Pak. J. Bot., 41(3): 1137-1154, 2009.

NUTRITIONAL EVALUATION OF SOME FORAGE PLANTS FROM HARBOI RANGELAND, KALAT, PAKISTAN

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Abstract

The proximate composition and cell wall analysis of some fodder species from Harboi rangeland, Kalat, Balochistan was conducted at three phenological stages. It was concluded that grasses generally had more DM, CF, carbohydrates, NFE, NDF, ADF and hemicelluloses than shrubs while shrubs were generally high in ash, CP, EE, N, GE, ADL contents than grasses. There were insignificant differences in TDN, DE and ME between grasses and shrubs. Generally DM, CF, NDF, ADF, ADL, carbohydrate and hemicellulose contents increased with the maturity of plants; while ash, CP, EE, N and ME declined with maturity of plants. Some parameters like NFE, GE, DE and TDN did not differ among various phenological stages. The nutritive quality of forage decreased with the advancement of phenological growth stages in all analyzed plants. Across all the grazing seasons the forage for sheep and goats was generally deficient in most of the nutrients required for growth and maintenance. It is concluded that the poor livestock productivity in Harboi rangeland is partially due to insufficient amount of available poor quality forage that requires attention of the range mangers to improve the habitat and livestock breeds.

Introduction

Range animal productivity depends upon the amount and nutritive quality of vegetation available to grazing animals. The nutritional demands of livestock vary with age and physiological functions of the grazing animal such as growth maintenance, gestation, fattening and lactation etc. Plant material is divisible into fibrous and non-fibrous fractions. In ruminants, fibre fractions that provide energy are important as celluloses and hemicelluloses are easily digestible. The phenolic polymers like lignin are almost indigestible that may hinder carbohydrate digestion. Most rangelands of Pakistan have insufficient forage of low palatability due to over-stocking. Many studies have assessed the nutritional value of forage in natural rangelands (Malik & Khan, 1965, 1966, 1967, 1971; Kalmbacher & Martin, 1981; Kalmbacher *et al.*, 1981; Kalmbacher, 1983; Vallentine, 1990; Khan *et al.*, 2002; Islam *et al*., 2003; Nasrullah *et al*., 2003; Khan *et al*,, 2005) and in cultivated fodder species (Azim *et al.*, 1989; Ashraf *et al.*, 1995). Studies have indicated that the quality of forage varies with the soil, season, rainfall, chemical nature, and age of the plants that affects palatability and health of grazing animals (Malik & Khan, 1971; Fierro & Bryant, 1990; Wahid, 1990; Liu, 1993; Robles & Boza, 1993; Saleem, 1997; Theunissen, 1995; Ganskopp & Bohnert, 2001). Holecheck *et al*., (1998) reported high crude protein in actively growing forage compared to dormant stage. Sultan *et al*., (2007) suggested that there is a need of 13.5 and 110.3 m tons of crude proteins and total digestible nutrients for maintaining livestock but the present feed resources only provide 40% and 75% of crude protein and total digestible nutrients. Since the health of livestock depends on the nutritional value of available forage, it therefore becomes necessary for the stockmen and range managers to understand the nutritional dynamics of forage to sustain adequate growth and reproduction of animals (Ganskopp & Bohner, 2001). The review indicates that there are some studies made on the floristic characteristic, palatability, and productivity of Harboi rangeland (Durrani *et al*., 2005; Hussain & Durrani, 2007, 2008, 2009; Durrani & Hussain, 2005), but no such effort has been made to assess the nutritional status of the forage plants of Harboi rangeland. The present study was therefore conducted to evaluate the nutritional status of some grasses and shrubby plants of this rangeland at different phenological stages. The findings will help the stockmen and range managers to improve the forage quality for the betterment of animal health and their productivity.

Materials and Methods

The location, climatic, floristic and other ecological characteristics have been provided in details in our previous papers (Durrani *et al*., 2005; Durrani & Hussain, 2005, Hussain & Durrani, 2007).

Collection and preparation of plant samples: Plant samples of six shrubs and four grasses (Table 1) were collected at three phenological stages (seedling/pre-reproductive, flowering/reproductive and post-reproductive). Samples were oven dried at 65^{o}C for 7 h and powdered for further analysis.

1. Proximate composition: The proximate composition including dry matter (Anon., 1990), ash contents (Anon., 1990), organic matter (Anon., 1990), crude protein (Anon., 1990), crude fibre (Anon., 1990), ether extract (Galyean, 1985), nitrogen and nitrogen free extract (Galyean, 1985), gross energy (Garrett & Johnson, 1983) and total digestible nutrients (Harris *et al*., 1967), carbohydrate contents, total digestible energy for goats and sheep (Anon., 1982) and metabolizable energy (Moe & Tyrrel, 1976) were determined following standard methods.

2. Cell wall constituents: The cell wall constituents including neutral detergent fibre (Van Soest & Robertson, 1990; Goering & Van Soest, 1970), acid detergent fibre (Van Soest, 1963; Van Soest & Wine, 1967), acid detergent lignin (Georing & Van Soest, 1970) and hemicelluloses (Van Soest & Robertson, 1985) and total carbohydrates (Galyean, 1985) were determined following standard methods.

Statistical analysis: For the comparison of chemical contents of grasses and shrubs t-test was applied. For the comparison of chemical contents among phenological stages; and among grasses and shrubs, randomized block design was used (Steel *et al.*, 1997).

Results and Discussion

A. Proximate composition: The results of proximate analyses (Table 2) and its statistical treatment (Table 3) are discussed as follows.

1. Dry matter (DM %): Generally, grasses had more dry matter than shrubs (Table 2). Among grasses, DM increased from 63.41% (*Pennisetum orientale*), 69.04% (*Stipa pennata*), 73.78% (*Cymbopogon jwarancusa*) to 80.9% (*Tetrapogon villosus*). Among shrubs, the DM ranged from 52.23% in *Perovskia abrotanoides* to 71.7% in *Artemisia maritima*. It was least at pre reproductive stage that gradually increased with the advancing age in *Artemisia*. There were highly significant differences in DM of grasses and shrubs at reproductive and post reproductive stages (Table 3). It was observed that dry matter of grasses and shrubs generally increased with maturity. The results agree with other studies (Vallentine, 1990; Ashraf *et al.*, 1995; Kramberger & Klemencic, 2003) who also observed increased dry matter with maturity of fodder plants.

Table 1. Palatability of plants with their phenological stage used for chemical analysis.

	Species	Palatability at		
		Pre reproductive	Reproductive (Flowering)	Post reproductive (Post fruiting)
	Shrubs			
1.	*Artemisia maritima* L.	Highly palatable	Highly palatable	Highly palatable
2.	*Perovskia abrotanoides* Karel	Rarely palatable	Highly palatable	Highly palatable
3.	*Perovskia atriplicifolia* Bth.	Rarely palatable	Highly palatable	Highly palatable
4.	*Convolvulus leiocalycinus* Boiss.	Highly palatable	Highly palatable	Highly palatable
5.	*Sophora griffithii* Stocks	Non palatable	Shoots non- palatable/pods moderately palatable	Highly palatable
6.	*Hertia intermedia* (Boiss) O. Ktze	Non palatable	Mostly palatable	Non-palatable
	Grasses			
7.	*Pennisetum orientale* L.	Highly palatable	Highly palatable	Highly palatable
8.	*Stipa pennata* L.	Highly palatable	Highly palatable	Highly palatable
9.	*Tetrapogon villosus* Desf.	Highly palatable	Highly palatable	Highly palatable
10.	*Cymbopogon jwarancusa* (Jones) Schult.	Least palatable	Least palatable	Least palatable

Table 2. Proximate composition % of some grasses and shrubs of Harboi Hills.

S. No.	Species	Phenological stages	Dry matter %	Organic matter %	Nitrogen %	Crude protein %	Crude fiber %	Ether extract %	Ash %	NFE* %	Carbohydrates %
	Ggrasses										
1.	***Stipa pennata***										
		Pre-Rep. Stage	40.7	91.5	1.9	11.9	23.2	2.6	8.5	53.8	17.7
		Reproductive Stage	72.3	90.2	1.52	9.55	24.46	2.99	9.8	53.2	49.96
		Post Rep. Stage	94.1	92.2	1.01	6.35	29.96	2.71	7.8	53.18	77.24
		Mean	**69.03**	**91.30**	**1.48**	**9.27**	**25.87**	**2.77**	**8.70**	**53.39**	**48.30**
2.	***Pennisetum orientale***										
		Pre-Rep. Stage	51.38	89.67	2.28	14.26	22.1	2.5	10.33	50.81	24.29
		Reproductive Stage	58.55	90.2	1.59	9.98	19.9	13.4	9.8	46.92	25.37
		Post Rep. Stage	80.3	93.3	0.9	5.61	29.8	1.9	6.7	55.99	66.09
		Mean	**63.41**	**91.06**	**1.59**	**9.95**	**23.93**	**5.93**	**8.94**	**51.24**	**38.58**
3.	***Tetrapogon villosus***	Pre-Rep. Stage	58.2	83.8	1.45	9.1	20.4	2.31	16.2	51.99	30.59
		Reproductive Stage	93.8	92.8	1.14	7.15	30.16	1.45	7.2	54.04	78
		Post Rep. Stage	90.7	92.2	1.32	8.3	30	2.14	7.8	51.76	72.46
		Mean	**80.9**	**89.60**	**1.30**	**8.18**	**26.85**	**1.97**	**10.40**	**52.60**	**60.35**
4.	***Cymbopogon jwarancusa***										
		Pre-Rep. Stage	58.67	90.8	1.15	7.2	25.2	2.3	9.2	56.1	39.97
		Reproductive Stage	71.75	91.9	1.1	6.9	26.9	1.9	8.1	56.2	54.85
		Post Rep. Stage	81.60	93.2	1.02	6.4	26.6	2.95	6.8	57.25	74.75
		Mean	**70.67**	**91.97**	**1.09**	**6.83**	**26.23**	**2.38**	**8.03**	**56.52**	**56.52**

Table 2. (Cont'd.).

S. No.	Species	Phenological stages	Dry matter %	Organic matter %	Nitrogen %	Crude protein %	Crude fiber %	Ether extract %	Ash %	NFE* %	Carbohydrates %
	Shrubs										
1.	***Artemisia maritima***										
		Pre-Rep. Stage	58.7	90.3	2.52	15.8	14.1	9.2	9.7	51.2	24
		Reproductive Stage	74.8	93.1	1.14	7.12	27.8	6.9	9.5	48.7	51.28
		Post Rep. Stage	81.6	91.7	1.85	11.6	22.9	8.3	9.6	47.6	52.1
		Mean	**71.70**	**91.70**	**1.84**	**11.51**	**21.60**	**8.13**	**9.60**	**49.17**	**42.46**
2.	***Perovskia abrotanoides***										
		Pre-Rep. Stage	43.73	90.8	2.22	13.9	13.5	8.3	9.2	55.1	12.33
		Reproductive Stage	55.6	91.2	1.5	9.4	24.8	7.2	8.8	49.8	29.3
		Post Rep. Stage	57.36	92.6	0.96	6	23.3	8.2	7.4	55.1	35.76
		Mean	**52.23**	**91.53**	**1.56**	**9.77**	**20.53**	**7.90**	**8.47**	**53.33**	**25.80**
3.	***Perovskia atriplicifolia***										
		Pre-Rep. Stage	47.62	89.5	1.53	9.6	14.6	7.5	10.5	57.8	20.02
		Reproductive Stage	62.4	92.1	1.23	7.7	26	7.2	7.9	51.2	39.6
		Post Rep. Stage	72.22	88.2	1.39	8.7	19.3	7.9	11.8	52.3	43.82
		Mean	**60.75**	**89.93**	**1.38**	**8.67**	**19.97**	**7.53**	**10.07**	**53.77**	**34.48**
4.	***Convolvulus leiocalycinus***										
		Pre-Rep. Stage	66.28	88.31	2.45	15.37	26.7	1.53	11.69	44.71	37.69
		Reproductive Stage	54.05	95.16	0.69	4.37	28.6	4.57	4.84	57.62	40.27
		Post Rep. Stage	84.4	91.8	1.32	8.3	32.7	2.98	8.2	47.82	64.92
		Mean	**68.24**	**91.76**	**1.49**	**9.35**	**29.33**	**3.03**	**8.24**	**50.05**	**47.63**
5.	***Sophora griffithii***										
		Pre-Rep. Stage	48.17	95.25	1.91	11.97	22.5	2.01	4.75	58.77	29.44
		Reproductive Stage	52.45	91.11	1.9	11.89	24	5.4	8.89	49.82	26.27
		Post Rep. Stage	63.8	94.28	1.63	10.2	21.4	7.9	5.72	54.78	39.98
		Mean	**54.81**	**93.55**	**1.81**	**11.35**	**22.63**	**5.10**	**6.45**	**54.46**	**31.90**
6.	***Hertia intermedia***										
		Pre-Rep. Stage	37.3	87.2	1.39	8.7	14.3	12.7	12.8	51.5	3.1
		Reproductive Stage	35.64	88.4	1.26	7.9	27.5	4.5	11.6	48.5	11.64
		Post Rep. Stage	75.00	90.9	1.29	8.1	16.3	8.4	9.1	58.1	49.4
		Mean	**49.31**	**88.83**	**1.31**	**8.23**	**19.37**	**8.53**	**11.17**	**52.70**	**21.38**

Table 3. Statistical comparison of proximate composition of grasses and shrubs at three phenological stages.

	Pre-Rep.		Reproductive		Post-Rep.			Pre-Rep.		Reproductive		Post-Rep.	
	Grass	Shrubs	Grass	Shrubs	Grass	Shrubs		Grass	Shrubs	Grass	Shrubs	Grass	Shrubs
	Ash							Crude protein					
	8.50	9.70	9.80	9.50	7.80	9.60		11.90	15.80	9.55	7.12	6.35	11.6
	10.33	9.20	9.80	8.80	6.70	7.40		14.26	13.90	9.98	9.40	5.61	6.0
	16.20	10.50	7.20	7.90	7.80	11.80		9.10	9.60	7.15	7.70	8.30	8.7
	9.20	11.69	8.10	4.84	6.80	8.20		7.20	15.37	6.90	4.37	6.40	8.3
		4.75		8.89		5.72			11.97		11.89		10.2
		12.80		11.60		9.10			8.70		7.90		8.1
Sum	**11.0575**	**9.773333**	**8.725**	**8.588333**	**7.275**	**8.636667**	**Sum**	**10.615**	**12.5567**	**8.395**	**8.063333**	**6.665**	**8.816667**
Variance	**12.32189**	**7.786067**	**1.675833**	**4.912177**	**0.369167**	**4.275267**	**Variance**	**9.631567**	**8.83971**	**2.543767**	**6.223867**	**1.318567**	**3.677667**
t-Test	**0.53643**	**0.563994**	**0.915049**	**0.905276**	**0.243762**	**0.178242**	**t-Test**	**0.348809**	**0.36031**	**0.821267**	**0.804112**	**0.081199**	**0.057609**
	NS		**NS**		**S**			**NS**		**NS**		**NS**	
	Crude fiber							Ether extract					
	23.20	14.10	24.46	27.80	29.96	22.90		2.60	9.20	2.99	6.90	2.71	8.30
	22.10	13.50	19.90	24.80	29.80	23.30		2.50	8.30	13.40	7.20	1.90	8.20
	20.40	14.60	30.16	26.0	30.0	19.30		2.31	7.50	1.45	7.20	2.14	7.90
	25.20	26.70	26.90	28.60	26.60	32.70		2.30	1.53	1.90	4.57	2.95	2.98
		22.50		24.0		21.40			2.01		5.40		7.90
		14.30		27.50		16.30			12.70		4.50		8.40
Sum	**22.725**	**17.61667**	**25.355**	**26.45**	**29.09**	**22.65**	**Sum**	**2.4275**	**6.87333**	**4.935**	**5.961667**	**2.425**	**7.28**
Variance	**4.049167**	**31.15367**	**18.6777**	**3.295**	**2.763067**	**30.919**	**Variance**	**0.021692**	**18.7989**	**32.26523**	**1.667217**	**0.2379**	**4.48**
t-Test	**0.12237**	**0.081148**	**0.588555**	**0.658532**	**0.057987**	**0.03593**	**t-Test**	**0.079446**	**0.0537**	**0.672453**	**0.744375**	**0.002212**	**0.001874**
	S		**NS**		**S**				**S**	**NS**		**S**	
	NFE*							Carbohydrate					
	53.80	51.20	53.20	48.70	53.18	47.60		17.70	24.0	49.96	51.28	77.24	52.10
	50.81	55.10	46.92	49.80	55.99	55.10		24.29	12.33	25.37	29.30	66.09	35.76
	51.99	57.80	54.04	51.20	51.76	52.30		30.59	20.02	78.0	39.60	72.46	43.82
	56.10	44.71	56.20	57.62	57.25	47.82		39.97	37.69	54.85	40.27	74.75	64.92
		58.77		49.82		54.78			29.44		26.27		39.98
		51.50		48.50		58.10			3.1		11.64		49.40
Sum	**53.175**	**53.18**	**52.59**	**50.94**	**54.545**	**52.61667**	**Sum**	**28.1375**	**21.0967**	**52.045**	**33.06**	**72.635**	**47.66333**
Variance	**5.314567**	**26.95252**	**15.8852**	**11.64304**	**6.3415**	**17.83783**	**Variance**	**89.92249**	**151.055**	**465.811**	**189.1564**	**22.84897**	**107.1973**
t-Test	**0.99862**	**0.998402**	**0.502197**	**0.523454**	**0.440145**	**0.392889**	**t-Test**	**0.363458**	**0.33877**	**0.124023**	**0.183821**	**0.002138**	**0.001106**
	NS		**NS**		**NS**			**NS**		**NS**		**S**	

S= Significant
NS= Non-significant

2. Ash contents (total minerals): Ash contents (total minerals) of shrubs were greater than those of grasses (Table 2). It varied from 6.45% in *Sophora griffithii* to 11.17% in *Hertia intermedia* at pre reproductive stage. The lowest ash contents were recorded in *Sophora griffithii* and *Convolvulus leiocalycinus* at pre reproductive stages. At post reproductive stage, ash contents were highest in *Perovskia atriplicifolia* and lowest in *Sophora griffithii*. The ash contents of grasses were as high as 10.4% in *Tetrapogon villosus*, which declined to 8.03% in *Cymbopogon jwarancusa*. At pre reproductive stage, *Stipa pennata* had the lowest ash contents that enhanced at reproductive and post reproductive stages. The highest and lowest ash contents for *Pennisetum* were observed at reproductive and post reproductive stages, respectively (Table 2). The differences between ash contents of grasses and shrubs were non-significant at all phenological stages (Table 3). Generally, the ash contents were higher at pre reproductive stage, which gradually decreased maturity of plants. However, in some cases (*Stipa* and *Sophora* at reproductive stage; and *Perovskia atriplicifolia* at post reproductive stage) an insignificant increase was observed at later growth stage. Ash contents play important role in promoting balanced growth of animals. Similar to our findings, Kilcher (1981) also reported that ash contents of forage progressively decline with advancing maturity. However, Azim *et al.,* (1989), Wahid (1990) and Liu (1993) observed high ash contents with increasing degree of maturity of plants. In the present study we also recorded higher ash contents in some cases like *Artemisia maritima* and *Perovskia atriplicifolia* at advanced growth stage. This increase or decrease of ash contents with advancing age by different plants may be due to variation in soil and other habitat features that need to be explored.

3. Crude protein (CP): Crude protein, referring to all the nitrogenous compounds present in forage feed, is reliable source of over all nutritional status. They are directly related to digestibility, vitamin, calcium and phosphorus contents. These all features decline with low crude protein to almost deficient levels (Ganskopp & Bohner, 2001). The CP contents among grasses ranged from 9.95% in *Pennisetum orientale* at pre- and reproductive stages to 6.83% in *Cymbopogon jwarancusa* (Table 2). *Tetrapogon* had highest CP contents at post reproductive stage. Shrubs contained significantly higher CP than grasses. It ranged from 8.23% (*Hertia intermedia*) to 11.51% (*Artemisia maritima*) among shrubs. *Artemisia* had highest value at pre- and post reproductive stages, whereas *Hertia* contained the lowest crude protein at these stages. *Sophora* and *Convolvulus* respectively had highest and lowest CP contents at reproductive stage only. Generally, CP concentration averaged high at pre reproductive stages than at other growth stages. This agrees with Ganskopp & Bohner (2001) and Khan *et al*. (2002) who also reported high CP contents during spring and lowest in late September. However, in *Artemisia maritima*, *Perovskia atriplicifolia* and *Hertia intermedia* at post reproductive stages a slight increase in crude protein contents was observed in later growth stages probably due to re-growth of plants after summer season. Sheep and goats need protein for maintaining growth and reproduction. The deficiency of proteins leads to reduced appetite, low feed intake and poor food efficiency that in turn results in poor growth and development of livestock (Anon., 1981, 1985). The present study showed that shrubs generally contained slightly higher CP than grasses. Our results agree with those of Vallentine (1990), Holechek *et al.,* (1998) and Robles & Boza (1993), who also reported high CP contents in shrubs compared to herbs. For healthy productivity a continuous supply of CP is required (Holechek *et al.,* 1998). The livestock is healthier in season when forage is rich in protein contents. The health of animals might decline with decreased protein availability in the range plants. Crude protein contents were generally higher at pre-reproductive stage (vegetative) than at other stages with few exceptions such as *Artemisia maritima*, *Perovskia abrotanoides* and *Hertia intermedia*, whereas CP augmented at post reproductive stage. Plants need more nitrogenous food for vegetative growth and therefore they efficiently store protein in early stages of growth, which is later on consumed during flowering and fruiting followed by dormant phase whereby their nutritional status reduces.

Among grasses, 8.65% and 5.55% decrease of crude protein was observed for *Pennisetum orientale* and *Stipa pennata* toward maturity. The findings agree with those of Kramberger & Klemencic (2003), Distel *et al*., (2005) and Sultan *et al*., (2007), who observed decreased CP with maturity of grasses. While among shrubs, 8.68% to 11% decrease of CP was observed for *Artemisia maritima* and *Convolvulus leiocalycinus* (Table 2). It has been suggested that sheep require 13-14% CP during March to May and 9-10% from June to December (Anon., 1985) whereas goats need 12-13% crude protein during March to May and upto 11% during June to December. This need is related to the physiological requirement of goats and sheep. When compared to NRC recommendations (1981, 1985), the CP contents in the present study were lower in all the tested grasses at all the growth stages for both the livestock. However, *Pennisetum orientale* at pre-reproductive stage had 14.26% crude protein. While some shrubs like *Artemisia maritima*, *Perovskia abrotanoides* and *Convolvuls leiocalycinus* had sufficient CP contents at pre-reproductive stage. *Artemisia* also had satisfactory level of crude protein in October. The average crude protein contents of *Artemisia maritima* was lower than (13.1%) *Artemisia paucilfora* (Kurganova & Olovyannikova, 1993). The livestock are likely to face severe protein deficiency problems during all the seasons in the Harboi rangeland. A similar decreasing trend for CP for various forage plants from the beginning of grazing season toward autumn was observed by other workers (Pinchak *et al.,* 1990; Fierro & Bryant, 1990; Andrighetto *et al.,* 1993; Ashraf *et al.,* 1995) and these all studies support the present findings.

Arid rangelands like Harboi are generally dominated by high quality vegetation during early vegetative growth that declines as the forage matures. In Harboi rangeland, where plants were rich in protein contents during early vegetative phase but declined subsequently with the maturity of plants. The growing season starts from March that terminates during November in Harboi rangelands. During this period, dry spell from May to October is characteristic for the area (Durrani *et al*., 2005). This is the time when besides reduction in over all availability of forage (Hussain & Durrani, 2007; Durrani & Hussain, 2007), plants also become poor in quality including crude protein contents. Thus, livestock are compelled to utilize protein deficient feed that causes poor growth.

4. Crude fibre (CF): Grasses generally had greater crude fibre contents than shrubs (Table 2). Holechek *et al.,* (1998) reported that grasses generally had more crude fibre than forbs and shrubs. Among grasses, it ranged from 23.93% in *Pennisetum* to 26.85% in *Tetrapogon*. It was high at reproductive and post reproductive stages in *Tetrapogon*, while *Cymbopogon* had highest CF at pre reproductive stage. Among shrubs, *Convolvulus* maintained the highest CF contents at all the three stages (Table 2). It was followed by *Sophora*, *Artemisia*, *Perovskia*, and *Hertia*. Crude fibre contents differed significantly (P = 0.01) between grasses and shrubs and between pre- and post reproductive stages (Table 3). Mature plants usually contained high CF than young plants. Seasonal variation affects the crude fibre contents (Azim *et al.,* 1989). A similar trend was observed in the present study as plants had high CF contents at reproductive and post-reproductive stages Crude fibre is less nutritional than cell contents due to its slow digestibility. Annual grasses showed greater decline in nutritive quality than the perennial grasses (Holechek *et al.,* 1998). This was true in our case as *Tetrapogon villosus* (annual) contained high amount of CF at maturity than perennial grasses such as *Pennisetum* and *Cymbopogon*. Annuals complete their life cycle within one season and this might be the reason that annuals quickly end up with high CF. The range of crude fibre in the present study was greater when compared to other forage species (Ashraf *et al.,* 1995).

5. Ether extract (EE) and crude fat (CF): Shrubs had higher ether extract than grasses (Table 2). The differences were significant between pre- and post reproductive stages (Table 3). It was high in *Pennisetum* (5.93%) and least in *Tetrapogon* (1.97%). *Stipa*, *Pennisetum* and *Cymbopogon* had high ether extract at pre reproductive, reproductive and post reproductive stages, respectively. Maximum ether extract value (8.5%) was achieved for *Hertia*, especially at pre- and post reproductive stages, which narrowed down to 3.02% in *Convolvulus*. Both species of *Perovskia* had highest ether extract at reproductive stage (Table 2).

6. Nitrogen contents: Nitrogen contents were slightly higher in shrubs than grasses (Table 2) with non-significant differences between grasses and shrubs at all phenological stages (Table 3). Among shrubs, it was highest in *Artemisia* (1.83%) and lowest in *Hertia* (1.31%). Among grasses, *Pennisetum* had the highest (1.59%) and *Cymbopogon* the lowest (1.09) nitrogen contents. The nitrogen contents were generally high at pre reproductive stage than at other phenological stages in all the tested species.

7. Carbohydrate contents: There was an increasing trend of carbohydrates from pre reproductive towards post reproductive stage in all the analysed species. Carbohydrate contents were usually higher in grasses than shrubs (Table 2). Among grasses, *Tetrapogon* had the maximum (60.35%) and *Pennisetum* the least (38.58%) value. In shrubs, it was maximum in *Convolvulus* (47.67%) and least in *Hertia* (21.38%). The differences were highly significant ($p=0.05$) between grasses and shrubs at post reproductive stages only (Table 3). High level of carbohydrate in fodder plants are considered better than high lignin contents as they provide readily available energy and easily digestible. Its requirement cannot be ordinarily compensated by protein (Holechek *et al.,* 1998). There was a progressive increase in the carbohydrate contents from pre-reproductive to post-reproductive stages in all tested samples (Table 2). But, high carbohydrates contents at late phenological stage become less beneficial to livestock due to their low digestibility in the form of celluloses and hemi-celluloses.

8. Nitrogen free extract (NFE): Although grasses had slightly higher NFE value than shrubs (Table 2), yet the differences were insignificant between grasses and shrubs at all the three phenological stages (Table 3). *Cymbopogon* (56.52%) had the highest and *Pennisetum* (51.24%) the lowest NFE value among grasses. Among shrubs NFE was highest in *Sophora* (54.46%) and lowest in *Convolvulus* (50.05%). The NFE values ranged higher in the present case as compared to those reported by Liu (1993) for other arid land pasture plants. Like Cook & Stubbendieck (1986), who reported nearly equal NFE in many types of forage, we also achieved similar results.

9. Total digestible nutrients (TDN %): Total digestible nutrients ranged in between 58.20% (*Tetrapogon*) to 65.10%, (*Stipa*) among grasses; and 74.35% (*Perovskia abrotanoides*) to 59.88% in *Convolvulus leiocalycinus* among shrubs (Table 4). The differences between grasses and shrubs and between different phenological stages were non-significant (Table 4).

10. Gross energy (GE), digestible energy (DE) and metabolized energy (ME): Gross energy represents the total combustible energy in a feed stuff, which is necessary for calculating metabolized energy (ME). Metabolized energy is the most suitable index for energy furnishing qualities for range forages. Gross energy among grasses fluctuated between 406.08 in *Tetrapogon* to 434.42 in *Pennisetum*. Among shrubs, it varied from 424.42 in *Convolvulus* to 444.69 in *Artemisia* (Table 4). Cook & Harris (1968) observed that grasses had higher gross energy than shrubs. On the contrary, our results show that shrubs contained slightly higher gross energy than the grasses.

In grasses DE was highest in *Stipa* (2.87 Mcal/kg) followed by *Pennisetum*, *Cymbopogon* (2.7 Mcal/kg) and *Tetrapogon* (2.56 Mcal/kg). Among the shrubs, the DE ranged in between 3.28 Mcal/kg (*Perovskia abrotanoides*) to 2.64 Mcal/kg (*Convolvulus leiocalycinus*) (Table 4). The differences between grasses and shrubs; and between different phenological stages were non-significant (Table 4). The metabolized energy averaged in between 3.67 (*Stipa*) to 3.04 (*Tetrapogon villosus*) among grasses and between 3.76 (*Perovskia abrotanoides*) to 3.12 (*Convolvulus leiocalycinus*) among shrubs (Table 4). The differences were non-significant between grasses and shrubs and between phenological stages (Table 4). The present study indicated that the analysed plants partially fulfil the DE requirement of livestock as all the species had low DE and ME throughout the growing season. Contrary to our findings, Liu (1993) reported 70 to 79% total digestible nutrients in desert rangeland plants. The nutritional energy deficiency for livestock in Harboi rangeland might result due to inadequate quantity of forage of low nutrient status. It was observed that, there were non-significant differences between total digestible nutrients, metabolized energy and digestible energy or between shrub and grasses at all phenological stages (Table 4). The findings of Robles & Boza (1993) agree with our findings as they reported non-significant differences in metabolized energy contents of shrubs, perennial herbaceous species and annual rangeland species. Sultan *et al.,* (2007) observed decrease in ME with the maturity of grasses and in the present study we also got decrease in ME with advanced phenological stage of plants. The energy requirement of sheep and goats must be met for maintenance, optimum production and to prevent nutritional deficiency. Goats are more active travelling longer distances than sheep thus increasing their energy requirement. The energy requirements vary with environmental factors of rangeland and physiological activity of livestock. Goats and sheep on the average require 50 to 66% total digestible nutrients, 0.7 to 6.88 Mcal/kg/day digestible energy and 0.5 to 5.62 Mcal/kg/day metabolized energy for their routine maintenance. An additional amount of 4.38 Mcal/kg/day digestible energy and 3.58 Mcal/kg/day metabolized energy is required for the growing body size and weight (Anon., 1985).

Table 4. Different energy available to livestock.

S. No.	Species	Phenological stages	Gross energy (GE) (Kcal/g)	TDN %	DE Mcal/Kg	ME Mcal/Kg
	Grasses					
1.	***Stipa pennata***					
		Pre-Rep. Stage	420.71	63.33	2.79	4.25
		Reproductive Stage	414.59	72.16	3.18	3.66
		Post Rep. Stage	419.89	59.80	2.63	3.11
		Mean	**418.40**	**65.10**	**2.87**	**3.67**
2.	***Pennisetum orientale***					
		Pre-Rep. Stage	415.94	61.95	2.73	3.21
		Reproductive Stage	468.79	70.92	3.12	3.60
		Post Rep. Stage	418.52	62.38	2.75	3.27
		Mean	**434.42**	**65.08**	**2.87**	**3.36**
3.	***Tetrapogon villosus***					
		Pre-Rep. Stage	381.23	56.24	2.48	2.95
		Reproductive Stage	416.92	59.26	2.61	3.09
		Post Rep. Stage	420.10	59.10	2.60	3.08
		Mean	**406.08**	**58.20**	**2.56**	**3.04**
4.	***Cymbopogon jwarancusa***					
		Pre-Rep. Stage	409.83	61.01	2.69	3.16
		Reproductive Stage	412.86	60.84	2.68	3.16
		Post Rep. Stage	422.76	61.68	2.72	3.20
		Mean	**415.15**	**61.18**	**2.70**	**3.17**
	Shrubs					
1.	***Artemisia maritima***					
		Pre-Rep. Stage	451.65	64.94	2.86	3.34
		Reproductive Stage	435.70	61.70	2.72	3.20
		Post Rep. Stage	446.72	65.92	2.91	3.38
		Mean	**444.69**	**64.19**	**2.83**	**3.31**
2.	***Perovskia abrotanoides***					
		Pre-Rep. Stage	445.08	72.74	3.21	3.69
		Reproductive Stage	441.65	82.41	3.63	4.12
		Post Rep. Stage	445.88	67.90	2.99	3.47
		Mean	**444.20**	**74.35**	**3.28**	**3.76**
3.	***Perovskia atriplicifolia***					
		Pre-Rep. Stage	429.03	70.17	3.09	3.57
		Reproductive Stage	443.32	64.83	2.85	3.33
		Post Rep. Stage	428.03	65.42	2.88	3.36
		Mean	**433.46**	**66.81**	**2.94**	**3.42**
4.	***Convolvulus leiocalycinus***	Pre-Rep. Stage	410.53	57.11	2.52	2.99
		Reproductive Stage	437.61	65.10	2.87	3.35
		Post Rep. Stage	425.13	57.44	2.53	3.01
		Mean	**424.42**	**59.88**	**2.64**	**3.12**
5.	***Sophora griffithii***					
		Pre-Rep. Stage	432.18	68.03	2.99	2.47
		Reproductive Stage	435.05	67.07	2.82	3.30
		Post Rep. Stage	456.66	70.98	3.13	3.61
		Mean	**441.30**	**68.69**	**2.98**	**3.13**
6.	***Hertia intermedia***					
		Pre-Rep. Stage	446.46	70.66	3.11	3.59
		Reproductive Stage	415.12	58.03	2.55	3.02
		Post Rep. Stage	438.35	71.15	3.13	3.62
		Mean	**433.31**	**66.61**	**2.93**	**3.41**

The differences between grasses and shrubs were non significant in all phenological stages.
TDN% = Total digestible nutrients
DE = Digestible energy
ME = Metabolized energy

Table 5. Cell wall constituents of some grasses and shrubs of Harboi hills at three phenological stages.

S. No.	Species	Phenological stages	NDF %	ADF %	Hemi-Cellulose %	ADL %
	Grasses					
1.	***Stipa pennata***					
		Pre-Rep. Stage	63.1	36.6	25.5	4.6
		Reproductive Stage	66.2	37.9	28.3	6.7
		Post Rep. Stage	70	42.9	27.1	6.8
		Mean	**66.43**	**39.13**	**26.97**	**6.03**
2.	***Pennisetum orientale***					
		Pre-Rep. Stage	38	32.8	5.2	8.9
		Reproductive Stage	36.7	28.9	7.8	11.6
		Post Rep. Stage	74.1	44.5	29.6	8.8
		Mean	**49.60**	**35.40**	**14.20**	**9.77**
3.	***Tetrapogon villosus***					
		Pre-Rep. Stage	68.2	43	25.2	11.6
		Reproductive Stage	73.6	43.1	30.5	11.5
		Post Rep. Stage	69.3	40.9	28.4	6.6
		Mean	**70.37**	**42.33**	**28.03**	**9.90**
4.	***Cymbopogon jwarancusa***					
		Pre-Rep. Stage	55.5	38	17.5	6.8
		Reproductive Stage	73.1	43.4	29.7	4.7
		Post Rep. Stage	68.4	36	32.4	6.3
		Mean	**65.67**	**39.13**	**26.53**	**5.93**
	Shrubs					
1.	***Artemisia maritima***					
		Pre-Rep. Stage	31.1	22.7	8.4	5.8
		Reproductive Stage	52.7	36.7	16	7.9
		Post Rep. Stage	48.8	33.2	9.6	15.4
		Mean	**44.20**	**30.87**	**11.33**	**9.70**
2.	***Perovskia abrotanoides***					
		Pre-Rep. Stage	36.6	26.8	9.8	9
		Reproductive Stage	48.3	40	8.3	11.8
		Post Rep. Stage	44.8	35.6	9.2	15.4
		Mean	**43.23**	**34.13**	**9.10**	**12.07**
3.	***Perovskia atriplicifolia***					
		Pre-Rep. Stage	38.3	29.9	8.4	11.8
		Reproductive Stage	49	37.4	10.6	11.8
		Post Rep. Stage	56	33.1	22.9	16.5
		Mean	**47.77**	**33.47**	**13.97**	**13.37**
	Convolvulus leiocalycinus					
4.		Pre-Rep. Stage	47.1	32	15.1	10.4
		Reproductive Stage	55.5	42.5	13	7.1
		Post Rep. Stage	39.1	38.2	0.9	13.2
		Mean	**47.23**	**37.57**	**9.67**	**10.23**
5.	***Sophora griffithii***					
		Pre-Rep. Stage	39.5	36.8	2.7	7.3
		Reproductive Stage	49.6	38	11.6	9.4
		Post Rep. Stage	48.1	34.8	13.3	11
		Mean	**45.73**	**36.53**	**9.20**	**9.23**
6.	***Hertia intermedia***					
		Pre-Rep. Stage	24.7	17.8	6.9	6.3
		Reproductive Stage	43.8	30.8	13	8.7
		Post Rep. Stage	31.5	24.9	6.6	9
		Mean	**33.33**	**24.50**	**8.83**	**8.00**

B. Cell wall constituents: The cell wall constituents (Table 5) are discussed below.

Table 6. Statistical comparison of cell wall consitutents of grasses and shrubs at three phenological stages.

	Pre-reproductive		Reproductive		Post reproductive	
	Grass	**Shrubs**	**Grass**	**Shrubs**	**Grass**	**Shrubs**
NDF						
	63.1	31.1	66.2	52.7	70	48.8
	38.0	36.6	36.7	48.3	74.1	44.8
	68.2	38.3	73.6	49.0	69.3	56.0
	55.5	47.1	73.1	55.5	68.4	39.1
		39.5		49.6		48.1
		24.7		43.8		31.5
Sum	**56.200**	**36.216667**	**62.4**	**49.81667**	**70.45**	**44.716667**
Variance	**174.4467**	**58.505667**	**304.9533**	**15.96567**	**6.35**	**72.333667**
t-Test	**0.015452**	**0.0474722**	**0.118548**	**0.245901**	**0.000415**	**0.0003701**
	S		**NS**		**S**	
ADF						
	36.6	22.7	37.9	36.7	42.9	33.2
	32.8	26.8	28.9	40	44.5	35.6
	43	29.9	43.1	37.4	40.9	33.1
	38	32	43.4	42.5	36	38.2
		36.8		38		34.8
		17.8		30.8		24.9
Sum	**37.6**	**27.666667**	**38.325**	**37.56667**	**41.075**	**33.3**
Variance	**17.78667**	**45.990667**	**45.85583**	**15.40267**	**13.61583**	**20.432**
t-Test	**0.032318**	**0.0213451**	**0.826239**	**0.848661**	**0.021517**	**0.0215166**
	S		**NS**		**S**	
ADL						
	4.6	5.8	6.7	7.9	6.8	15.4
	8.9	9	11.6	11.8	8.8	15.4
	11.6	11.8	11.5	11.8	6.6	16.5
	6.8	10.4	4.7	7.1	6.3	13.2
		7.3		9.4		11
		6.3		8.7		9
Sum	**7.975**	**8.4333333**	**8.625**	**9.45**	**7.125**	**13.416667**
Variance	**8.9225**	**5.6586667**	**12.07583**	**3.907**	**1.289167**	**8.5536667**
t-Test	**0.793511**	**0.8063438**	**0.64129**	**0.687385**	**0.003751**	**0.0021226**
	NS		**NS**		**S**	
Hemicelluloses						
	25.5	8.4	28.3	16	27.1	9.6
	5.2	9.8	7.8	8.3	29.6	9.2
	25.2	8.4	30.5	10.6	28.4	22.9
	17.5	15.1	29.7	13	32.4	0.9
		2.7		11.6		13.3
		6.9		13		6.6
Sum	**18.35**	**8.58**	**24.075**	**12.08333**	**29.375**	**10.416667**
Variance	**90.56333**	**20.357**	**118.5492**	**6.753667**	**5.109167**	**54.285667**
t-Test	**0.051661**	**0.1303489**	**0.028685**	**0.112936**	**0.001185**	**0.0008822**
	S		**S**		**S**	

S = Significant, NS = Non-significant

1. Neutral detergent fibre (NDF): NDF concentration of grasses was higher than shrub sduring all the seasons (Table 5). The differences were highly significant ($p = 0.05$) at pre- and post reproductive stages (Table 6). It was observed that the average NDF value was maximum (70.36%) in *Tetrapogon* and lowest (49.6%) in *Pennisetum*. *Tetrapogon* gained highest value at pre- and reproductive stages while *Pennisetum* had the highest NDF contents at post reproductive stage. The results agree with other studies of Ganskopp & Bohner (2001), Kramberger & Klemencic (2003) and Sultan *et al*., (2007), which reported increase in NDF concentration with maturity of plants. Among the shrubs, the highest NDF contents (47.76%) were recorded for *Perovskia atriplicifolia* and the lowest (33.33%) for *Hertia* (Table 4). The latter species registered the lowest values at all the three stages. *Convolvulus* had the highest NDF value at pre- and reproductive stages. There was an increasing trend of NDF from pre reproductive to reproductive stage and thereafter it declined. However, for *Perovskia atriplicifolia* the trend was reversed (Table 5). NDF of plants is positively related to phenology as both NDF and ADF are strongly affected by maturation of plants (Dabo *et al.,* 1980; Wahid, 1990). The present study indicated a tendency for increasing NDF value towards maturity of plants. The lower NDF (>50%) in shrubs throughout the season might cause energy deficiency problem for sheep and goats in Harboi rangeland. It is suggested that energy rich feed must be provided to grazing livestock or stocking density may be reduced to improve animal health and productivity. Wahid (1990) also observed similar trend of NDF for forage plants of Zarchi range. The findings also are in line with those of Angrighetta *et al.,* (1993) who reported increased in NDF contents in late phenological stages of plants.

2. Acid detergent fibre (ADF): ADF contents of grasses were significantly (p = 0.05) higher than shrubs at pre reproductive and post reproductive stages (Table 6). It was 42.33% in *Pennisetum* and 35.4% in *Tetrapogon* (Table 5). The trend of ADF value was almost similar to that of NDF value at pre reproductive and post reproductive stages. At reproductive stage, ADF value was highest in *Cymbopogon* and the lowest in *Pennisetum*. Our results are supported by the findings of Cherney *et al*., (1993), Kramberger & Klemencic (2003) and Sultan *et al*. (2007), who reported increased ADF with maturity of grasses. *Convolvulus* showed the highest (37.56%) and *Hertia* the lowest (24.5%) ADF value at all the three stages. *Convolvulus* had the highest ADF contents at reproductive and post reproductive stages. *Sophora* gave highest value at pre reproductive stage (Table 5). The analysed species had low ADF values at pre-reproductive stage that reached to its maximum at blooming stage with minor decline in some cases at post-reproductive stages. Wahid (1990) also reported a similar trend in plants of Zarchi rangeland, Balochistan. Similarly, Ashraf *et al.,* (1995) observed increase in NDF and ADF in fodder species at different growth stages and our results agree with them.

3. Hemicelluloses: Grasses generally had greater hemicellulose contents than shrubs (Table 5). The differences were significant (p=0.05) between grasses and shrubs at all the phenological stages (Table 6). Among the grasses, it ranged from 28.03% (*Tetrapogon*) to 14.20% (*Pennisetum*). It was high in *Stipa*, *Tetrapogon* and *Cymbopogon* at pre reproductive, reproductive and post reproductive stages, respectively. Among the shrubs, hemicellulose contents were the highest (13.97%) in *Perovskia atriplicifolia* and the lowest (8.83%) in *Hertia*. It was high in *Convolvulus* at pre reproductive stage, *Artemisia* at reproductive stage and *Perovskia* a*triplicifolia* at post reproductive stage. Variation in the amount of structural carbohydrates occurs with seasonal changes as well as with growth stages of plant. Livestock preferred grasses as they can efficiently use cellulose and hemi-cellulose because the microorganisms in their digestive system are capable of digesting them (Holecheck *et al.,* 1998).

4. Acid detergent lignin (ADL): Lignin is higher in stems than in leaves that increases in aging plants and is negatively related to paltability (Holecheck *et al.*, 1998; Kramberger & Klemencic, 2003). The present study shows that ADL value was significantly (p = 0.05) greater in shrubs than grasses at post reproductive stage (Tables 5, 6). The present findings are in line with those of Robles & Boza (1993) who found higher lignin contents in shrubs than grasses. We also observed that ADL increases from pre-reproductive to post-reproductive stage. Similarly, Azim *et al.,* (1989) also reported that lignin contents increase with age and cause a corresponding decrease in the nutritive value. Lignin digestibility of plants is quite variable and unpredictable by animal species. Wahid (1990) reported that in *Artemisia maritima* the lignin was highly digestible at flowering stage but less digestible at vegetative stage for both goats and sheep. However, we observed that *Artemisia maritima* was highly preferred by livestock in early spring at vegetative stage. The reason might be that these animals had adapted to digest such feed as they have less choice due to lack of sufficient number of and amount of palatable species (Hussain & Durrani, 2007). The ADL value ranged in between 9.9% (*Tetrapogon*) to 5.93% (*Cymbopogon*) among grasses. *Pennisetum* gave the highest value at reproductive and post reproductive stages, while *Tetrapogon* manifested the highest ADL value at pre reproductive stage. Likewise among shrubs, a maximum of 13.36% ADL was recorded in *Perovskia atriplicifolia* and the least value (8%) in *Hertia*. *Perovskia atriplicifolia* exhibited high value at all the three stages. There was a tendency of increasing ADL from pre reproductive to post reproductive stage in shrubs. While in grasses *Tetrapogon* and *Cymbopogon* had the highest value at pre reproductive stage, *Pennisetum* at reproductive stage and *Stipa* manifested the highest value at post reproductive stage (Table 5). Sultan *et al*., (2007) observed enhanced ADL contents with maturity of plants and this is what we also report for the analysed plants of Harboi rangeland.

Young plant tissues are biochemically active capturing more energy, synthesizing higher protein and fats contents than older tissues. Plants contain fixed energy largely in the form of complex carbohydrates, waxes, terpenes and essential oils, which are inversely related to nutritional value of grazing animal because of low digestibility. Holechek *et al.,* (1998) stated that nutritive quality of forage vary seasonally. The level of cell solubles, crude protein and phosphorous are higher in actively growing forages. Some plant species such as *Ebenus stellata*, *Caragana stocksii*, *Stipa pennata* and *Poa bulbosa* although have sufficient nutritive values but they showed poor distribution and foliage thus their availability is limited in Harboi rangeland. On the other hand more readily available species such as *Euphorbia*, *Hertia* and some other plants are frequent in the investigated area but they were less palatable having poor nutrition. It is obvious that non palatable species grow vigorously with better distribution and plant cover. Hussain & Chaghtai (1984), Hussain & Durrani (2007, 2008) and Sultan *et al*., (2007) suggested that rapid accumulation of cell wall components, fast lignification and rapid reduction in CP may allow the unpalatable plants to avoid grazing. NDF, ADF and lignins are negatively related with digestibility.

The present and some past studies (Durrani *et al*., 2005; Durrani & Hussain, 2005; Hussain & Durrani, 2007, 2008) suggest that Harboi rangeland is not only suffering from deficiency of required amount of forage especially from October till April, but also the vegetation is deficient in nutrition. Both these factors contribute to over all low productivity of livestock. It is recommended that rangeland productivity may be improved by proper ecological management including quantity and quality of forage, stocking rate, grazing periods, fertilization of soil and replacing of the existing livestock with improved varieties. This can be possible with awareness and participation of the locals of the area.

Acknowledgements

The authors are thankful to Forest authorities Kalat for facilitating this study in Harboi rangeland. We are extremely obliged to Mr. Abdul Hameed, Chief Chemist, Agriculture Research Institute, Quetta for providing help in analytical work. We extend our special gratitude to Dr. Ghaffar, Director and Dr. Atyya Azim, for their invaluable hospitality and help in analyzing the plant samples in the Animal Nutrition laboratories, Animal Science Institute, Islamabad. Dr. Abdul Wahid, Range Management Institute, Islamabad. Dr. Mohammad Munir, Arid Zone Research Institute, Quetta, also provided help in the form of literature and suggestions. MJD is thankful to University of Balochistan, Quetta for providing an opportunity to carry this study at University of Peshawar towards her Ph.D. The help of Mr. Saeed-ur-Rehman in the field is highly acknowledged. The authors are thankful to Mr. S. Ghulam Mohammad DFO for his valuable suggestion and help during this study.

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(Received for publication 26 December 2007)