Mineral Composition and Anti-nutritional Components of Shrubs: Rangeland Species from the Upland Balochistan, Pakistan

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Summary

Little of the rangeland resources of Balochistan, Pakistan have been assessed and there is little to no information on how abiotic factors such as soil type and topography influence the nutritive value of native species. Leaf nitrogen concentrations in all species showed broadly similar patterns of change with season. In all species, non-protein nitrogen (NPN) accounted for more than 35-50% of total N. The effect of season on the concentration of phosphorus was highly significant. In all shrubs, there was similar response of concentration of Ca, Mg and K. There was a significant effect of season on the concentration of both total phenol and condensed tannins in all species.

Key words

Rangeland shrubs, mineral composition, phenolics, tannins, seasonal variation, Balochistan.

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Introduction

Balochistan is one of the four provinces of Pakistan but is by far the largest and 93 % of its area is rangeland. The climate in much of the province is arid or even hyper-arid (Van Gils and Baig, 1992) and rainfall patterns vary from Mediterranean to monsoonal. Large areas of the province are mountainous where the climate is cold and dry and a large proportion of the 200-300 mm of annual precipitation is deposited as snow. Land-use varies according to the landscape-the fertile valleys are used for intensive agriculture when there are sources of water for irrigation and the intensity of use diminishes with distance from the drainage lines in the valley floor. Irrigated vegetable crops and fruit trees give way to cereal and grain crops that, in turn, are replaced first by land used for intensive grazing and eventually by open rangeland. Grazing is almost the only land use in the foot hills and lower slopes of the largely arid mountains.

Generally, plant species in Balochistan are deficient in total digestible nutrients and in digestible protein and dry matter with respect to animal requirements (FAO, 1983). Little of the rangeland resources of Balochistan have been assessed and there is little to no information on how abiotic factors such as soil type and topography influence the nutritive value of native species. A single study of the dietary composition of the Zarchi and Tomagh rangelands suggested that most of the native species were deficient in nitrogen and phosphorus (Wahid, 1990).

There is widespread agreement that the deterioration of most of the Balochistan rangelands during the last two to three decades has, in part, been exacerbated by migration of Afghan refugees who bring their livestock to add to those of the local population. Further degradation has been caused by removal of the vegetation for use as fuelwood. Nutrients exported in grazing animals or in fuelwood have not been replaced and there is an argument that rangeland degradation might include diminished nutrient capital.

In many arid and semi arid regions of the world, shrubs have long been recognised as important rangeland resources. Compared to grasses, fodder shrubs have relatively higher concentration of crude protein and minerals. Due to less variation in the concentration of these contents their value enhance as a dry season feed for livestock (Ibrahim, 1981; Wilson, 1977). In Balochistan, due to sever drought in last five to six years, the native shrubs are also playing a vital role in the livestock productivity. At this time, the game animals also greatly depend on them. The palatability of shrubs depends upon a number of interacting factors linked to animals as well as environment. The animal factors include species, physiological status and previous experience with specific vegetation, while the environmental variables comprise botanical composition, plant structure, forage quality and grazing pressure.

Exact definition of the quality of plants as feed for animals remains elusive as the answer to the question why herbivores have not ‘over-run’ green plants (Hartley and Jones, 1997). Although the concentration of total nitrogen in tissues remains the most widely quoted estimate of quality, many other factors are also important. For example, in non-domesticated plants a considerable proportion of total N may be present as compounds that are distasteful, toxic, carcinogenic or outright poisons (Harborne, 1988; Hartley and Jones, 1997; Main, 1981). Herbivore intake and digestion of green leaves is also limited by the presence of other, often carbon-based compounds, such as tannins, that derive their anti-nutritional properties from smell, taste or physiological activity within the animal (Hanley et al., 1992; Lindroth, 1988; Zucker, 1983). Barry (1989) reported that a variety of ‘anti-nutritional components’ form complexes with carbohydrates, cellulose, hemi-cellulose and amino acids that are either ingested or produced in the gut and thus reduce their digestibility. Phenolic compounds are prime examples of this class of anti-nutritional factors and their concentrations in plants are usually increased by low soil fertility, high light intensity, high temperature and drought (Barry and Forss, 1983).

Some animals have adapted to cope with either specific or general anti-nutritional factors. Cattle are less well adapted to tannin-rich fodders than are goats or deer (Kumar and Singh, 1984; Robbins et al., 1987 a, b) that produce tannin-binding proteins in their saliva (Austin et al., 1989; Mehansho et al., 1992). Distel and Provenza (1991) reported that goats also have the ability to detoxify tannins or their degraded products and have an active tannase in the rumen (Begovic et al., 1978). Generally, the acceptance or palatability of a feed remains dependent on the identification of feed fractions that consistently affect digestibility and in particular lignification and ligno-cellulose ratios (Van Soest, 1982).

The purpose of this study was to examine the concentration of nitrogen, phosphorus and other major nutrients and the seasonal variation in the concentration of primary and secondary anti-nutritional components in the main shrubs of upland Balochistan.

Material and methods

The study was conducted at Hazarganji Chiltan National Park near Quetta (30º 07’ N, 66º 58’ E, 1700 m altitude), and Tomagh (Loralai), Pakistan. The region has Mediterranean climate, characterised by cold winter and hot dry summer. Annual rainfall varies between 250 and 300 mm and is dominated by winter snowfall. During the hot dry summers, plant growth is poor and only winter precipitation is effective in supporting plant growth.

Bulk foliage and stem samples were collected from three individuals of each species from each plot on four sampling occasions from April 2002 till October 2003. Foliage samples were oven-dried for two days at 70ºC. Dried samples were finely ground (to pass a 1 mm sieve) in a ball mill. Total nitrogen, phosphorus and cations were determined by acid digestion of 100 mg of plant sample at 320ºC with H_2SO_4 and H_2O_2. Diluted digests were analysed colorometrically for nitrogen and phosposrus by the procedure described by Keeney and Nelson (1982) and Murphy and Riley (1962) respectively. Cations were analysed using Atomic Absorption Spectroscopy. Plant samples were analysed for non-protein nitrogen (NPN) using the tungstic acid extraction method described by Licitra et al. (1996).

Total phenols and condensed tannins were determined using the colorimetric methods described by Makkar et al. (1993). Phenols were quantified using the Folin-Ciocalteau reagent. Condensed tannins were measured using the butanol-HCL-Fe^{3+} method described by Porter et al. (1986). The concentration of phenols was expressed as tannic acid equivalents and condensed tannins as leucocyanidin equivalents. All chemical analyses were carried out in duplicate and mean values were used for statistical analysis. Data were analysed using analysis of variance to evaluate the effects of season and treatment. A significance level of $P < 0.05$ was used for all statistical tests.

Results

Leaf nitrogen concentrations in all species showed broadly similar patterns of change with season (Table 1-4).

Table 1. Concentrations of total N, non-protein N, P, Ca, Mg and K (% oven dry weight) in the foliage of native shrubs growing in Hazarganji National Park, Quetta during 2002.

Species	Sampling							
	April		June		August		October	
	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.
Total N								
Caragana ambigua	2.26	±0.04	2.44	±0.07	2.24	±0.05	2.05	±0.15
Salvia cabulica	2.15	±0.03	2.15	±0.06	1.94	±0.02	1.41	±0.06
Sophora griffithii	1.90	±0.07	2.25	±0.05	2.17	±0.09	1.78	±0.09
Perowskia atriplicifolia	1.98	±0.04	2.21	±0.05	1.78	±0.07	1.22	±0.04
Prunus eburnea	2.34	±0.03	2.38	±0.11	2.18	±0.10	2.10	±0.05
Wild Cherry	2.45	±0.03	2.35	±0.04	2.10	±0.10	2.00	±0.06
Non-Protein Nitrogen								
Caragana ambigua	0.98	±0.06	0.85	±0.05	0.74	±0.07	0.65	±0.08
Salvia cabulica	0.78	±0.04	0.75	±0.03	0.85	±0.04	0.76	±0.04
Sophora griffithii	1.05	±0.04	0.89	±0.06	1.10	±0.07	0.78	±0.06
Perowskia atriplicifolia	0.89	±0.06	0.85	±0.04	0.72	±0.05	0.65	±0.08
Prunus eburnea	0.92	±0.04	0.75	±0.08	0.85	±0.05	0.54	±0.04
Wild Cherry	0.95	±0.06	0.78	±0.06	0.74	±0.04	0.65	±0.08
Phosphorus								
Caragana ambigua	0.15	±0.08	0.11	±0.05	0.09	±0.04	0.08	±0.05
Salvia cabulica	0.14	±0.06	0.10	±0.04	0.08	±0.02	0.05	±0.03
Sophora griffithii	0.13	±0.08	0.09	±0.06	0.07	±0.06	0.04	±0.09
Perowskia atriplicifolia	0.12	±0.04	0.11	±0.06	0.08	±0.03	0.03	±0.04
Prunus eburnea	0.12	±0.06	0.10	±0.08	0.08	±0.04	0.06	±0.05
Wild Cherry	0.14	±0.04	0.11	±0.05	0.09	±0.04	0.07	±0.03
Calcium								
Caragana ambigua	1.06	±0.04	1.25	±0.07	1.45	±0.05	1.97	±0.15
Salvia cabulica	1.14	±0.03	1.55	±0.06	1.84	±0.02	1.93	±0.06
Sophora griffithii	1.20	±0.02	1.32	±0.04	1.75	±0.08	1.98	±0.05
Perowskia atriplicifolia	1.18	±0.06	1.34	±0.04	1.45	±0.06	1.72	±0.04
Prunus eburnea	1.22	±0.04	1.38	±0.09	1.48	±0.08	1.76	±0.03
Wild Cherry	1.32	±0.06	1.58	±0.05	1.43	±0.08	1.65	±0.04
Magnesium								
Caragana ambigua	0.86	±0.08	1.25	±0.07	0.75	±0.04	0.65	±0.11
Salvia cabulica	0.78	±0.03	1.20	±0.09	0.58	±0.06	0.54	±0.08
Sophora griffithii	0.96	±0.04	1.42	±0.03	0.78	±0.05	0.65	±0.08
Perowskia atriplicifolia	1.05	±0.08	1.25	±0.04	0.89	±0.08	0.75	±0.03
Prunus eburnea	0.92	±0.06	1.08	±0.11	0.78	±0.08	0.74	±0.05
Wild Cherry	1.10	±0.04	1.28	±0.08	0.98	±0.06	0.78	±0.04
Potassium								
Caragana ambigua	2.78	±0.10	3.45	±0.06	2.90	±0.04	2.10	±0.12
Salvia cabulica	2.24	±0.08	2.75	±0.04	1.95	±0.07	1.24	±0.04
Sophora griffithii	2.35	±0.08	2.65	±0.07	1.98	±0.08	1.34	±0.08
Perowskia atriplicifolia	2.75	±0.06	3.54	±0.08	2.17	±0.06	1.32	±0.09
Prunus eburnea	3.42	±0.08	4.15	±0.11	2.68	±0.08	1.45	±0.03
Wild Cherry	2.65	±0.06	3.45	±0.08	1.65	±0.09	1.25	±0.06

Table 2. Concentrations of total N, non-protein N, P , Ca, Mg and K (% oven dry weight) in the foliage of native shrubs growing in Hazarganji National Park, Quetta during 2003.

Species	Sampling							
	April		June		August		October	
	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.
Total N								
Caragana ambigua	2.55	±0.08	2.64	±0.04	2.12	±0.06	2.08	±0.12
Salvia cabulica	2.27	±0.06	2.38	±0.09	1.98	±0.08	1.58	±0.04
Sophora griffithii	2.15	±0.09	2.75	±0.04	1.98	±0.06	1.48	±0.08
Perowskia atriplicifolia	2.25	±0.06	2.54	±0.04	1.84	±0.06	1.13	±0.06
Prunus eburnea	2.34	±0.08	2.69	±0.08	2.10	±0.08	1.98	±0.07
Wild Cherry	2.25	±0.04	2.23	±0.07	2.05	±0.07	1.85	±0.08
Non-Protein Nitrogen								
Caragana ambigua	0.74	±0.12	0.87	±0.09	0.75	±0.06	0.70	±0.04
Salvia cabulica	0.75	±0.08	0.80	±0.04	0.96	±0.05	0.82	±0.06
Sophora griffithii	0.78	±0.06	0.90	±0.08	0.94	±0.09	0.78	±0.08
Perowskia atriplicifolia	0.74	±0.07	0.85	±0.06	0.98	±0.06	0.65	±0.05
Prunus eburnea	0.69	±0.08	0.70	±0.10	0.72	±0.06	0.57	±0.06
Wild Cherry	0.65	±0.07	0.78	±0.08	0.80	±0.08	0.45	±0.06
Phosphorus								
Caragana ambigua	0.16	±0.06	0.12	±0.03	0.10	±0.06	0.09	±0.04
Salvia cabulica	0.15	±0.04	0.09	±0.05	0.09	±0.07	0.07	±0.03
Sophora griffithii	0.14	±0.06	0.09	±0.07	0.07	±0.05	0.06	±0.06
Perowskia atriplicifolia	0.15	±0.04	0.10	±0.06	0.07	±0.05	0.07	±0.04
Prunus eburnea	0.14	±0.06	0.12	±0.08	0.10	±0.03	0.09	±0.04
Wild Cherry	0.16	±0.04	0.11	±0.05	0.11	±0.02	0.08	±0.06
Calcium								
Caragana ambigua	1.02	±0.09	1.18	±0.06	1.25	±0.08	1.47	±0.12
Salvia cabulica	1.10	±0.05	1.45	±0.05	1.74	±0.06	1.83	±0.09
Sophora griffithii	1.30	±0.08	1.32	±0.07	1.85	±0.08	1.91	±0.04
Perowskia atriplicifolia	1.28	±0.04	1.35	±0.07	1.65	±0.04	1.92	±0.06
Prunus eburnea	1.32	±0.08	1.41	±0.05	1.58	±0.06	1.66	±0.04
Wild Cherry	1.22	±0.05	1.48	±0.08	1.83	±0.08	1.95	±0.10
Magnesium								
Caragana ambigua	0.75	±0.03	1.35	±0.06	0.65	±0.07	0.45	±0.10
Salvia cabulica	0.70	±0.03	1.21	±0.07	0.68	±0.08	0.64	±0.12
Sophora griffithii	0.86	±0.06	1.32	±0.05	0.88	±0.04	0.69	±0.05
Perowskia atriplicifolia	1.10	±0.08	1.12	±0.04	0.90	±0.06	0.65	±0.07
Prunus eburnea	0.99	±0.06	1.12	±0.08	0.88	±0.05	0.76	±0.06
Wild Cherry	1.14	±0.08	1.22	±0.04	0.89	±0.07	0.82	±0.07
Potassium								
Caragana ambigua	2.98	±0.05	3.75	±0.08	2.45	±0.05	1.98	±0.08
Salvia cabulica	2.54	±0.10	2.98	±0.10	1.25	±0.04	1.04	±0.06
Sophora griffithii	2.55	±0.04	3.10	±0.08	1.88	±0.02	1.14	±0.04
Perowskia atriplicifolia	2.98	±0.05	3.64	±0.06	2.46	±0.07	1.05	±0.03
Prunus eburnea	3.72	±0.03	3.98	±0.04	2.85	±0.06	1.12	±0.08
Wild Cherry	2.95	±0.07	3.65	±0.06	1.45	±0.07	0.98	±0.02

There was no significant difference among both years but there were significant differences among months ($p < 0.05$, Table 1-4). At both locations, nitrogen concentrations in foliage of *Caragana ambigua, Prunus eburnean* and wild cherry were greater than in other species. Concentrations of nitrogen in leaves of all species increased after winter rains. In all species non-protein nitrogen (NPN) accounted for more than 35-50% of total N.

The effect of season on the concentration of phosphorus was highly significant ($p<0.001$, Table 1-4) and concentrations in leaves were generally greater after rains and decrease drastically as the soil moisture decreased in the later months (Table 1-4). In all the shrubs there was a similar response of concentration of calcium, magnesium and potassium. With the exception of calcium, cation concentration fluctuates significantly ($p<0.05$).

Concentrations of total phenols (TP) and condensed tannins (CT) fell between March and June after winter rains (Table 5-6). Overall, concentrations of TP in *Caragana ambigua, Prunus eburnean* and wild cherry were lower than in other species. There was a significant effect of season ($p<0.001$, Table 5-6) on the concentration of both TP and CT in all species. No significant changes ($p>0.05$) in the concentration of TP and CT were induced by year.

Table 3. Concentrations of total N, non-protein N, P, Ca Mg and K (% oven dry weight) in the_foliage of native shrubs_growing in Tomagh Forest area during 2002.

Species	Sampling							
	April		June		August		October	
	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.
Total N								
Phlomis stewartii	2.25	±0.05	2.25	±0.06	1.85	±0.07	1.37	±0.10
Veronica seniola	2.36	±0.07	2.18	±0.04	1.88	±0.05	1.46	±0.05
Cotonistar	2.04	±0.10	2.15	±0.10	1.78	±2.08	1.45	±0.02
Perowskia atriplicifolia	2.15	±0.06	2.22	±0.03	2.02	±0.07	1.35	±0.06
Rhannus persica	2.15	±0.03	2.25	±0.06	1.78	±0.04	1.25	±0.04
Caragana ambigua	2.50	±0.08	2.65	±0.07	2.10	±0.12	1.75	±0.08
Ephedra intermedia	2.35	±0.07	2.50	±0.04`	2.05	±0.10	1.55	±0.07
Non-Protein Nitrogen								
Phlomis stewartii	0.97	±0.06	1.10	±0.06	0.86	±0.04	0.89	±0.12
Veronica seniola	0.82	±0.05	0.99	±0.04	0.77	±0.06	0.75	±0.09
Cotonistar	0.93	±0.04	1.02	±0.08	0.84	±0.03	0.65	±0.08
Perowskia atriplicifolia	0.87	±0.08	0.98	±0.04	1.12	±0.08	0.70	±0.06
Rhannus persica	0.90	±0.10	1.00	±0.06	0.89	±0.05	0.80	±0.06
Caragana ambigua	0.74	±0.08	0.82	±0.10	0.87	±0.04	0.55	±0.12
Ephedra intermedia	1.02	±0.06	1.11	±0.08	1.04	±0.06	0.94	±0.05
Phosphorus								
Phlomis stewartii	0.16	±0.02	0.10	±0.08	0.09	±0.06	0.08	±0.06
Veronica seniola	0.14	±0.10	0.12	±0.10	0.08	±0.04	0.07	±0.04
Cotonistar	0.15	±0.11	0.10	±0.06	0.08	±0.06	0.07	±0.06
Perowskia atriplicifolia	0.16	±0.06	0.09	±0.08	0.07	±0.08	0.06	±0.02
Rhannus persica	0.13	±0.04	0.10	±0.12	0.09	±0.04	0.07	±0.04
Caragana ambigua	0.15	±0.08	0.12	±0.02	0.10	±0.02	0.09	±0.06
Ephedra intermedia	0.14	±0.10	0.10	±0.10	0.07	±0.08	0.06	±0.04
Calcium								
Phlomis stewartii	1.12	±0.08	1.12	±0.03	1.21	±0.06	1.30	±0.07
Veronica seniola	1.00	±0.04	1.25	±0.06	1.22	±0.02	1.48	±0.10
Cotonistar	0.99	±0.03	1.22	±0.12	1.28	±0.07	1.32	±0.08
Perowskia atriplicifolia	1.12	±0.12	1.12	±0.06	1.14	±0.06	1.30	±0.04
Rhannus persica	1.18	±0.08	1.16	±0.08	1.33	±0.12	1.28	±0.02
Caragana ambigua	1.15	±0.04	1.11	±0.10	1.16	±0.05	1.21	±0.10
Ephedra intermedia	1.28	±0.08	1.18	±0.08	1.28	±0.07	1.23	±0.08
Magnesium								
Phlomis stewartii	0.76	±0.02	1.24	±0.03	0.87	±0.11	0.75	±0.04
Veronica seniola	0.82	±0.10	1.18	±0.06	0.81	±0.07	0.71	±0.05
Cotonistar	0.88	±0.08	1.12	±0.07	0.90	±0.03	0.78	±0.12
Perowskia atriplicifolia	0.99	±0.10	1.13	±0.04	0.78	±0.04	0.85	±0.09
Rhannus persica	0.94	±0.08	1.24	±0.05	0.99	±0.05	0.82	±0.08
Caragana ambigua	0.92	±0.05	1.08	±0.04	0.92	±0.11	0.84	±0.07
Ephedra intermedia	0.97	±0.02	0.99	±0.06	0.85	±0.08	0.80	±0.04
Potassium								
Phlomis stewartii	2.76	±0.05	2.65	±0.04	1.99	±0.10	1.56	±0.09
Veronica seniola	2.84	±0.04	2.84	±0.06	2.05	±0.02	1.42	±0.06
Cotonistar	2.85	±0.10	2.78	±0.06	2.25	±0.09	2.00	±0.10
Perowskia atriplicifolia	2.98	±0.12	2.79	±0.05	2.33	±0.04	1.65	±0.04
Rhannus persica	2.92	±0.08	2.18	±0.11	1.75	±0.10	1.36	±0.04
Caragana ambigua	2.95	±0.05	2.68	±0.08	2.19	±0.13	1.10	±0.06
Ephedra intermedia	2.80	±0.03	2.75	±0.04	2.27	±0.07	0.99	±0.04

Discussion

Concentrations and availability of both nutritional (Rhoades, 1979) and anti-nutritional (e.g. Haslam, 1988) factors in animal feed play major roles in determining patterns of plant growth and grazing. Nitrogen is critical for both plant growth and animal nutrition. The concentrations of nitrogen in foliage of all shrubs grown on both locations varied little within the year despite large changes in edaphic conditions and in rates of plant growth after rainfall. The traditional approach of converting the concentration of total nitrogen to crude protein yields an estimate of protein concentrations in leaves of about 12-14 % (dry weight basis). However, about half of this is non-protein nitrogen (Tables 1-4). Although ruminants may convert a variable proportion of non-protein N to microbial protein that then becomes an 'available' protein source,

Table 4. Concentrations of total N, non-protein N, P, CA, Mg and K (% oven dry weight) in the foliage of native shrubs growing in Tomagh Forest area during 2003.

Species	Sampling							
	April		June		August		October	
	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.
Total N								
Phlomis stewartii	2.15	±0.08	2.25	±0.08	1.87	±0.11	1.47	±0.08
Veronica seniola	2.26	±*0.04*	2.38	±0.07	1.98	±0.08	1.56	±0.10
Cotonistar	2.10	±0.10	2.65	±0.10	1.65	±2.12	1.50	±0.06
Perowskia atriplicifolia	2.25	±0.10	2.45	±0.06	2.12	±0.06	1.34	±0.08
Rhannus persica	2.18	±*0.07*	2.25	±0.06	1.99	±0.09	1.56	±0.12
Caragana ambigua	2.30	±*0.10*	2.55	±0.08	2.18	±0.10	1.95	±0.09
Ephedra intermedia	2.42	±*0.12*	2.50	±0.07`	2.14	±0.12	1.70	±0.10
Non-Protein Nitrogen								
Phlomis stewartii	0.91	±0.04	1.05	±0.04	0.82	±0.10	0.80	±0.10
Veronica seniola	0.85	±0.03	0.95	±0.06	0.78	±0.03	0.68	±0.06
Cotonistar	0.85	±0.07	0.99	±0.10	0.88	±0.09	0.72	±0.07
Perowskia atriplicifolia	0.81	±0.04	0.92	±0.06	1.12	±0.07	0.85	±0.11
Rhannus persica	0.87	±0.03	0.90	±0.08	0.92	±0.08	0.82	±0.08
Caragana ambigua	0.75	±0.06	0.82	±0.12	0.76	±0.04	0.61	±0.09
Ephedra intermedia	1.04	±0.04	*1.02*	±0.11	1.12	±0.07	0.85	±0.10
Phosphorus								
Phlomis stewartii	0.14	±0.08	0.11	±0.05	0.10	±0.05	0.08	±0.04
Veronica seniola	0.14	±0.12	0.10	±0.12	0.09	±0.02	0.07	±0.02
Cotonistar	0.16	±0.08	0.11	±0.11	0.08	±0.10	0.06	±0.06
Perowskia atriplicifolia	0.15	±0.04	0.08	±0.12	0.08	±0.05	0.06	±0.08
Rhannus persica	0.14	±0.10	0.09	±0.08	0.09	±0.12	0.08	±0.10
Caragana ambigua	0.15	±0.08	0.12	±0.06	0.10	±0.05	0.09	±0.04
Ephedra intermedia	0.13	±0.05	0.10	±0.10	0.07	±0.08	0.07	±0.12
Calcium								
Phlomis stewartii	1.10	±0.02	1.16	±0.02	1.27	±0.04	1.28	±0.08
Veronica seniola	1.08	±0.09	1.25	±*0.04*	1.32	±0.02	1.38	±0.10
Cotonistar	0.98	±0.06	1.18	±*0.12*	1.20	±0.08	1.29	±0.06
Perowskia atriplicifolia	1.05	±0.04	1.12	±*0.06*	1.18	±0.06	1.32	±0.06
Rhannus persica	1.08	±0.04	1.18	±*0.07*	1.23	±0.08	1.26	±0.05
Caragana ambigua	1.11	±0.07	1.10	±0.10	1.10	±0.04	1.20	±0.03
Ephedra intermedia	1.10	±0.04	1.15	±*0.04*	1.21	±0.10	1.24	±0.04
Magnesium								
Phlomis stewartii	0.89	±0.04	1.15	±0.04	0.90	±0.07	0.65	±0.11
Veronica seniola	0.87	±0.08	1.10	±0.10	0.85	±0.12	0.75	±0.05
Cotonistar	0.92	±0.10	1.05	±*0.07*	0.82	±0.09	0.65	±0.03
Perowskia atriplicifolia	0.96	±0.12	1.15	±*0.08*	0.86	±0.07	0.80	±0.08
Rhannus persica	0.90	±0.06	1.08	±*0.06*	0.98	±0.12	0.85	±0.11
Caragana ambigua	0.94	±0.08	1.10	±*0.05*	0.95	±0.09	0.87	±0.06
Ephedra intermedia	0.93	±0.11	0.98	±0.02	0.86	±0.08	0.84	±0.08
Potassium								
Phlomis stewartii	2.89	±0.08	2.85	±*0.07*	1.92	±0.08	1.62	±0.11
Veronica seniola	2.98	±0.08	2.85	±0.10	2.15	±0.03	1.52	±0.10
Cotonistar	2.90	±0.05	2.88	±*0.05*	2.40	±0.04	2.08	±0.09
Perowskia atriplicifolia	2.78	±0.07	2.72	±*0.08*	2.27	±0.06	1.56	±0.04
Rhannus persica	2.65	±0.05	2.18	±*0.12*	1.88	±0.06	1.26	±0.02
Caragana ambigua	2.88	±0.04	2.92	±0.14	2.24	±0.10	1.05	±0.06
Ephedra intermedia	2.98	±0.10	2.61	±0.06	2.27	±0.10	1.18	±0.05

we must assume that the total concentration of available protein will be less than 12% and most likely less than 9%. The quality of these species as a forage is hardly enough for the maintenance of grazing small ruminants (National Research Council, 1975).

Phosphorus is perhaps the most limiting nutrient for grazing animals in rangelands. Low concentrations of phosphorus are characteristic of the native flora and are associated with soils low in total phosphorus, rich in phosphorus-fixation capacity and the poor availability of moisture, or a combination of all three. Phosphorus also greatly limits rates of N-fixation by native legumes (Hanson and Pate, 1987). Phosphorus concentrations increased only after winter rains because water is necessary for solubilization of phosphorus. In all species, except in spring, the concentration of phosphorus was generally less than the minimum standard (0.12%) set for grazing animals (ARC, 1980; Little, 1970).

Table 5. Concentrations (% dry weight) of total phenolics and condensed tannins in the foliage of native shrubs growing in Hazarganji National Park, Quetta.

Species	Sampling							
	April		June		August		October	
	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.
				Year 2002				
Total phenolics								
Caragana ambigua	2.21	±0.37	2.45	±0.55	3.01	±0.28	3.42	±0.25
Salvia cabulica	2.20	±0.45	2.66	±0.29	3.75	±0.32	4.15	±0.26
Sophora griffithii	3.45	±0.27	3.93	±0.35	4.45	±0.18	5.42	±0.24
Perowskia atriplicifolia	3.23	±0.35	3.65	±0.25	4.20	±0.24	4.86	±0.28
Prunus eburnean	2.23	±0.40	2.43	±0.27	3.12	±0.26	3.15	±0.35
Wild Cherry	2.10	±0.28	2.13	±0.24	2.45	±0.24	3.12	±0.22
Condensed tannins								
Caragana ambigua	0.55	±0.08	0.95	±0.10	1.05	±0.13	1.10	±0.25
Salvia cabulica	0.64	±0.15	0.88	±0.18	1.10	±0.10	1.12	±0.21
Sophora griffithii	0.90	±0.24	0.99	±0.24	1.20	±0.35	1.45	±0.24
Perowskia atriplicifolia	0.79	±0.32	0.88	±0.32	0.90	±0.24	0.99	±0.32
Prunus eburnean	0.45	±0.12	0.56	±0.24	0.65	±0.32	0.75	±0.28
Wild Cherry	0.35	±0.28	0.40	±0.12	0.56	±0.28	0.65	±0.23
				Year 2003				
Total phenolics								
Caragana ambigua	1.98	±0.28	2.10	±0.44	2.72	±0.22	3.10	±0.32
Salvia cabulica	2.08	±0.34	2.24	±0.32	2.75	±0.26	3.12	±0.18
Sophora griffithii	3.11	±0.29	3.41	±0.30	3.87	±0.26	4.22	±0.19
Perowskia atriplicifolia	2.99	±0.32	3.22	±0.40	3.65	±0.35	4.23	±0.26
Prunus eburnean	1.98	±0.32	2.09	±0.27	2.22	±0.22	2.55	±0.28
Wild Cherry	1.88	±0.18	2.03	±0.27	2.25	±0.25	2.60	±0.21
Condensed tannins								
Caragana ambigua	0.65	±0.10	0.82	±0.28	1.00	±0.22	1.12	±0.21
Salvia cabulica	0.80	±0.12	0.90	±0.22	0.99	±0.24	1.05	±0.18
Sophora griffithii	0.84	±0.34	0.95	±0.24	1.15	±0.26	1.35	±0.14
Perowskia atriplicifolia	0.72	±0.28	0.92	±0.30	0.96	±0.32	1.05	±0.22
Prunus eburnean	0.42	±0.24	0.56	±0.14	0.62	±0.28	0.78	±0.24
Wild Cherry	0.30	±0.22	0.38	±0.18	0.48	±0.248	0.57	±0.18

Calcium concentrations were greater in all species and fulfilled the basic requirement of small ruminants: 0.27% to 0.58% (National Research Council, 1975). Calcium, phosphorus ratios were usually more than 7:1 in contrast with ratios of 1:2 to 2:1 that are optimum for absorption of both minerals. The concentration (0.5-08%)of potassium in all species was greater than those recommended by the National Research Council (1975).

In contrast with the results of Coley (1983) and Provenza and Malechek (1983), our results suggest that the concentrations of phenols and tannins increased during the hot, dry months (Baldwin et al., 1987; Lees et al., 1994). Some proportion of the success of native plants in nutrient poor systems is due to reducing tissue loss to herbivores via morphological or chemical defence. It remains arguable if the metabolic costs of production of such secondary compounds are expressed as a reduced capacity to produce, say, storage proteins or carbohydrates.

The results suggest that in Balochistan rangelands, classical approaches to measuring the protein concentrations of native plants for grazing animals are not appropriate and unlikely to ensure good management of fodder resources. The generally low palatability of majority of the species partially explains why they are not grazed by either native or domestic fauna and perhaps why some specialized, introduced herbivores such as goats seem to thrive in these regions (Davis et al., 1975; Martin and Huss, 1981).

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Table 6. Concentrations (% dry weight) of total phenolics and condensed tannins in the foliage of native shrubs growing in Tomagh Forest area near Ziarat.

Species	Sampling							
	April		June		August		October	
	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.
				Year 2002				
Total phenolics								
Phlomis stewartii	2.25	±0.25	2.88	±0.40	3.98	±0.22	4.32	±0.29
Veronica seniola	2.75	±0.32	2.35	±0.32	3.45	±0.42	4.25	±0.24
Cotonistar	2.45	±0.24	2.10	±0.33	3.12	±0.25	3.42	±0.32
Perowskia atriplicifolia	3.00	±0.21	3.45	±0.40	4.10	±0.35	4.86	±0.48
Rhannus persica	2.95	±0.26	3.05	±0.28	3.40	±0.24	4.12	±0.28
Caragana ambigua	1.98	±0.24	2.10	±0.32	2.65	±0.39	3.48	±0.25
Ephedra intermedia	2.50	±0.18	2.89	±0.28	3.45	±0.22	4.15	±0.28
Condensed tannins								
Phlomis stewartii	0.85	±0.08	0.90	±0.12	1.12	±0.18	1.19	±0.25
Veronica seniola	0.81	±0.12	0.86	±0.32	0.99	±0.16	1.08	±0.23
Cotonistar	0.75	±0.20	0.89	±0.26	0.98	±0.32	1.20	±0.19
Perowskia atriplicifolia	0.74	±0.21	0.83	±0.30	0.98	±0.24	1.10	±0.28
Rhannus persica	0.51	±0.18	0.59	±0.28	0.79	±0.21	0.99	±0.27
Caragana ambigua	0.55	±0.30	0.65	±0.18	0.88	±0.24	0.99	±0.24
Ephedra intermedia	0.98	±0.28	1.02	±0.16	1.05	±0.22	1.25	±0.32
				Year 2003				
Total phenolics								
Phlomis stewartii	2.18	±0.37	2.43	±0.55	3.25	±0.28	4.12	±0.21
Veronica seniola	2.10	±0.45	2.66	±0.29	3.24	±0.32	4.28	±0.32
Cotonistar	2.23	±0.27	2.05	±0.35	4.02	±0.18	3.32	±0.19
Perowskia atriplicifolia	2.65	±0.35	3.00	±0.25	4.12	±0.24	4.46	±0.32
Rhannus persica	1.78	±0.40	2.50	±0.27	3.12	±0.26	3.98	±0.30
Caragana ambigua	1.65	±0.28	2.08	±0.24	2.45	±0.24	3.40	±0.18
Ephedra intermedia	2.05	±0.32	3.00	±0.28	3.35	±0.28	4.10	±0.29
Condensed tannins								
Phlomis stewartii	0.68	±0.14	0.90	±0.10	1.10	±0.18	1.14	±0.21
Veronica seniola	0.80	±0.16	0.92	±0.18	1.05	±0.20	1.10	±0.32
Cotonistar	0.69	±0.28	0.84	±0.24	1.10	±0.24	1.18	±0.22
Perowskia atriplicifolia	0.72	±0.31	0.89	±0.32	0.99	±0.26	1.10	±0.42
Rhannus persica	0.52	±0.16	0.65	±0.24	0.85	±0.30	1.05	±0.26
Caragana ambigua	0.49	±0.22	0.58	±0.12	0.78	±0.31	0.99	±0.21
Ephedra intermedia	0.89	±0.18	0.99	±0.18	1.12	±0.29	1.45	±0.32

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