Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture.1081932

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 5 - Issue 3: 240-247 / July 2022

THE NUTRITIONAL DYNAMICS OF COMMON WEEDS IN THE RANGELANDS OF THE AKDAĞ MOUNTAINS, SAMSUN

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Abstract: In this study, common weed species (*Anthemis* sp., *Anthemis tinctoria* L., *Pilosella hoppeana* Schultes, *Doranicum orientale* Hoffm, *Muscari neglectum* Guss. ex Ten., *Ornithogalum armeniacum* Baker, *Ornithogalum narbonense* L., *Ornithogalum wiedemannii* Boiss., *Anchusa azurea* Miller, *Echium plantagineum* L., *Echium vulgare* L., *Ajuga orientalis* L., *Stachys germenica* L., *Juncus* sp., *Anacamptis pyramidalis* L., *Ophrys apifera* Huds., *Carex panicea* L., *Ranunculus* sp., *Hypericum perforatum* L., *Primula elatior* L. Hill., and *Galium rotundifolium* L.) of the rangelands of Akdağ mountains, Samsun were evaluated by principal component analysis (PCA) and cluster analysis (CA). These species were collected at least three times in two consecutive years. The proximate nutrients (organic matter, ash, crude protein, ether extract, neutral and acid detergent fibre, non-fibrous carbohydrate and hemicellulose), neutral detergent fibre properties (nitrogen-free neutral detergent fibre and *in vitro* neutral detergent fibre digestibility), and forage quality indicators (digestible dry matter, dry matter intake, metabolizable energy, net energy lactation, estimated net energy, total digestible nutrients, relative feed value, and relative forage quality) were assessed by chemical analysis and empirical equations. There were significant variations in the nutritional dynamics among the weed species. The PCA results demonstrated a relationship between the dietary dynamics assessed. Component 1 (65.5%) and component 2 (14.5%) described 80.0% of the total variation, with eigenvalues of 11.788 and 2.609 in the weed species, respectively. The loadings plot of components shows that most forage quality indicators were distributed to Quadrant 1 and Quadrant 4. Three clusters are observed from the CA for the weeds with significant linkage distance, indicating relatively high independence for each cluster. Due to high variation in their nutritional dynamics, the weed species (*P. elatior, O. wiedemannii, O. narbonense, and G. rotundifolium*) were more similar on component 1 ordination and in Cluster 1 of the dendrogram. In conclusion, our results suggest that the highlighted species have significant potential for grazing livestock as forages and could fulfilling the possible forage gap in the grazing system.

Keywords: Invader species, Weedy forbs, Proximate composition, Nutritive value, Energy value, Forage quality

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Received: March 02, 2022
Accepted: May 09, 2022
Published: July 01, 2022

Cite as: Aydın İ, Ocak N. 2022. The nutritional dynamics of common weeds in the rangelands of the Akdağ Mountains, Samsun. BSJ Agri, 5(3): 240-247.

1. Introduction

Rangeland-based livestock farming systems, called grazing systems, are still crucial in many countries, including Türkiye (Fırıncıoğlu et al., 2010; Uzun et al., 2015; Diaz-Medina et al., 2021). Sustainable use and maintenance of rangelands has been very considerable because of the vital feed resource for grazing ruminants (Uzun and Ocak, 2019; Diaz-Medina et al., 2021). Early and intensive grazing in grazing systems causes edible or desirable species to be replaced by non-preferred species (Töngel and Ayan, 2005; Uzun and Ocak, 2019). As a result, non-preferred plant species, which are frequently regarded as less desirable or even worthless and harmful plants, have been classified as invaders or weeds (Khan et al., 2013; Koç et al., 2021).

The weeds are indicators of unproductive, unhealthy rangelands (Koç et al., 2021). However, many rangeland weeds, belonging to grasses, legumes, and other botanical families, are consumed by grazing animals (Abaye et al., 2009; Khan et al., 2013; Uzun and Ocak, 2019). Therefore, knowing the potential quality of individual weed species is essential for determining grazing time and range grazing capacity concerning meeting the nutrient requirements of grazing animals (Abaye et al., 2009; Kohl et al., 2012). For farmers in the grazing system, the aerial parts of several weeds are consumed as forage by livestock and play an essential role in the conventional household economy in countries like Türkiye (Gutiérrez et al., 2008; Aydin et al., 2019). We determined that the ratio of species preferred and unpreferred was 70.5% and 29.5%, respectively, in mountainous rangelands (Akdağ) in Samsun, Türkiye. In that study, Aydın et al. (2020) revealed that the other botanical families such as *Asteraceae*, *Lamiaceae*, *Boraginaceae*, *Liliaceae,* and *Scrophulariaceae* dominated most of the weed species that are preferred or somewhat preferred by ruminants. The high percentage of weed species may pose a risk to the quantity and quality of forages, livestock health, and the floristic patterns of the rangelands (Gutiérrez et al., 2008; Maduro Dias et al., 2020).

Awareness of the forage value of all rangeland species is essential to meet nutritional requirements of grazing ruminants and determine the suitable grazing time and rangeland grazing capacity (Kohl et al., 2012; Aydin et al., 2019). Furthermore, when grazing rangelands containing weed species that belong to the other botanical families, range management has essential importance to successful weed utilization and suppression (Abbaye et al., 2009). All weed species are considered low in quality and yield and harmful to the productivity and health of rangelands and grazing animals (Abaye et al., 2009; Koç et al., 2021). However, it has been stated that the forage quality of perennial weeds varied considerably among species but was equal or superior to that of the most desirable grass and legume species (Frost et al., 2008; Abaye et al., 2009; Kazemi and Valizadeh, 2019). As seen, the importance of weed species concerning their nutritional dynamics has been debatable, mainly proximate nutrients (PN) and forages quality indicators (FQI). Unfortunately, published data addressing the nutritional quality of rangeland weeds in the studied area is almost nonexistent.

Multivariate analysis techniques such as principal component analysis (PCA) and cluster analysis (CA) can assess the complex PN and FQI of weed species by showing the relationship and interdependency among the variables and their relative weights. The PCA and CA techniques have been used in some subjects, such as describing relationships among several quantitative variables in feeds and, according to this, classification of forages (Jayanegara et al., 2011; Uzun and Ocak, 2022). To our knowledge, these techniques have not been used in screening and evaluating weed species in terms of some nutritional dynamics based on acceptable forage quality. Therefore, the objectives of this study were 1) to assess the nutritional dynamics of 21 weed species commonly found in the mountainous rangelands by multivariate analyses and 2) to discuss their relation to the nutrient requirements of livestock.

2. Material and Methods

2.1. Study Area and Weed Species

This study was conducted as part of the major research project (TOVAG - 214O228), namely "Experiments on development of quality index in forage crops based on relative forage quality (RFQ)". In this study, we evaluated 21 weed species, the most dominant species (Uzun and Ocak, 2019; Aydın et al., 2020) for the rangelands of Akdağ Mountains, Samsun, Türkiye (at nearly 1200 m above sea level). These rangelands, open to public grazing, has a climate in which summers are warm and humid, and winters are cool and damp (Aydin et al., 2019). The weed samples were collected at least three times by 15-day intervals from May 5 (before-flowering) to July 5 (after-flowering stage) 2015 and 2016. These weeds, which are non-legumes forbs, belonged to 11 different families (Table 1). The seasonal growth cycle of these species, except for *E. vulgare,* is perennial. *E. vulgare* is a biennial or monocarpic perennial.

Table 1. The common name and family of common weed species in the rangelands of Akdağ Mountains[1]

Scientific name	Symbol in text	Common name	Family
Anthemis sp.	*Anthemis* sp.	Chamomile	Asteraceae
Anthemis tinctoria L.	*A. tinctoria*	Golden chamomile	Asteraceae
Pilosella hoppeana Schultes	*P. hoppeana*	Hawkweed	Asteraceae
Doranicum orientale Hoffm.	*D. orientale*	Leopard's bane	Asteraceae
Muscari neglectum Guss. ex Ten.	*M. neglectum*	Grape hyacinths	Asparagaceae[1]
Ornithogalum armeniacum Baker.	*O. armeniacum*	Saliva grass	Asparagaceae
Ornithogalum narbonense L.	*O. narbonense*	Star of bethlehem	Asparagaceae
Ornithogalum wiedemannii Boiss.	*O. wiedemannii*	Star of bethlehem	Asparagaceae
Anchusa azurea Miller	*A. Azurea*	İtalian bugloss	Boraginaceae
Echium plantagineum L.	*E. plantagineum*	Viper's-bugloss	Boraginaceae
Echium vulgare L.	*E. vulgare*	Blueweed	Boraginaceae
Ajuga orientalis L.	*A. orientalis*	Bugleweed	Lamiaceae
Stachys germenica L	*S. germenica*	Downy woundwort	Lamiaceae
Anacamptis pyramidalis L.	*A. pyramidalis*	Pyramidal orchid	Orchidaceae
Ophrys apifera Huds.	*O. apifera*	Bee orchid	Cyperaceae
Carex panicea L.	*C. panicea*	Carnation sedge	Hypericaceae
Hypericum perforatum L.	*H. perforatum*	St. John's Wort	Hypericaceae
Juncus sp.	*Juncus* sp.	Rush	Juncaceae
Primula elatior L. Hill.	*P. elatior*	True oxlip	Primulaceae
Galium rotundifolium L	*G. rotundifolium*	Bedstraw	Rubiaceae
Ranunculus sp.	*Ranunculus* sp.	Buttercup	Ranunculaceae

[1]These species involved to Asparagaceae are formerly considered to be part of the Liliaceae.

2.2. Proximate Analysis and Cell Wall Constituents

About 300 g of species dried at 60 °C for 72 h were ground in a mill with a 1 mm screen before analyses. These were assessed for proximate analysis, namely dry matter (DM), total ash (Ash), crude protein (CP), and ether extract (EE) determined by standard methods of AOAC International (AOAC, 2005). Cell wall constituents, neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using the ANKOM A200/220 (ANKOM Technology Corp., Fairport, NY, USA) filter bag technique following Van Soest et al. (1991). The 48-hour *in vitro* NDF digestibility (NDFD, % of NDF) was determined as described by Hoffman et al. (2001). The organic matter (OM), hemicellulose (HC), and non-fibrous carbohydrate (NFC) contents of the weeds were calculated as follows and expressed as % of DM: OM=DM%-Ash%; HC=NDF%-ADF%; NCF=100-(NDFn+CP + EE + ash); where NDFn is nitrogen-free NDF, estimated as NDF×0.93.

2.3. Forage Quality Indicators

Digestible DM (DDM), DM intake (DMI), metabolizable energy (ME), net energy lactation (NEL), estimated net energy (ENE), total digestible nutrients (TDN), relative feed value (RFV) and relative forage quality (RFQ) of weeds were calculated (Undersander et al., 2010; Pflueger et al., 2020; Aydın et al., 2022). The NEL and TNE values were expressed converting to MJ/kg DM. DDM (%)=88.9-(0.799×ADF, % of DM); DMI (% of body weigh [BW])=120/NDF, % of DM; RFV=(DDM, % of DM×DMI, % of BW)/1.29; RFQ=(DMI, % of BW×TDN, % of DM)/1.23; In the RFQ calculation, DMI (% of BW)=120/NDF+(NDFD-45)×0.374/1350×100; ME (Mj/kg DM)=(0.17×DDM, % of DM)-2; NEL (Mcal/kg DM) =1.085+(0.0124×ADF, % of DM); ENE (Mcal/kg DM) =(0.0307×TDN, % of DM)-0.764; TDN=(NFC×0.98) +(CP×0.93)+((EE-1)×0.97×2.25) +(NDFn×(NDFD/100)-7.

2.4. Statistical Analysis

Because the data set in this study is a collection of the data of individual weed species, it used descriptive statistics to describe the basic features of the nutritional dynamics. To identify the species' relationships with each other and with studied traits, the PCA was performed due to the suitability of the data (Kaiser-Meyer-Olkin: 0.816; χ^2: 8507.5, P<0.001). To describe most of the total data variations, the principal components (PCs) that had eigenvalues of >1.0 were considered significant (Jolliffe, 2002). Also, we used the CA to explore the similarities and differences in PN and FQI among the 21 weed species (Zhao et al., 2008). All statistical analyses were performed using the IBM SPSS (SPSS v21.0: IBM Corp.) software package.

3. Results and Discussion

A complete statistical summary of the distribution parameters for the PN and the FQIs of the weed species is given in Table 2 and Table 3, respectively. These tables show that the evaluated species had essential variation in PN, cell wall constituents, and FQI values from species to species, based on descriptive statistics. According to QS suggested by Aydin et al. (2019), the *P. hoppeana, C. panicea* and *Juncus sp.* species had lower values than all other species (Table 3). The QS of *E. vulgare, H. perforatum and S. germenica* species and *Ranunculus sp* were very good and promising, respectively. *A. azura* and *A. tinctoria* species were average and fair, respectively. Other weed species had premium QS. Because chemical composition affects the performance of ruminants, it is one of the critical determinants of animal production based on the grazing system (Abaye et al., 2009; Hassan and Tanveer, 2020). Since there were considerable variations in chemical composition between the weeds (Hassan and Tanveer, 2020), these weeds could affect the performance of animals that consume them to varying degrees. The results on CP, NDF, ADF, ME, and TDN were found to be comparable to the desirable perennial species in rangelands (Algan et al., 2017; Aydin et al., 2019: Aydin et al., 2022) to meet the nutrient requirements of all types of grazing livestock (Abaye et al., 2009; Maduro Dias et al., 2020).

Multivariate analyses showed that the overlap of weed species on the x-axis (Figure 1) and the weed species in the cluster dendrogram (Figure 2) were more similar to each other than either due to high variation in their nutritional dynamics. However, the significant difference between weed species on the y-axis and in subclusters indicates that these invaders had strong, species-specific spatial associations with other species. Similar results have been reported by Uzun and Ocak (2022) for some *Sorghum Bicolor* cultivars. As a result of the PCA, the loading plot of the PCA demonstrated a relationship between the nutritional dynamics evaluated in our study (data not shown). The PCA results revealed the presence of three principal components (PC) with eigenvalues >1, which accounted for 89.1% of the total variance in the weed species. The eigenvalues and % of variance for PC1, PC2 and PC3 were 65.5% and 11.788, 14.5% and 2.609, and 9.1% and 1.630, respectively. However, we only retained PC1 and PC2 that described 80.0% of the total variation for the score and loading plots of the PCA (Figure 1) since the inspection of the scree plot (not presented) showed a clear break after PC2 (Jolliffe, 2002).

Figure 1a presents the factor loadings of the 18 nutritional variables (eight PN, two NDF properties and eight FQI) for the weed species on the PC1 and PC2. The plot of the regression factor scores showed that data points were separated across both the PC1 and PC2 axis. Therefore, the nutritional variables were distributed in all quadrants of the PCA. Based on natural groupings in the PC2 versus PC1 plot, the nutritional dynamics loading on Quadrant 1 (upper right) were ash [0.431 and 0.305], CP [0.348 and 0.433] contents, NDFD [0.001 and 0.954) and some FQIs such as DDM [0.944 and 0.222], ME [0.944 and 0.222] TDN [0.944 and 0.223] and ENE [0.945 and 0.222] with positive loadings for PC1 and PC2.

Table 2. The nutrient contents and the neutral detergent fibre properties of common weeds in the rangelands of Akdağ Mountains

Weed species	Proximate nutrients, % of dry matter								Properties of NDF	
	OM	Ash	CP	EE	ADF	NDF	HC	NFC	NDFn	NDFD
A. orientalis	79.3±0.22	10.3±0.26	11.2±0.28	2.0±0.10	28.4±1.00	33.6±1.98	5.2±0.99	45.4±1.76	31.2±1.84	36.1±0.92
A. pyramidalis	87.2±0.05	5.7±0.29	12.0±0.29	2.3±0.03	28.5±1.00	40.2±2.84	11.7±1.84	42.6±2.03	37.4±2.64	33.0±1.91
A. azurea	77.5±1.31	16.3±1.51	14.8±3.97	1.6±0.31	38.0±0.91	50.1±2.18	12.1±2.02	20.6±0.68	46.6±2.03	55.3±3.49
Anthemis sp.	80.9±2.11	11.1±1.45	11.5±1.38	2.7±0.31	30.0±4.33	42.0±3.41	11.9±2.08	35.7±3.55	39.0±2.96	46.7±4.28
A. tinctoria	86.7±0.64	9.2±0.48	7.7±0.10	2.8±0.03	40.2±1.44	55.8±1.41	15.7±0.03	28.5±0.77	51.9±1.31	39.8±1.57
C. panicea	84.9±0.57	8.2±0.22	12.5±0.36	1.5±0.28	30.8±0.88	65.5±1.83	34.7±1.01	14.0±1.98	60.9±1.71	61.1±1.00
D. orientale	79.4±0.12	11.3±0.25	15.6±0.82	6.0±0.36	27.5±0.64	36.0±2.70	8.5±2.06	33.6±2.28	33.5±2.50	31.3±2.92
E. plantagineum	81.1±0.09	10.4±0.21	15.6±2.03	1.9±0.05	26.8±0.86	37.7±1.45	10.9±0.59	37.1±0.52	35.1±1.35	47.7±0.58
E. vulgare	77.9±1.64	14.5±0.42	12.8±0.54	2.2±0.38	31.0±2.64	43.2±2.20	12.2±1.56	30.3±1.48	40.2±3.91	54.7±1.66
G. rotundifolium	82.0±0.66	10.3±0.13	12.3±0.76	3.3±0.21	22.7±1.06	31.4±2.24	8.6±1.18	45.0±1.23	29.2±2.08	40.4±2.66
H. perforatum	86.4±1.38	6.3±0.92	10.7±0.52	5.5±1.61	34.0±2.70	46.1±2.34	12.2±2.59	34.6±0.08	42.9±1.18	24.5±1.09
Juncus sp.	87.3±0.85	6.1±0.20	11.9±0.71	1.6±0.22	36.6±0.54	68.8±2.13	32.1±1.59	16.4±0.84	64.0±1.98	52.6±0.84
M. neglectum	84.5±0.79	6.9±0.08	11.1±1.14	2.3±0.04	28.3±2.47	39.3±3.28	10.9±1.81	43.2±1.51	36.5±3.77	34.8±0.52
O. apifera	82.8±1.60	8.0±0.17	17.2±1.48	2.8±0.13	27.8±3.56	38.5±3.46	10.7±0.52	36.2±1.55	35.8±3.22	37.3±2.88
O. armeniacum	79.1±0.60	11.2±0.27	15.4±0.38	2.5±0.23	29.5±1.56	38.5±0.32	9.0±1.24	35.1±0.57	35.8±0.30	43.0±2.77
O. narbonense	79.4±0.36	11.6±0.33	13.8±0.34	2.6±0.23	22.6±1.12	30.4±1.87	7.8±0.75	43.8±1.78	28.3±1.74	47.2±0.99
O. wiedemannii	77.3±0.01	12.5±0.12	25.1±0.01	3.1±0.01	18.9±0.01	30.1±0.01	11.1±0.01	31.3±0.02	27.9±0.07	59.2±0.07
P. hoppeana	85.1±1.83	8.6±0.86	10.1±0.52	4.3±0.40	40.9±0.60	55.5±0.05	14.6±0.65	25.5±1.73	51.6±0.05	34.1±0.17
P. elatior	79.4±0.61	13.0±0.17	13.5±1.76	3.2±0.76	22.2±0.83	28.1±1.11	6.0±0.28	44.2±1.64	26.2±1.03	46.5±2.23
Ranunculus sp.	80.2±0.36	9.4±0.21	12.2±0.43	1.5±0.14	33.6±0.02	45.4±0.31	11.8±0.28	34.7±0.08	42.2±0.29	42.4±1.18
S. germenica	84.4±1.91	10.1±1.04	11.2±0.26	2.2±0.44	32.4±1.11	45.5±2.24	13.0±1.56	34.1±1.12	42.3±2.09	44.3±2.29

OM= organic matter, Ash= total ash, CP= crude protein, EE= ether extract, ADF= acid detergent fibre, NDF= neutral detergent fibre, HC= hemicellulose, NFC= non-fibrous carbohydrate, NDFn= nitrogen-free NDF (% of NDF), NDFD= 48-hour *in vitro* NDF digestibility (% of NDF).

Table 3. The forage quality indicators of common weeds in the rangelands of Akdağ Mountains

Weed species	Forage quality indicators								QS
	DDM	DMI	ME	NEL	ENE	TDN	RFV	RFQ	
A. orientalis	66.8±0.78	3.6±0.21	9.4±0.13	1.4±0.01	1.1±0.02	61.3±0.74	186.7±13.25	179.6±12.81	P
A. pyramidalis	66.7±0.78	3.0±0.21	9.3±0.13	1.4±0.01	1.1±0.02	61.2±0.74	156.2±12.95	150.2±12.50	P
A. azurea	59.3±0.71	2.4±0.11	8.1±0.12	1.6±0.01	0.9±0.02	54.2±0.67	110.5±5.61	105.9±5.40	A
Anthemis sp.	65.5±3.37	3.0±0.40	9.1±0.57	1.5±0.05	1.1±0.10	60.0±3.18	153.5±26.98	147.6±16.12	P
A. tinctoria	57.6±1.12	2.2±0.05	7.8±0.19	1.6±0.02	0.9±0.03	52.6±1.06	96.3±4.32	92.2±4.19	F
C. panicea	64.9±0.69	1.8±0.05	9.0±0.12	1.5±0.01	1.1±0.02	59.5±0.65	92.5±3.65	88.9±3.53	U
D. orientale	67.5±0.50	3.4±0.25	9.5±0.08	1.4±0.01	1.1±0.01	61.9±0.47	176.5±14.60	169.8±14.08	P
E. plantagineum	68.0±0.67	3.2±0.12	9.6±0.11	1.4±0.01	1.2±0.02	62.4±0.63	168.6±8.17	162.2±7.90	P
E. vulgare	64.7±2.05	2.8±0.28	9.0±0.34	1.5±0.03	1.1±0.06	59.3±1.93	142.9±18.56	137.4±17.96	V
G. rotundifolium	71.2±0.83	3.9±0.28	10.1±0.14	1.4±0.01	1.2±0.02	65.4±0.78	213.5±17.81	205.7±17.22	P
H. perforatum	62.5±3.66	2.6±0.14	8.6±0.62	1.5±0.06	1.0±0.11	57.2±3.45	127.4±14.23	122.3±13.88	V
Juncus sp.	60.4±0.42	1.8±0.05	8.3±0.07	1.5±0.01	0.9±0.01	55.2±0.39	81.9±3.11	78.5±3.00	U
M. neglectum	66.8±4.26	3.3±0.65	9.4±0.72	1.4±0.07	1.1±0.12	61.3±4.02	174.7±24.79	168.1±13.39	P
O. apifera	67.2±2.77	3.2±0.28	9.4±0.47	1.4±0.05	1.1±0.08	61.6±2.61	166.1±21.25	159.8±15.63	P
O. armeniacum	65.9±1.22	3.1±0.03	9.2±0.21	1.5±0.02	1.1±0.03	60.4±1.15	159.5±4.88	153.3±14.20	P
O. narbonense	71.3±0.87	4.0±0.25	10.1±0.15	1.4±0.01	1.2±0.03	65.5±0.83	220.4±16.34	212.3±15.81	P
O. wiedemannii	74.1±0.05	3.9±0.07	10.6±0.03	1.3±0.01	1.3±0.01	68.2±1.01	229.3±24.03	221.2±18.03	P
P. hoppeana	57.1±0.47	2.2±0.01	7.7±0.08	1.6±0.01	0.8±0.01	52.1±0.44	95.7±5.70	91.6±2.69	U
P. elatior	71.6±0.65	4.3±0.17	10.2±0.11	1.4±0.01	1.3±0.02	65.8±0.61	237.9±11.60	229.2±11.23	P
Ranunculus sp.	62.8±0.02	2.6±0.02	8.7±0.01	1.5±0.01	1.0±0.01	57.5±1.03	128.7±4.91	123.6±10.88	G
S. germenica	63.6±0.86	2.7±0.14	8.8±0.15	1.5±0.01	1.0±0.02	58.3±0.82	131.0±8.63	125.9±8.34	V

DDM= digestible dry matter, DMI= dry matter intake, ME= metabolizable energy, NEL= net energy lactation, ENE= estimated net energy, TDN= total digestible nutrients, RFV= relative feed value, RFQ= relative forage quality, QS= quality scores based on RFQ ranges (P, premium [>138], V= very good [125-137], G= good [115-124], A= average [99-114], F= fair [93-98], U= low/utility [<93]) according to Aydin et al. (2019).

Quadrant 2 (upper left) had the NDF [-0.942 and 0.272], NFDn [-0.942 and 0.272] and HC [-0.652 and 0.591 with negative loadings for PC1 and positive loadings for PC2. The main variables loading on Quadrant 3 (lower left) were OM [-0.636 and -0.285], ADF [-0.944 and -0.223] and NEL [-0.946 and -0.219] with negative loadings for PC1 and PC2. The variables loading on Quadrant 4 (lower right) were EE [0.228 and -0.489] and NFC [0.776 and -0.515] contents and some FQIs (DMI [0.969 and -0.170], RFV [0.983 and -0.077] and RFQ [0.983 and -0.075]) with positive loadings for PC1 and negative loadings for PC2. The loadings plot of the PC1 and PC2 (Figure 1a) shows that most FQI was distributed to Quadrant 1 and Quadrant 4. Because the position of each variable in the loading plot describes its relationship to the other variables, the grouping of FQIs in the loadings plot suggests their significant mutual positive correlation (Pelletier et al., 2010; Uzun and Ocak, 2022).

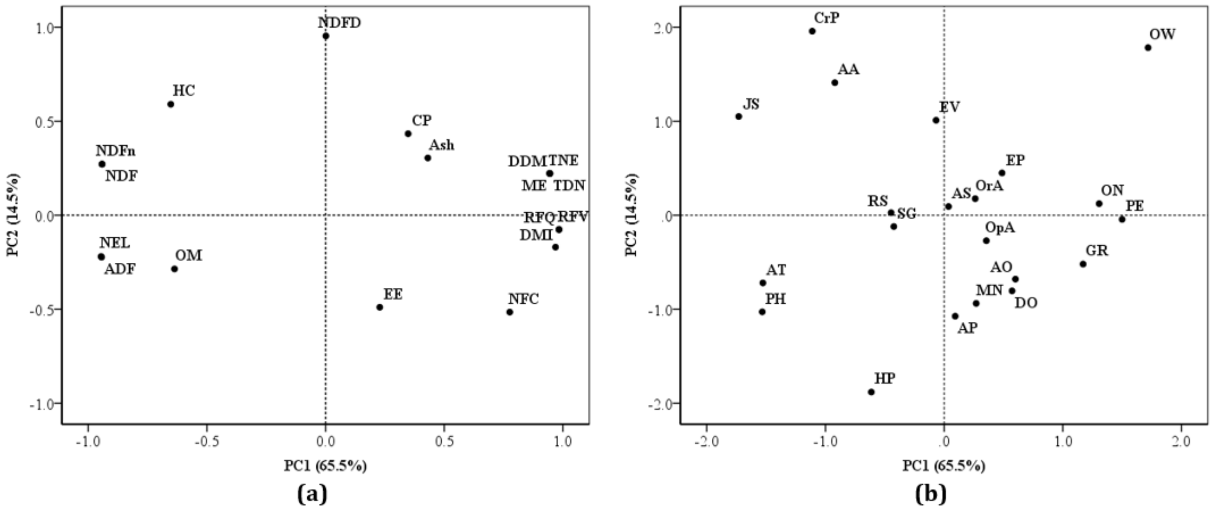

Figure 1. Loading plots (a) and score plots (b) of principal components (PC1 and PC2) for the nutritional dynamics of common weed species in the rangelands of Akdağ Mountains. OM= organic matter, Ash= total ash, CP= crude protein, EE= ether extract, ADF= acid detergent fibre, NDF= neutral detergent fibre, HC= hemicellulose, NFC= non-fibrous carbohydrate, NDFn= nitrogen-free NDF (% of NDF), NDFD= 48-hour *in vitro* NDF digestibility, DDM= digestible dry matter, DMI= dry matter intake, ME= metabolizable energy, NEL= net energy lactation, ENE= estimated net energy, TDN= total digestible nutrients, RFV= relative feed value, RFQ= relative forage quality, AO= *A. orientalis*, AP= *A. pyramidalis*, AA= *A. azurea*, AS= *Anthemis* sp., AT= *A. tinctoria*, CrP= *C. panacea*, DO= *D. orientale*, EP= *E. plantagineum*, EV= *E. vulgare*, GR= *G. rotundifolium,* HP= *H. perforatum*, JS= *Juncus* sp., MN= *M. neglectum*, OpA= *O. apifera*, OrA= *O. armeniacum*, ON= *O. narbonense*, OW= *O. wiedemannii*, PH= *P. hoppeana*, PE= *P. elatior*, RS= *Ranunculus* sp., SG= *S. germenica*.

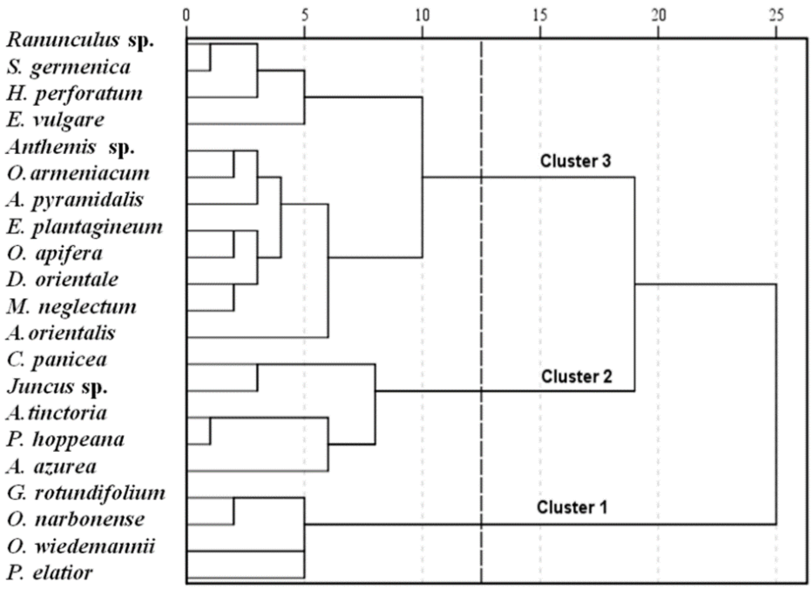

Figure 2. Dendrogram using average linkage (between species) of common weed species in the rangelands of Akdağ Mountains based on a total of 18 nutritional variables (eight proximate nutrients, two neutral detergent fibre properties and eight forage quality indicators).

Morevere, Jayanegara et al. (2011) noted that close variables in any quadrant have high correlations and variables on the opposite side of origin (0.0) are negatively correlated. According to relation matrix loadings (≥0.75 and positive factor loadings) of the variables, these FQIs such as DDM, ME, TDN and ENE contributed most strongly to PC1, while ash, CP contents and NDFD contributed less strongly (Uzun and Ocak, 2022).

The scatter diagram arranged on loading scores of PCs showed that the scatter plots of the weed species were cross-distributed among the quadrants or that there was a contrasted distribution of the species along PC1 and PC2 (Figure 1b). Weeds arranged in the same direction with the nutritional dynamics such as DDM, ME, TDN and ENE were considered good quality compared whit the weed species in the other quadrants. Based on the dataset of other quadrants, weeds were partially related to low forage quality. On the *x*-axis, the nine species, *S. germenica, C. panicea, A. tinctoria, H. perforatum, E. vulgare, A. azurea, Juncus sp., Ranunculus sp., P. hoppeana*, were opposed to the 12 species, *O. armeniacum A. orientalis, A. pyramidalis, Anthemis sp., D. orientale, E. plantagineum, G. rotundifolium, M. neglectum, O. apifera, O. narbonense, O. wiedemannii, P. elatior*. Pelletier et al. (2010) noted that this contrast is related to the nutritional dynamics arranged on the respective quadrants. Indeed, one end of the axis had higher CP, ash and some FQIs, whereas the other had higher fibre concentrations. This result confirms the idea that forage quality had positively correlated with CP but negatively with NDF and ADF contents (Zhao et al., 2008; Zhai et al., 2018).

Three clusters were observed from the dendrogram (Figure 2) for the nutritional variables in the weed species with significant linkage distance, indicating relatively high independence for each cluster. The four weed species (*P. elatior, O. wiedemannii, O. narbonense and G. rotundifolium*) formed a cluster group (Cluster 1). Cluster 2 consisted of five accessions formed by *A. azurea, P. hoppeana, A. tinctoria and C. panacea* species. The remaining 12 species (*A. orientalis, D. orientale, H. perforatum, E. plantagineum, E. vulgare, Juncus sp., M. neglectum, Ranunculus sp., S. germenica, Anthemis sp., O. armeniacum, O. apifera* and *A. pyramidalis*) were clustered into one group (Cluster 3). Cluster 2 and Cluster 3 had two subgroups. The first subgroup of Cluster 3 was the largest group consisting of eight accessions, representing *A. orientalis, M. neglectum, E. plantagineum, D. orientale, O. armeniacum, O. apifera, Anthemis sp.* and *A. pyramidalis* species.

The results on cell wall constituents showed that the weeds contained favourable levels of NDF, ADL, ADF and HC and, thus, a good and valuable source of these nutrients, as were reported by Khan et al. (2017). Although protein requirement varies with each type and stage of life of grazing animals (Abaye et al., 2009; Kirilov et al., 2016), the dietary adequate-protein level required for maximal growth and activity of ruminal microorganisms is higher than 7% CP (Sampaio et al., 2010; Maduro Dias et al., 2020). The CP content of all the weeds in the present study had more excellent than this value. Hall et al. (2009) noted that acceptable quality is forage of >56% TDN and >10% CP, whereas unsuitable quality is forage of 50-55% TDN and 8-9% CP. As the ADF and NDF contents increases, DMI, DDM and subsequently nutritive value declines due to increasing fibre (Abaye et al., 2009; Zhai et al., 2018). As noted herein, the high CP and low ADF and NDF contents of forages are generally associated with increased energy value or good forage quality (Kirilov et al., 2016; Zhai et al., 2018). Therefore, the highlighted weeds may be relative adequate to meet the nutritional needs of grazing livestock (Gutiérrez et al., 2008; Bunton et al., 2020; Maduro Dias et al., 2020) depending on the ratio of weeds in the rangeland (Uzun and Ocak, 2019). Indeed, a mixture containing 15% weeds and 85% desirable forages did not influence the forage intake or digestibility compared to 100% quality grass and legume mixture (Abaye et al., 2009).

The nutritional dynamics and anti-nutritional factors of forages impact voluntary feed intake of grazing animals. The presence of anti-nutritional factors, which depress digestibility in ruminants and sometimes are toxic, limits the utilization of some weeds (Töngel and İlknur, 2005; Abaye et al., 2009). Unfortunately, we did not determine whether weeds contain anti-nutritional factors or toxins (Burritt and Hart, 2014). However, *Ranunculus* sp., *E. vulgare, E. plantagienum and H. perforatum* species are toxic or poisonous species commonly found in the experimental area (Töngel and İlknur, 2005). Generally, these plants are avoided by all types of livestock because animals learn what to eat and avoid (Abaye et al., 2009; Burritt and Hart, 2014). Otherwise, these species have a significantly higher risk of toxicity to grazing animals eating a single plant species (Töngel and İlknur, 2005; Burritt and Hart, 2014). Even if an animal has eaten any weed evaluated due any reason, this does not mean the animal can survive on a sole diet of that weed. Therefore, any assessed weeds, except for the toxic or poisonous weeds, together with desirable legumes and grasses could be incorporated and satisfactory for grazing without significant problems (Abaye et al., 2009; Burritt and Hart, 2014). Our results conform with the suggestion that not all weeds in a grazing system are detrimental from the standpoint of nutritive value (Abbaye et al., 2009; Bunton et al., 2020). Forage value for the grazing system is the total value of desirable and undesirable (or weeds) forage species in rangeland relative to grazing animal productivity and gain (Khan et al., 2017; Collins and Newman, 2018; Bunton et al., 2020).

The performance of grazing animals in rangelands varies depending on the proportion of high-quality forage species available and accessible. Accordingly, there is an immediate need for forages species with high quality produced abundantly and widely distributed for rangelands subjected to early and overgrazing (Uzun and Ocak, 2019). Annual forage species might meet this instant need (Aydın et al., 2015; Kazemi and Valizadeh, 2019; Uzun and Ocak, 2019), but annual species without autumn to spring cycles are not essential components of sustainable grazing systems (Frost et al., 2008; Abbaye et al., 2009; Uzun and Ocak, 2019). Based on our RFV and RFQ results, weeds had better values than desirable legumes (*Lotus corniculatus, Medicago sativa, Trifolium pratense, Trifolium repens*), grasses *(Dactylis glomerata, Festuca ovina, Lolium perenne)* and other families (*Cichorium intybus and Sanguisorba minör*) collected from same rangelands (Aydın et al., 2022). Similarly, perennial weeds in rangelands have had equal or superior forage quality compared with some desirable grasses and legumes species (Frost et al., 2008; Abaye et al., 2009; Kazemi and Valizadeh, 2019). This situation may be related to grass and legume forages with similar digestibility and voluntary feed intake; there is little difference in ADF or NDF levels (Collins and Newman, 2018). Most weeds in the present study may be alternatives for forages needed instant if there is high grazing pressure on rangelands (Gutiérrez et al., 2008; Khan et al., 2017; Bunton et al., 2020). It should be forgotten that there is a reduction in the nutritional values of many perennial weeds towards the end of the growing season. Furthermore, some weed species are consumed voluntarily due to greater nutritive values during the early stages of the growing season (Bunton et al., 2020). In such cases, the movement and grazing of animals and forage utilization may differ depending on meeting nutrient requirements (Gutiérrez et al., 2008). Our results indicate that non-preference weeds have the potential to preserve plant diversity and contribute to forage resources in overgrazed rangelands (Uzun and Ocak, 2019).

Because the NDFD is a measure of the digestible rations of NDF (Foster et al. 2009), a weed species with a higher NDFD is a forage with high quality and provided the NDF with more digestible and usable to the animal (Bunton et al., 2020). The NFC that differ from carbohydrates found in NDF is needed to satisfy the activity of rumen microbes and thus animals' health and performance (Tan et al., 2002). The PCA and CA results indicate that the evaluated weeds widely vary in NFC (comprised primarily of starch, sugars, pectin and β-glucans) and depend mainly on the NDF, ADF and CP levels, as in forage grasses (Pelletier et al., 2010). Mayland et al. (2000) observed that the NFC concentration of *Festuca arundinacea* cultivars close relationship to animal grazing preference. As such, grazing animals may likely prefer some weeds (such as *A. Pyramidalis, M. Neglectum, O. Narbonense, P. Elatior, G. rotundifolium* and *A. orientalis*) to others, including all range forage species due to a difference in their NFC concentration. Weeds with high NFC concentration might have relative lower CP, ADF and NDF contents but a relative higher NDFD and, as a result, higher TDN, ME, NET and ENE (Pelletier et al., 2010). Weeds with high NFC concentration might have relative lower CP, ADF and NDF contents but a relative higher NDFD (Pelletier et al., 2010) and thus a higher TDN, ME, NET and ENE. These results and knowledge may explain why the weeds in Quadrant 1 and Cluster 1 are of better quality.

4. Conclusion

Except for four poisonous species (*Ranunculus* sp., *E. vulgare, E. plantagienum and H. perforatum*), the 17 weed species were nutritionally beneficial to grazing livestock and satisfactory for damaged rangelands. Assessed weeds possess a great potential for their utilization as range forage and may be very effective in overcoming the possible shortage of forage. These results may help producers make management decisions based upon the potential benefit or detriment a weed may provide to the overall nutritional value of the grazing system. Thus, weed species not only improve livestock production if there is a forage gap in the grazing system but also benefit biodiversity, a "win-win" solution for farmers and environmentalists. Further research is needed to quantify the anti-nutritional factors and palatability of weedy forage.

Author Contributions

İ.A. (100%) designed the experiment and carried it out. N.O. (100%) analyzed the data and wrote the original draft. İ.A. (50%) and N.O. (50%) submission and revision. All authors reviewed and approved final version of the manuscript.

Conflict of Interest

The authors declared that there is no conflict of interest.

Acknowledgments

The Scientific and Technological Research Council-TUBITAK funded the project (TOVAG-214O228), from which this study was obtained. The authors would like to acknowledge B. Pak, R.P. Süzer and C. Topçugil for data collection.

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