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FORAGE QUALITY OF DECIDUOUS WOODY AND HERBACEOUS SPECIES THROUGHOUT A YEAR IN MEDITERRANEAN SHRUBLANDS OF WESTERN TURKEY

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ABSTRACT

Nutritional stress during dry summer period is considered as a primary factor limiting goat production in the Mediterranean region. In this study, forage quality of two deciduous woody species (gall oak (*Quercus infectoria* Oliv.) and Christ's thorn (*Paliurus spina-cristi* Mill.)) and herbaceous species in a shrubland in the South Marmara was determined to assess their quality and capacity to meet goats needs. Dry matter (DM), ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), dry matter digestibility (DMD), metabolic energy (ME), Phosphorus (P) and Calcium (Ca) were determined in the shrubs and herbaceous. Results showed that DM and Ca in the gall oak were distinctly low in April. On the other hand, its CP and P were high in April while DMD and ME were high in May and June. Contents of DM, ash and Ca in the Christ's thorn showed a decrease in April-May and those of CP, DMD, and ME increased in May. Herbaceous had their lowest DM, NDF, and ADF in April and highest CP, DMD, and ME in March-April. Consequently, when goats' needs were considered, goats should be fed with supplementary energy feed throughout the year except for spring months, and with CP during autumn months in order to obtain satisfactory productivity.

Key Words: forage quality, Mediterranean basin, Shrublands, gall oak, Christ's thorn.

I Shrub vegetation spreads in the great part of the territory of the countries around the Mediterranean basin. Shrub lands are a source of forage for livestock in the region with sheep and goat production comprising 60-80% of the total agricultural output. In addition, these lands are used for firewood, landscape and recreation, soil protection, and water production (Liacos 1982). Lands in the Northwestern Turkey are mostly covered with evergreen species. However, their nutritive value is not sufficient to meet maintenance requirements during summer, autumn and winter (Ozaslan-Parlak *et al*. 2011). Studies by Dini (1993); Platis and Papanastasis (1993); Papachristou and Papanastasis (1994); Papachristou (1997) and Ainalis *et al*. (1998) suggested that certain deciduous woody species due to good nutritive value are promising animal feed during the dry season for animal productivity. Goats generally preferred deciduous wood fodder over other forages during summer (Papachristou and Nastis 1996). During summer when herbaceous plants are dormant and herbage is low in quality and availability, browse (leaves and twigs) has to meet nutritional requirements of the grazing animals (Le Houerou 1993). Shrubs develop long roots reaching deeper soil layers than the herbaceous vegetation, and are able to maintain green phytomass late in the season when the herbaceous layer is dry (Olea *et al*. 1992). Two deciduous species, Christ's thorn, and gall oak, are commonly found throughout the Mediterranean native shrub lands. However, information on the nutritive value of Christ's thorn, gall oak and herbaceous species are very limited.

The objective of this study was to determine nutrient profile of two deciduous shrubs and herbaceous species during different seasons of a year.

MATERIALS AND METHODS

Study area: The study was conducted on Çanakkale, located in northwest part of Turkey. Çanakkale has a typical Mediterranean climate (Türkeş *et al*. 2002). The mean annual precipitation is 615.5 mm and falls mainly in the winter and spring. The rainy season typically begins in October and ends in May, while summer is dry and hot. The mean annual temperature is 15^{o}C.

Sample collection and analysis: Plant samples were collected from both the shrubs (between April- December 2006, 2007) and herbaceous species (between October 2006- November 2007) in the middle of every month. All samples were collected before the exposure of shrub land to grazing. Representative hand plucked shrubs browse (leaves and twigs of up to 2 mm diameter; (Cook 1964) similar to those consumed by animals were collected for the assessment of their nutritive value. Samples for shrubs were randomly taken from ten plants with similar size and 1.6 m high upon which animals can graze. The selected shrubs were labeled with metal plates in order to obtain samples from the same plants

throughout the year. Availability of herbaceous vegetation was estimated by hand clipping 10 randomly selected quadrats of 0.5 x 0.5 m during each collection time. Plant material was clipped at ground level and placed in individual paper bags. Herbaceous samples included both green and dried material. Collected samples were dried at 60°C for 48 h, and then ground in a mill to pass through 1 mm screen prior to analyses. All analyses were carried out on duplicate samples and results reported on DM basis. The DM content was determined by oven drying at 105°C for 24 h, ash was determined by ashing samples in a muffle furnace at 600°C for 16 h (AOAC 1990). Nitrogen content was measured by the Kjeldahl method (AOAC 1990) and crude protein was calculated by multiplying N with 6.25. NDF, ADF, and ADL were measured using the procedure described by Van Soest *et al*. (1991). As Weiss (1994) suggested, accurate data on digestibility of forages would greatly assist diet formulation and economic valuation of different collection period. Although the value of accurate digestibility data is unequivocal, obtaining actual data is time consuming, expensive, and requires large amounts of the forage samples that was not feasible in this study. Dry matter digestibility (DMD) was estimated using the formula developed by Oddy *et al*. (1983): DMD%= 83.58-0.824 ADF%+2.626 N%.

Table 1. Shrubland soil physical and chemical properties.

pH	6.98	Exchangeable Calcium (C mol kg^{-1})	13.32
Electrical conductivity (dS m^{-1})	0.35	Exchangeable Magnesium (C mol kg^{-1})	2.85
Total Nitrogen (g kg^{-1})	2.30	Exchangeable Potassium (C mol kg^{-1})	0.17
Organic Carbon (g kg^{-1})	24.70	Exchangeable sodium (C mol kg^{-1})	0.07
Available Phosphorus (mg kg^{-1})	18.14	Clay (g kg^{-1})	122.60
$CaCO_3$ (g kg^{-1})	6.30	Silt (g kg^{-1})	301.20
CEC (C mol kg^{-1})	16.41	Sand (g kg^{-1})	576.20
		Aggregate stability (%)	81.21

The shrubland is covered mostly with gall oak (*Quercus infectoria* Oliv.) and Christ's thorn (*Paliurus spina-cristi* Mill.). The dominant herbaceous species were *Dactylis glomerata*, *Lolium perenne*, *Hordeum spantaneum, Avena clauda Trifolium* sp*., Anagallis arvensis,* and *Crepis zacinta.*

Dry matter digestibility values were used to estimate digestible energy (DE, kcal kg^{-1}) using the regression equation reported by Fonnesbeck *et al*. (1984): DE (Mcal kg^{-1}) = 0.27+0.0428 (DMD %). Then DE values were converted to ME using the formula reported by Khalil *et al*. (1986): ME (Mcal kg^{-1}) = 0.821 x DE (Mcal kg^{-1}).

P and Ca elements were determined using inductively coupled plasma-optical emission spectrometry method (ICP-OES; Kacar and İnal 2008).

Statistical analysis: All data were subjected to analysis of variance (ANOVA) based on general linear models for repeated measurements. Statistical analysis used the SPSS statistical package. Means were separated using the comparisons based upon the least significant difference (LSD) (Level of significance $P<0.05$).

RESULTS AND DISCUSSION

Changes in the nutritional composition (DM, Ash, CP, DMD, ME, Ca, and P) of gall oak and Christ's thorn were found significant while NDF, ADF and ADL did not indicate any significance between the months (Table 2). All components other than ash content also showed significant differences in the herbaceous (Table 3).

Minimum dry matter content of the gall oak was recorded (316.2 g kg^{-1}) in April when leaves started to sprout. It stayed at the same level in July-August-October in 2007 and November in 2006 and was highest in December (771.0 g kg^{-1}). Ash was highest in July and November (72.0, 72.6 g kg^{-1}, respectively). Crude protein was found to be the highest (180.0 g kg^{-1}) in April during which gall oak were first growing, and it significantly decreased in the other times. It was specifically very low in November and December with the leaves started to turn yellow. DMD and ME were high between May and October, and at the lowest level in December. Phosphorus contents of the plant showed a peak in April with leafing out, dropping significantly in the following months. Calcium displayed a reverse pattern. It was lowest at the beginning of the growth and highest between September and October, 2007.

DM in the Christ's thorn was at the lowest level in April, May and June and at the highest level in August and September. Lowest ash content was received in April and May, and it was stable in the other months. CP, DMD and ME were highest in May. P was most prominent in April, significantly decreasing especially in the summer and fall. Ca displayed a reverse progress.

Highest dry matter content in the herbaceous was attained in the summer and fall in which they were dry (Table 3). Crude protein content of the herbs was high in the January-May period (91.0-116.8 g kg^{-1}) and lowest in the summer and winter months, especially in August (47.8 g kg^{-1}) and September (47.6 g kg^{-1}). NDF and ADF exhibited a significant decrease in April and

May, later started to increase and kept their highest levels in the summer, fall and winter. ADL, which shows the lignin content in the plant, displayed a reverse situation. It was only high during winter and lower in the other seasons. DMD and ME increased in March and April, and most decreased in September and October. Lowest Ca was obtained in July and August, and it showed a considerable increase in November. High content of P in the early spring decreased significantly in May and June, and peaked in July and August.

Dry matter contents of gall oak and Christ's thorn were lowest in April and May, tending to increase in the following months reaching to maximum in November and December during which the leaves turned yellow. These shrubs sprout new leaves in April. Protoplasm contains more water because cell wall is not completely formed in these types of physiologically active tissues (Huston and Pinchak 1991). DM in the herbaceous plants was the least in April and May due to the similar reasons. Furthermore, there is tight relationship between physiological activities of plants and water content. Physiological events slow down in drying plants and DM increases as the amount of water inside the cells decreases. A significant relationship exists between DM ratio and growth season for that reason (Mountousis *et al*. 2008) and as the plant matures DM ratio also increases (Bakoğlu *et al*. 1999; Khorchani *et al*. 2000).

Table 2. Nutritional composition of gall oak and Christ's thorn in the Mediterranean shrubland (mean values, DM basis).

Month	DM ($g\ kg^{-1}$)	Ash ($g\ kg^{-1}$)	CP ($g\ kg^{-1}$)	NDF ($g\ kg^{-1}$)	ADF ($g\ kg^{-1}$)	ADL ($g\ kg^{-1}$)	DMD (%)	ME ($Mcalg^{1}$)	Ca ($mgkg^{-1}$)	P ($mgkg^{1}$)
Gall oak										
October	554.3^{cd*}	50.3^{d}	68.8^{g}	545.0	412.8	205.5	52.45^{ab}	2.06^{ab}	12.451^{e}	2.008^{b}
November	539.8^{cd}	48.0^{d}	42.8^{h}	560.6	466.6	203.4	46.93^{de}	1.87^{de}	13.611^{cde}	2.145^{b}
December	771.0^{a}	52.5^{cd}	31.5^{i}	577.6	474.8	208.4	45.78^{e}	1.83^{e}	13.136^{de}	2.289^{b}
April	316.2^{f}	53.1^{cd}	180.0^{a}	608.0	449.5	168.8	47.86^{de}	1.90^{de}	2.822^{g}	4.142^{a}
May	467.2^{e}	54.3^{cd}	111.3^{c}	606.8	456.6	184.1	53.53^{a}	2.10^{a}	7.812^{f}	2.331^{b}
June	529.9^{d}	57.7^{c}	98.0^{d}	569.4	423.7	191.4	53.34^{a}	2.10^{a}	9.502^{f}	2.159^{b}
July	545.4^{cd}	72.0^{a}	91.7^{e}	603.6	450.1	216.7	50.60^{bc}	2.00^{bc}	12.681^{de}	2.120^{b}
August	551.2^{cd}	64.2^{b}	109.7^{c}	580.6	432.6	204.6	51.78^{ab}	2.04^{ab}	15.197^{bc}	2.074^{b}
September	584.8^{bc}	65.2^{b}	115.1^{b}	591.7	436.2	212.0	52.24^{ab}	2.06^{ab}	17.152^{a}	2.260^{b}
October	568.8^{bcd}	70.5^{ab}	79.7^{f}	588.2	427.4	200.4	53.19^{a}	2.09^{ab}	16.879^{ab}	2.175^{b}
November	619.1b	72.6^{a}	67.9^{g}	560.6	466.6	203.4	48.48^{cd}	1.93^{cd}	14.448^{cd}	2.091^{b}
Mean	549.8	60.0	90.6	581.1	445.2	199.9	50.56	2.00	12.336	2.345
P value	0.000	0.000	0.000	0.180	0.103	0.385	0.000	0.000	0.000	0.000
Christ's thorn										
October	512.2^{c}	65.2^{a}	87.9^{c}	402.0	274.6	158.2	64.64^{bc}	2.49^{bc}	21.519^{bc}	1.866^{def}
November	447.2^{d}	60.9^{a}	87.7^{c}	374.7	263.6	151.2	65.54^{abc}	2.53^{abc}	34.400^{a}	2.010^{de}
April	281.2^{e}	53.7^{b}	95.8^{c}	406.5	307.1	163.8	62.29^{bc}	2.41^{bc}	8.489^{f}	5.743^{a}
May	301.6^{e}	55.2^{b}	220.4^{a}	510.2	235.3	134.4	73.45^{a}	2.80^{a}	12.295^{e}	3.717^{b}
June	276.3^{e}	61.1^{a}	154.6^{b}	475.0	256.7	107.0	68.92^{ab}	2.65^{ab}	11.384^{ef}	2.625^{c}
July	482.9^{cd}	60.8^{a}	107.8^{c}	523.3	363.0	188.0	58.19^{cd}	2.27^{cd}	19.943^{c}	2.085^{d}
August	595.6^{a}	61.2^{a}	100.6^{c}	588.0	428.6	203.8	52.48^{d}	2.07^{d}	16.875^{d}	1.828^{def}
September	591.8^{a}	66.1^{a}	92.0^{c}	503.1	343.4	192.0	59.15^{cd}	2.30^{cd}	22.394^{bc}	1.701^{ef}
October	551.4^{b}	65.2^{a}	84.7^{c}	490.7	350.7	175.4	58.23^{cd}	2.27^{cd}	24.099^{b}	1.646^{f}
Mean	448.9	61.0	114.6	474.8	313.7	176.3	62.54	2.48	19.044	2.850
P value	0.000	0.006	0.000	0.194	0.163	0.153	0.002	0.000	0.000	0.000

*Means in a column with no common superscript differ significantly at 5% level of significance.
DM, Dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin; DMD, dry matter digestibility; ME, Metabolizable energy.

Ash increased in the both shrub species after spring growth. This was the result of increased uptake of mineral elements from the soil at this time and later deposition of an important part of these elements into the cell walls (Spears 1994). Tolunay *et al*. (2009); Haddi *et al*. (2003) recorded that ash content increased significantly with maturation in kermes oak and halophyte shrubs, respectively. Gonzalez-Andres and Ceresuela (1998) reported that in the *Medicago arborea* and *M. strasseri* shrubs, ash was low in the spring and high in the summer. Herbaceous contained more ash than the shrubs, showing that the shrubs depleted more mineral element.

Protein was high in the gall oak and Christ's thorn during the spring and summer and in herbaceous during the spring, fall and winter. Protein synthesis is stimulated as the plants starts to grow in the spring. Number of young cells increase and the physiological

events are induced (Kacar *et al*. 2006). These events are the results of enzyme activities derived from proteins. Young cells also have high ratio of protoplasm. Most of the proteins in a cell are located in the protoplasm. Christ's thorn had the highest protein in May when it flowered because the flowers stayed until after they set fruit and shed their leaves. Papachristou *et al*. (2005) stated that protein content of the deciduous oaks changed between 77.0-146.8 g kg^{-1} between May and November and that it was high in the spring and summer and low in the fall.

No significant changes were observed for NDF, ADF, and NDL contents of the shrubs. The lowest NDF and ADF of the herbaceous vegetation were attained in April and they were high in the summer months. Due to the fact that they are deciduous shrubs, their fiber contents were similar. Fibrous compounds are found in the cell wall. Cell wall components are more abundant in the older cells than the younger ones (Lyons *et al*. 1999). Cell wall development is related to plant development and as the plant matures wall compounds, such as NDF and ADF, increases and protoplasm compounds like crude protein decreases (Haddi *et al*. 2003; Parissi *et al*. 2005). In addition, stem ratio Increases more than leaf ratio over time with plant development (Frost *et al*. 2008). These result in fibrous compounds like NDF, ADF, and ADL being low at the beginning of plant development and higher as the development progresses. NDF, ADF, and ADL also increased from spring to fall in the wheatgrass species (Holechek *et al*. 1989).

Shrubs had their highest levels of DMD and ME in May and June while the herbs in March and April. DMD and ME of the grazable plant material are related inversely with cell wall components and linearly with CP and ash (Mountousis *et al*. 2008). So browse had low DMD and ME, both generally associated with thick cell walls (Cutler *et al*. 1977), highly lignified NDF, and low level of protein. Papachristou *et al*. (2005) reported that digestibility was high in May and June, later decreasing in the deciduous oaks.

Table 3. Nutritional composition of herbaceous vegetation in the Mediterranean shrub land (mean values, DM basis).

Month	DM ($g\ kg^{-1}$)	Ash ($g\ kg^{-1}$)	CP ($g\ kg^{-1}$)	NDF ($g\ kg^{-1}$)	ADF ($g\ kg^{-1}$)	ADL ($g\ kg^{-1}$)	DMD (%)	ME ($Mcalg^{-1}$)	Ca ($mgkg^{-1}$)	P ($mgkg^{-1}$)
October	391.5^{ef}	129.3	78.5^{d}	546.9^{abc}	371.9^{ab}	109.2^{abc}	49.96^{ef}	1.98^{de}	9.539^{c}	1.909^{fgh}
November	381.8^{ef}	126.4	59.7^{e}	470.4^{cde}	332.3^{a-d}	119.0^{ab}	53.69^{c-f}	2.11^{cde}	8.508^{cd}	1.989^{e-h}
December	386.0^{ef}	124.3	75.0^{d}	546.3^{abc}	329.0^{a-d}	116.5^{ab}	54.70^{bcd}	2.14^{bcd}	9.256^{c}	2.089^{d-g}
January	331.7^{fg}	123.0	98.7^{bc}	534.6^{a-d}	323.4^{a-d}	97.1^{abc}	56.34^{abc}	2.20^{abc}	7.650^{cde}	2.549^{bc}
February	430.6^{de}	121.5	95.2^{bc}	529.7^{a-d}	313.6^{bcd}	95.3^{bc}	57.24^{abc}	2.23^{abc}	7.573^{cde}	2.248^{cde}
March	330.1^{fg}	122.5	116.8^{a}	503.6^{b-e}	301.4^{cd}	89.0^{bc}	59.48^{a}	2.31^{a}	9.464^{c}	2.326^{cd}
April	257.7^{g}	129.8	99.3^{bc}	413.7^{e}	294.7^{d}	99.3^{abc}	59.49^{a}	2.31^{a}	8.991^{c}	2.174^{def}
May	343.7^{f}	134.8	91.0^{c}	436.3^{de}	300.5^{cd}	102.1^{abc}	58.50^{ab}	2.28^{ab}	8.159^{cd}	1.702^{hi}
June	734.9^{c}	132.3	52.4^{ef}	528.1^{a-d}	335.3^{a-d}	92.8^{bc}	53.06^{c-f}	2.09^{cde}	7.327^{cde}	1.505^{i}
July	851.7^{ab}	121.9	55.7^{ef}	585.8^{ab}	353.0^{a-d}	93.6^{bc}	51.26^{def}	2.02^{de}	6.215^{de}	2.972^{a}
August	894.4^{a}	124.3	47.8^{f}	625.1^{a}	351.8^{a-d}	78.2^{c}	51.05^{def}	2.02^{de}	5.513^{e}	2.747^{ab}
September	912.1^{a}	127.5	47.6^{f}	580.6^{ab}	366.2^{abc}	83.0^{c}	49.47^{f}	1.96^{e}	11.882^{b}	1.795^{ghi}
October	813.2^{b}	129.3	88.8^{c}	596.8^{ab}	384.8^{a}	80.6^{c}	49.14^{f}	1.95^{e}	8.533^{d}	1.900^{f-i}
November	490.9^{d}	126.6	102.5	498.5^{b-e}	340.0^{a-d}	127.5^{a}	54.64^{b-e}	2.14^{bcd}	13.475^{a}	2.277^{cde}
Mean	539.3	126.7	79.2	528.3	335.6	98.8	54.14	2.12	8.785	2.156
P value	0.000	0.464	0.000	0.000	0.003	0.001	0.000	0.000	0.000	0.000

Means in a column with no common superscript differ significantly at 5% level of significance

The lowest Ca and highest P in the shrubs were determined in April. Calcium involves in the structure of harder tissues (cell walls) (Spears 1994). Protoplasm compounds of the cell are high and cell wall components are low at the beginning of plant growth. Therefore, Ca was low in the young shoots of the shrubs taken during fast growth in April and May. Increase in P in April was caused by fast plant growth and their high level of physiological activity. Phosphorus is the core element of energy systems (ATP) and nucleic acids (DNA and RNA) (Kacar *et al*. 2006). These compounds enhance physiological events. At the beginning of plant growth during which cells divide and elongate rapidly P content increased.

Subjects in the research were interpreted on the basis of the requirement for maintenance of goats that benefit from shrubby areas. A goat with 50 kg average weight should daily intake minimum 75 g CP, 2.25 Mcal ME (NRC, 2007), 0.96 g P (Pfeffer 1989), and 2.13 g Ca (Meschy 2000). Daily dry matter consumption of a goat is equal to 2.36% of live weigth and this level is about 1.18 kg day^{-1} for a 50 kg goat (NRC, 2007). Papachristou *et al.* (2005) reported that goats' feed was a mixture of oak browse (45%), herbaceous species (33%), and other woody species browse (22%). Considering these results, after a calculation of goat feed composed of 2/3 brushes and 1/3 herbaceous species, in the grazing goats there is a deficiency of CP in October, November, and December,

of ME in all the months except for March, April and May and P and Ca was sufficient.

Conclusions: In the gall oak, DM and Ca were low and CP, P was high in April, and DMD and ME were high in May and June. In the Christ's thorn, DM, ash and Ca were low in April and May, and CP, DMD, and ME were high in May. Herbs had their DM, NDF, and ADF lowest in April, and CP, DMD and ME highest in May. Consequently, goats should be fed with supplementary energy feed throughout the year except for spring months, and with feedstuff high in CP during autumn months in order to obtain satisfactory productivity.

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