±7.41	1.71±0.01
D-50	47.35±0.14	2.4±0.01	7.62±0.05	55.19±0.44	19.77±2.11	29.93±6.08	2.39±0.17
D-51	44.50±2.85	2.8±0.01	7.68±0.04	59.93±0.27	21.83±0.56	32.09±7.67	1.84±0.27
Max	49.20	2.8	11.05	59.93	22.48	35.21	2.81
Min	38.90	1.3	6.57	44.96	9.17	26.03	0.62
Avg	44.57	2.1	8.33	54.41	18.42	30.51	1.57

²reported as g 100 g⁻¹ fresh weight

component of chestnut kernels, and consist mainly of starch, followed by sugar (12, 23). The starch content varied from 26.0 to 35.2 g 100 g⁻¹ dry weight (Table 7), which agrees with other reported data (36). Accession D-30 had the lowest and D-5 the highest starch content. Total sugar content varied from

9.17 to 22.48 g 100 g⁻¹ dry weight. Accession D-25 contained the least, and the highest amount of sugar was found in D-49. Previous research described a similar range (20, 21). The main sugar in chestnuts is sucrose (16, 28). This disaccharide is one of the important parameters for the assessment of commercial

quality. The average fat content was 1.57 g 100 g⁻¹, and ranged from 0.62 (D-28) to 2.81 g 100 g⁻¹ (D-48). Concerning the basic proximate composition, the data lead one to conclude that chestnuts have a high potential for human nutrition. There is genetic variation with respect to biochemical composition in our research accessions. Like all other fruits, the composition of chestnut also varies with variety, climate and soil properties.

Conclusions. The microclimate in Isparta district created an optimal ecological framework for developing localized populations of chestnut. The chestnut trees are natural hybrids with significant genetic variability, some of which has horticultural importance. We selected 13 accessions (D-48, D-5, D-49, D-50, D-26, D-51, D-28, D-30, D-25, D-9, D-18, D-41 and D-10) using the WR method, taking into consideration yield, nut and kernel characteristics. These accessions can be used for breeding, and also, after clonal propagation, as local cultivars. All selected accessions that appeared to be resistant to major diseases and pests will also be used for this purpose.

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