Pak. J. Bot., 40(1): 237-248, 2008.

MINERAL PROFILE, PALATABILITY AND DIGESTIBILITY OF MARGINAL LAND GRASSES OF TRANS-HIMALAYAN GRASSLANDS OF PAKISTAN

INAM-UR-RAHIM[*], JAVED IQBAL SULTAN[*], MUHAMMAD YAQOOB[**], HAQ NAWAZ[*], IJAZ JAVED[***] AND MANSOOR HAMEED[****]

[*]*Institute of Animal Nutrition and Feed Technology, University of Agriculture, Faisalabad-38040, Pakistan*
[**]*Department of Livestock Management, University of Agriculture, Faisalabad-38040 Pakistan*
[***]*Department of Physiology and Phaemacology, University of Agriculture, Faisalabad, Pakistan*
[****]*Department of Botany, University of Agriculture, Faisalabad, Pakistan*
Corresponding author e-mail: dr_haq_nawaz@yahoo.com

Abstract

The objective of this study was to explore the nutritive value of locally available marginal land grasses. Twelve marginal land grasses viz., *Cynodon dactylon*, *Apluda mutica*, *Setaria pumila*, *Panicum turgidum, Pennisetum orientale, Digitaria sanguinalis, Saccharum spontaneum*, *Rottboellia exaltata*, *Arthraxon prionodes*, *Cenchrus ciliaris*, *Desmostachya bipinnata* and *Andropogon squarrosus* were identified and analyzed for dry matter (DM), macro-minerals (Ca, P, K and Mg) and micro-minerals (Cu, Zn, Mn and Co). The DM, Ca, P, K and Mg at early bloom stage were 30.1±1.080, 0.31±0.044, 0.024±0.003, 0.63±0.047 and 0.005±0.001%, respectively. The Cu, Zn, Mn and Co at early bloom stage were 17.25±1.42, 10.30±1.961, 7.35±0.489 and 0.020±0.005 ppm, respectively. The DM, Ca, P, K and Mg at maturity were 39.4±0.75, 0.32±0.044, 0.041±0.002, 0.53±0.044 and 0.007±0.003 %, respectively. The Cu, Zn, Mn and Co at maturity were 18.48±2.383, 4.30±0.853, 4.675±0.716 and 0.007±0.003 ppm, respectively. In marginal land grasses the highest potential intake rate (PIR) was observed for *Cynodon dactylon* (55.25±12.26 g/4 minute) and lowest for *Andropogon squarrosus* (7.30±2.39 g/4 minute). However, the highest relative preference (RP) was noted for *Setaria pumila* (83.40±2.42%) and lowest for *Andropogon squarrosus* (2.25±0.66%). The mean *in vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME) of marginal land grasses at early bloom stage were 58.4±2.05% and 7.74±0.29 MJ/kg DM, respectively, whereas, at mature stage were 43.3±1.89% and 5.64±0.25 MJ/kg DM, respectively. It is suggested that the macro and micro mineral composition, IVDMD, RP and PIR values of marginal land grasses are suitable for feeding to livestock with some supplementation for different levels of production and classes of livestock.

Introduction

Grazing of livestock is an important component of land management system in non-agricultural marginal areas, whereas, rangeland livestock grazing represents the most suitable land use (Jones & Martin, 1994). The rangelands support 30 million herds of livestock, which contribute US $ 400 million to Pakistan's annual export earnings (Anon., 2006). Past policies favored crops over livestock production which resulted in misuse of land having economically inefficient production potentials. Good pastures were converted into croplands leaving increasingly poorer lands for livestock production (Pratt *et al.*, 1997), without thinking about the conservation of soil. There was no appreciation of the value of grasses and their ability to hold the soil against destructive erosion (Heath *et al*., 1985). In the northern areas of Pakistan, livestock contributes nearly 55% to the gross provincial income by the agriculture sector. The mostly hilly terrain (73%) of the province has little land for crop agriculture, hence, dependence on livestock is relatively high, particularly for rural subsistence (Anon., 1998). To match the maintenance requirements of livestock, there is a need of 13.5 and 110.3 million tons of crude protein (CP) and total digestible nutrients (TDN), respectively (Anon., 2006). The present feed resources provide 40% CP and 75% TDN to the livestock (Younas & Yaqoob, 2005). The deficiency of nutrients leads to under nutrition low productivity and predisposes the livestock to parasitism, epidemics and breeding problems. The improper utilization of rangelands has resulted in great changes in their ecosystem. The more palatable grass species are becoming extinct and are replaced by less palatable weeds (Humphreys, 1984). An indicator to range deterioration, in NWFP is the decline in range dependent sheep and goat population by 10.43% and 39.23%, respectively during 1986 to 1996 (Anon., 1996).

There is a loin share of various grass species to the feeding regimens of animals during scarcity periods. For prolonged winter scarcity, the grasses are harvested from protected hillside rangelands and are stored as hay. Grasses from fertile cropland sides and adjacent uneven areas are also cut several times during summer and are fed to livestock. Marginal land grasses are, however, still the main way of procuring feed but macro and micro minerals composition, potential intake rate (PIR), relative preference (RP) and *In vitro* dry matter digestibility (IVDMD) of locally available marginal land grass species have never been explored. Therefore, this study was conducted to determine DM, mineral compositionm, PIR, RP and IVDMD of marginal land grasses of Trans-Himalayan grasslands of Pakistan.

Materials and Methods

Study area: This study was conducted in North Trans-Himalayan moist zone occupying Malakand Division, North Western Frontier Province (NWFP), Pakistan. The study area has a humid subtropical to temperate environment. It extends from “Budhal” foothills (up to 800 meters altitude) in the south to “Burha Banr” in the north and northeast (more than 2000 meters altitude). Total surface area is approximately 209 square kilometer, with north and south parts divided by a mountain ridge known as “Sar Qala”. The annual precipitation varies from 600 to 1000 mm, mainly during summer and spring. In general the irrigated agriculture in the area is confined to the narrow valley bottom and adjoining gentle slopes. The gentle slopes on mid hills are mainly used for rain fed (Barani) agriculture. The medium to steep hill slopes near the residences and gentle to medium hill slopes away from the residences are protected during wet summer season for forage harvest. The forage is harvested at a mature stage during early autumn and fed as hay to the wintering livestock. The steeper hill slopes near the residences are generally used for free grazing by settled livestock throughout the year. The steeper slopes away from residences are generally scrub/bush lands and natural forest mostly grazed by nomadic sheep and goat flocks. The lower elevation rangelands are grazed during winter season and by nomadic flocks, while tracking to and fro of alpine pastures graze the upper elevation rangelands.

Sample collection and Identification of grass species: The farmers of various social groups at three elevations i.e., upper, middle and lower elevations were interviewed through a questionnaire to collect the information about the names of grasses in local language (Pashtu), growing season, distribution and frequency in relation to location, elevation and aspect and palatability. Ninety farmers (30 x 3, at each elevation) were interviewed in 9 villages (3 x 3, villages at each elevation). Twelve commonly available marginal land grass species were selected for detailed study. Samples of grass species harvested at early bloom and mature stages of growth were chopped to 2 to 3 cm in length, dried in air and stored in polythene bags for further analysis.

Dry matter and mineral composition of marginal land grasses: The air-dried samples were further dried in a forced draught oven at 60°C and were analyzed for dry matter (DM), macro minerals (Ca, P, K and Mg) and micro minerals (Cu, Zn, Mn and Co). The concentration of Potassium (K) was estimated with a flame photometer after wet digestion in nitric acid and per chloric acid. Concentration of Calcium (Ca), Phosphorus (P), Magnesium (Mg), Manganese (Mn), Cobalt (Co), Copper (Cu) and Zinc (Zn) were determined with atomic absorption spectrophotometry (Fritz & Schenk, 1979).

Palatability of marginal land grasses: Palatability of marginal land grasses were determined using four mature local sheep (average body weight 40 kg) purchased from the local market. These sheep were drenched for internal parasites before the start of experiment. An adoption period of five weeks was given to the sheep to accustom them with the hay and to train them in the experimental procedure before any measurement was taken. During preliminary periods each animal was fed a diet of 800 g/day. The diet consisted of 80% mixed grass hay and 20% concentrate mixture. The diet contained 10% crude protein (CP) and 8.37 MJ/kg metabolizable energy (ME). The mineral elements were also added in the diet to meet the sheep requirement (Anon., 1985). The potential intake rate (PIR) for different forages was determined through the procedure adopted by Rehman (1995). Each forage species was offered to sheep for a set of comparisons consisting of four consecutive periods of one minute duration each at 10 minutes interval. Sheep were offered forages in suitable plastic containers ensuring that part of forage was left over after one minute of intake. Relative preference (RP) was also evaluated in 95 days through the procedure used by Rehman (1995). The preference ranking of forages with in each group was determined by offering forages in pairs, initially with the forage having highest PIR and then with other forages, until all possible combination within a group was studied and similarly all forage groups were studied. Like PIR, RP test also consisted of a set of four consecutive period of one-minute duration each at ten minutes interval. There was one-hour gap before a new set of comparisons was started with a maximum of four sets in a day. The containers of both forages in a pair were reversed for each successive comparison to avoid left or right hand bias. The preference for particular forage was determined by the standard procedure developed by Bell (1959) for two choice tests, as the intake of forage expressed as a percentage of the combined intake of both test and standard forage.

$$\text{Relative preference (RP) \%} = \frac{\text{Amount of test forage eaten}}{\text{Amount of test + standard forage eaten}} \text{ X100}$$

***In vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME) MJ/kg DM:** For IVDMD determination, oven dried ground samples were incubated at 37±1°C for 48 hours between pH 6.7-7.0 in an all glass system using 45 ml of inoculums. The inoculums comprised of 36 ml of McDougal’s artificial saliva and 9.0 ml of strained fresh rumen liquor from grass fed sheep. After incubation and centrifugation the residue was then treated for 48 hours with pepsin in weak acid (pH 2.0). The final residue was

composed of undigested plant cell wall and bacterial debris and yield values were supposed to be comparable to *In vivo* apparent digestibility (Tilley & Terry, 1963). The IVDMD was used for calculating the metabolizable energy (ME) of grass species by the following equation (Anon., 1984).
ME (MJ/kg DM)= 0.15 IVDMD%
IVDMD% = 0.98 IVDMD% - 4.8

Statistical Analysis: The average values for dry matter (DM), macro and micro minerals, IVDMD and ME were integrated to develop a matrix of correlation (Steel *et al.*, 1997).

Results and Discussion

Identification of range grass species and their use pattern: The marginal land grasses included *Cynodon dactylon*, *Apluda mutica*, *Setaria pumila*, *Panicum turgidum, Pennisetum orientale*, *Digitaria sanguinalis*, *Saccharum spontaneum*, *Rottboellia exaltata*, *Arthraxon prionodes*, *Cenchrus ciliaris*, *Desmostachya bipinnata* and *Andropogon squarrosus. Setaria pumila*, *Pennisetum orientale* and *Rottboellia exaltata* were available at upper elevation, while the remaining grasses were commonly available at all elevations. The use pattern of individual grass species can not be described, as most of them were harvested combinely and stored as hay or freely grazed. However, for the purpose of discussion in their use pattern, these can be grouped on the basis of range type they occupy. It was observed that *Cenchrus ciliaris* was the most common grass of the field boundaries having intermediate to deep loamy soils on southern aspect of lower and middle elevations. On the northern sites *Apluda mutica* (deep soils) occupied similar areas. *Desmostachya bipinnata* and *Cynodon dactylon* were more commonly found on sandy soils, having high moisture contents. *Andropogon squarrosis* and *Saccharum spontaneum* were mainly steam-side loamy soil grasses. The results of present study were in line with the findings of Leede (1998), who reported that the free grazing rangelands grasses include *Cymbopogon jwarancusa*, *Heteropogon contortus* and *Chrysopogon aucheri* in the subtropical zone of Leganai range (Bunair) Malakand division, whereas, in Topdarra range of Bunair, *Chrysopogon aucheri*, *Themeda anathera* and *Heteropogon contortus* were the common grass species. It was observed that *Dichanthium annulatum* and *Cymbopogon schoenanthus* were the most common grasses covering field boundaries at low elevation and on deep soils having higher clay contents. On the other hand, *Themeda anathera*, *Chrysopogon montanus*, *Chrysopogon aucheri* and *Heteropogon contortus* were commonly found on shallow soil hill slopes.

Dry matter and mineral composition of marginal land grasses: The DM content and macro and micro mineral composition of free grazing rangeland grasses at early bloom and maturity are presented in Table 1 and 2, respectively. The DM content in free grazing rangeland grasses at early bloom varied from 23.8% (*Desmostachya bipinnata*) to 36.9% (*Andropogon squarrosus)* and the average was 30.1±1.08%. At mature stage, the DM content in these grasses varied from 34.7% (*Desmostachya bipinnata*) to 43.9% (*Andropogon squarrosus*) and the mean was 39.4±0.75%. The Ca concentration in marginal land grasses at early bloom varied from 0.18% (*Saccharum spontaneum*) to 0.74% (*Arthraxon prionodes)* and mean was 0.31±0.044%. The Ca concentration at maturity varied from 0.14% (*Rottboellia exaltata*) to 0.72% (*Arthraxon prionodes)* and the mean was 0.32±0.042%. The findings of present study revealed that Ca content in

Table 1. Dry matter (DM) content and mineral composition of marginal land grasses at early bloom stage of Trans-Himalayan Grasslands of Pakistan.

Grass name	DM %	Ca %	P %	K %	Mg %	Cu ppm	Zn ppm	Mn ppm	Co ppm
Cynodon dactylon	30.4	0.20	0.019	0.56	0.002	17.5	3.5	8.0	0.031
Apluda mutica	27.5	0.20	0.034	0.72	0.003	10.0	14.0	7.5	0.042
Setaria pumila	29.5	0.22	0.023	0.49	0.005	20.0	2.0	6.0	0.025
Panicum turgidum	26.7	0.28	0.013	0.95	0.007	7.5	11.0	9.0	0.015
Pennisetum orientale	33.8	0.20	0.023	0.71	0.002	25.0	4.0	5.0	0.013
Digiteria sanguinalis	28.6	0.24	0.013	0.78	0.007	16.5	3.5	7.5	0.05
Saccharum spontaneum	36.4	0.18	0.024	0.49	0.004	17.5	12.0	6.0	0.012
Rottboellia exaltata	32.9	0.22	0.032	0.33	0.001	22.5	4.5	9.4	0.016
Arthraxon prionodes	26.7	0.74	0.050	0.75	0.009	21.0	15.0	9.8	0.025
Cenchrus ciliaris	27.9	0.46	0.016	0.54	0.005	15.0	5.5	8.3	0.078
Desmostachya bipinnata	23.8	0.42	0.023	0.46	0.003	16.0	20.0	4.5	0.024
Andropogon squarrosus	36.9	0.28	0.021	0.62	0.007	18.5	8.5	7.2	0.014
Mean ± SE	30.1±1.080	0.31±0.044	0.024±0.003	0.63±0.047	0.005±0.001	17.25±1.42	10.30±1.961	7.35±0.489	0.02±0.005

Table 2. Dry matter (DM) content and mineral composition of marginal land grasses at maturity of Trans-Himalayan Grasslands of Pakistan.

Grass name	DM %	Ca %	P %	K %	Mg %	Cu ppm	Zn ppm	Mn ppm	Co ppm
Cynodon dactylon	38.8	0.32	0.060	0.40	0.003	13.7	1.9	1.5	0.002
Apluda mutica	40.0	0.28	0.045	0.55	0.002	3.0	3.5	3.2	0.001
Setaria pumila	37.9	0.32	0.040	0.45	0.005	16.0	2.5	2.7	0.002
Panicum turgidum	38.6	0.22	0.036	0.75	0.003	6.0	8.3	8.4	0.003
Pennisetum orientale	40.2	0.31	0.051	0.70	0.004	33.0	3.4	4.5	0.004
Digiteria sanguinalis	36.2	0.18	0.043	0.62	0.002	19.0	2.1	3.1	0.003
Saccharum spontaneum	43.5	0.09	0.034	0.41	0.006	21.0	4.2	4.0	0.002
Rottboellia exaltata	41.9	0.14	0.030	0.25	0.002	25.0	2.0	3.3	0.005
Arthraxon prionodes	38.0	0.72	0.050	0.75	0.003	31.0	10.5	9.4	0.004
Cenchrus ciliaris	38.8	0.41	0.037	0.50	0.010	17.0	2.0	3.0	0.030
Desmostachya bipinnata	34.7	0.31	0.047	0.35	0.003	18.5	8.1	7.2	0.020
Andropogon squarrosus	43.9	0.29	0.034	0.51	0.040	14.3	3.0	5.8	0.009
Mean ± SE	39.4±0.75	0.32±0.042	0.041±0.002	0.53±0.044	0.007±0.003	18.48±2.383	4.30±0.853	4.675±0.716	0.007±0.003

marginal land grasses generally increased with maturity. Optimum level of Ca in plants ranged from 0.40 to 0.60% and its level above 1.0% is considered high (Georgievskii, 1982), whereas, Minison (1990) reported Ca level from 0.31 to 1.98% and the mean as 0.63%. On the other hand Ca level in the diet of livestock to fulfill its maintenance and production requirements should remain within the range of 0.17 to 0.42% (Anon., 1975). The variation noted within the present grasses was in line with previous studies (Gohl, 1981; Skerman & Riveros 1990). The Ca contents determined in the forage grasses supported the findings of Khan *et al*., (2006) who reported that Ca contents of arid pastures were slightly higher than the minimum recommended levels in the diets of ruminants.

Phosphorus concentration in marginal land grasses at early bloom stage varied from 0.013% (*Digitaria sanguinalis*) to 0.050% (*Arthraxon prionodes*) and the mean was 0.024±0.003%. The P content at maturity varied from 0.030% (*Rottboellia exaltata)* to 0.60% (*Cynodon dactylon)* and the mean was 0.41±0.002%. The P content increased with age in marginal land grasses. The consistent low phosphorus content across all grasses might be due to low P content in the soil or high Ca in the soil. These results differed from those of Minson (1990) who reported declined P content with advancing age of the plants. The P content in tropical grasses varied from 0.02 to 0.06% of plant dry matter and this variation might be due to available P in the soil (Skerman & Riveros, 1990). These results revealed that P concentration in various forages was below the minimum requirement (0.082%) of livestock (Anon., 1975). These results also supported the findings of Sprague (1979) who reported that P was widely deficient in soils of rangelands in semi-arid and sub humid regions and consequently in the grasses grown in these areas. The P deficiency in the soil may hamper the growth of legumes, since high soil pH and higher Ca content caused formation of insoluble Ca phosphate that depressed availability of P (Kinzel, 1983). Forages of semi desert and savanna regions were reported to be widely deficient in P content due to low P content in the soil. Phosphorus deficiency in animals is most prevalent when forages are low in P and high in Ca. The temperate forages contained more P than the tropical forages i.e. 0.35% vs. 0.23% of the DM (Minson, 1990). They further reported that within each species, P concentration varied with cultivars, stage of growth, soil fertility and climate. They also reported that in tropical forages only 49% legumes and 35% grasses contained P above the critical level. The P concentration declines as plant increases in size and advances towards maturity. The rate of decline is higher in stem fraction as compared to other parts of the plants. The application of nitrogen fertilizers stimulates plant growth and depresses P concentration.

The K concentration in marginal land grasses at early bloom varied from 0.33% (*Rottboellia exaltata*) to 0.95% (*Panicum turgidum*) and the mean was 0.63±0.047%. The K concentration in these grasses at maturity varied from 0.25% (*Rottboellia exaltata*) to 0.75% (*Panicum turgidum*) and the mean was 0.53±0.44%. The K concentration increased with age in free grazing rangeland grasses. Minson (1990) reported that K concentration was lower in all rangeland grasses than the value noted in pasture (2.75%). However, application of K fertilizer resulted in improved productivity of legumes. Humphreys (1984) reported that K concentration varied in tropical grasses from 0.6% to 1.2%. The K content in temperate legumes were higher than for tropical legumes. The lower K content observed in the present study might be due to increased availability of Ca. Kinzel (1983) reported that high supply of lime with insufficient of supply of K caused decreased in K intake from the soil, leading to considerable variation of growth. Potassium activates many enzyme systems in the plant (Humphreys, 1984) which affect the plant growth.

Magnesium concentration in marginal land grasses at early bloom varied from 0.001% (*Rottboellia exaltata)* to 0.009% (*Arthraxon prionodes*) and the mean was *0.005*±0.001%. The Mg concentration at maturity varied from 0.002% (*Apluda mutica, Digitaria sanguinalis, Rottboellia exaltata)*, to 0.040% (*Andropogon squarrosus*) and the mean was 0.007±0.003%. The present study showed that Mg concentration decreased with plant age in marginal land grasses and these results supported the findings of Skerman & Riveros (1990) who reported that Mg content of tropical grasses varied from 0.04 to 0.90% with a mean. of 0.36%. In the present study it was noted that Mg content decreased in both leaf and stem with increasing plant age, whereas, Georgieviskii (1982) observed equal Mg content in leaf and stem. The Mg deficiency was most common on acid, sandy soil or soil deficient in Mg. The highest Mg concentration in forage plants was observed in early vegetative stage. Minson (1990) reported higher values for tropical grasses (0.36%) than temperate grasses (0.18%) and legumes (0.26 to 0.28%), he did not find interaction among fertilizer, Na, P and K, except in situations where soil Mg was depleted by more frequent forage harvesting. The Mg uptake from the soil was generally low at low temperature and in water logged soils. The proportion of Ca and Mg in the soil not only affected the uptake of Mg by the plant, but also affect the concentration of other cations and soil pH (Skerman & Riveros, 1990).

The Cu content in free rangeland grasses at early bloom varied from 7.5ppm (*Panicum turgidum*) to 25.0ppm (*Pennisetum orientale*) and the mean was 17.25±1.42ppm. The Cu concentration at maturity varied from 3.0ppm (*Apluda mutica*) to 33.0ppm (*Pennisetum orientale*) and the mean was 18.48±2.383 ppm. The Cu concentration increased with age in marginal land grasses. *Anon*., (1975) reported that Cu content in all grasses were higher than the livestock requirements (6-12ppm of diet DM), whereas, Minson (1990) reported increasing Mo intake prevented Cu toxicity in livestock. They also reported that increasing soil temperature from 12 to 20°C raised Cu concentration in plants. Temperate legumes generally contained more Cu than temperate grasses (7.8 vs. 4.70ppm). Tropical legumes contained low Cu than tropical grasses (3.9 vs 7.8ppm). Skerman & Riveros (1990) stated that Cu concentration of tropical grasses varied from 3 to 10ppm on dry matter basis. Shah *et al*.(1986) reported an increase in Cu concentration in forages with increasing maturity. The Cu concentration in the present study were in line with those of Gohl (1981), who reported decreased Cu concentration with age of the plant.

The Zn concentration in marginal land grasses at early bloom stage varied from 2.0ppm (*Setaria pumila*) to 20.0ppm (*Desmostachya bipinnata*) and the mean was 10.30±1.961ppm. The Zn concentration at maturity stage varied from 1.9ppm (*Cynodon dactylon*) to 10.5ppm (*Arthraxon prionodes*) and the mean was 4.30±0.853ppm. The concentration of Zn in grasses varied from 7.0 to 100.0ppm with a mean of 36.0ppm. The temperate forages contain less Zn content than tropical forages. Grasses contain less Zn than legumes (25 vs. 47.0ppm) and Zn deficiency rarely occur in ruminant fed such forages (Minson, 1990). Zinc concentration in such grasses was not affected by grass maturity or change in climate, however, was affected with the application of fertilizer.

The Mn concentration in marginal land grasses at early bloom stage varied from 4.5ppm (*Desmostachya bipinnata*) to 9.8 ppm (*Arthraxon prionodes*) and the mean was 7.35±0.0489ppm. The Mn concentration at maturity stage varied from 1.5 ppm (*Cynodon dactylon*) to 9.4ppm (*Arthraxon prionodes*) and the mean was 4.675±0.716ppm. The Mn content increased with age in marginal land grasses. These results were in agreement with those of Gohl (1981) who reported gradual increase of Mn content with plant maturity. The Mn content in free rangeland grasses were adequate to meet the livestock requirements (Perveen, 1988).

The Co concentration in free grazing rangeland grasses at early bloom stage varied from 0.012ppm (*Saccharum spontaneum*) to 0.078ppm (*Cenchrus ciliaris*) and the mean was 0.02±0.005ppm. The Co concentration at maturity stage varied from 0.001ppm (*Apluda mutica*) to 0.020ppm (*Desmostachya bipinnata*) and the mean was 0.007±0.003ppm. The Co content increased with age in free rangeland grasses. In most of the forage species in the study area, Co concentration was below the recommended requirement of livestock, hence supplementation to livestock rations was recommended (Anon., 1975). The Co concentration in tropical grasses varied from 0.02 to 0.91ppm in the DM with a mean 0.16ppm (Skerman & Riveros, 1990). The Co is essential for legume rhizobial symbiosis and affects the synthesis of vitamin B (Humphreys, 1984). Variation in the Co concentration of forages were reported to be less than 0.01 to 1.26ppm of the DM, associated with differences in soil Co. Forages grown on poorly drained soils contained about 7 times high Co as those of well drained soil (Minson, 1990). High soil moisture increased the concentration of Co in the soil and doubled the uptake of Co. Applying dolomite lime depresses the Co concentration in the forages. Fertilizer nitrogen, phosphorus and Potassium had no effect on Co concentration (Minson, 1990).

Palatability of marginal land grasses: Palatability refers to the relish with which feed is consumed as stimulated by the sensory impulses (Heath *et al*., 1985).The potential intake rate (PIR) and relative preference (RP) are considered the main indicators for palatability (Rehman, 1995). The PIR and RP of 12 marginal land grasses are presented in Table 3. The average PIR (grams consumed during 4 minutes per sheep) was the highest for *Cynodon dactylon* (55.25±12.26 g/4 minute) followed by *Apluda mutica* (51.50±15.03 g/4 minute), *Setaria pumila* (49.50±8.87 g/4 minute) and *Panicum turgidum* (47.8±8.81 g/4 minute). The lowest PIR values were for *Andropogon squarrosus* (7.3±2.29 g/4 minute). The RP was the highest for *Setaria pumila* (83.4±2.42%) followed by *Panicum turgidum* (74.95±0.62%), *Apluda mutica* (71.53±0.73%) and *Cynodon dactylon* (68.63±1.88%). The lowest RP was observed for *Andropogon squarrosus* (2.25±0.66%). Among the marginal land grasses *Cynodon dactylon* despite of its higher PIR values showed relatively lower RP. This might be due to the presence of an essential oil (piperitone) that made it less palatable. This essential oil is responsible for the peculiar smell and taste of the grass (Rehman, 1995) and might decrease its relative preference despite of its higher PIR. The PIR was more strongly affected by the degree of tenderness and stage of growth while the RP seemed to be more affected by the intrinsic chemical factors, hence when the grass was offered in pair with other forages having no such repellent essential oil, the other forage showed higher RP value despite of their lower PIR.

Correlation of palatability with macro and micro minerals and IVDMD is presented in Table 5. The RP and PIR were positively correlated (r=0.84) with each other across all grasses studied. These results supported the findings of Rehman (1995) who suggested PIR as a useful indicator of preference. The results of the present study revealed that although the PIR and RP were correlated with each other, their major determinant affects both the parameters differently. The PIR was influenced by the degree of tenderness, while RP was influenced by chemical factors. The present study suggests that more precise prediction equations can be developed if concentrations of sugars and chemical factors were determind and integrated.

Table 3. Potential intake rate (PIR) and relative preference (RP) of marginal land grasses of Trans-Himalayan Grasslands of Pakistan.

S. No.	Grass name	PIR (g/4 minute) ± SE*	RP (%) ± SE**
1.	*Cynodon dactylon*	55.25 ± 12.26 [a]	68.63 ± 1.88 [b]
2.	*Apluda mutica*	51.50 ± 15.03 [a]	71.53 ± 0.73 [c]
3.	*Setaria pumila*	49.50 ± 8.87 [ab]	83.40 ± 2.42 [a]
4.	*Panicum turgidum*	47.80 ± 8.81 [ab]	74.95 ± 0.62 [a]
5.	*Pennisetum orientale*	47.50 ± 6.23 [ab]	52.00 ± 1.92 [a]
6.	*Digiteria sanguinalis*	47.00 ± 10.41 [ab]	63.55 ± 0.93 [b]
7.	*Saccharum spontaneum*	42.00 ± 12.77 [ab]	43.08 ± 1.33 [e]
8.	*Rottboellia exaltata*	41.00 ± 10.11 [ab]	32.15 ± 0.86 [c]
9.	*Arthraxon prionodes*	39.00 ± 8.97 [abc]	54.42 ± 1.86 [d]
10.	*Cenchrus ciliaris*	38.80 ± 6.75 [abc]	46.55 ± 0.67 [d]
11.	*Desmostachya bipinnata*	36.50 ± 8.41 [cd]	32.75 ± 0.85 [g]
12.	*Andropogon squarrosus*	7.30 ± 2.39 [d]	2.25 ± 0.66 [h]

SE = Standard error
*Each figure represent mean (± standard error of the mean) of 4 samples.
*Figures having different letters are significant ($p<0.05$) within the same forage grass.
**Each figure represent mean (± standard error of the mean) of 48 comparisons.
Figures having different letters are significant ($p<0.05$) within the group.

Table 4. Digestibility and metabolizable energy of marginal land grasses of Trans-Himalayan Grasslands of Pakistan.

S. No.	Grass name	Early bloom		Maturity	
		IVDMD %	ME MJ/kg DM	IVDMD %	ME MJ/kg DM
1.	*Cynodon dactylon*	63.1	8.54	55.4	7.41
2.	*Apluda mutica*	60.2	8.12	48.6	6.40
3.	*Setaria pumila*	67.7	9.25	44.5	5.82
4.	*Panicum turgidum*	58.4	7.87	40.4	5.23
5.	*Pennisetum orientale*	69.3	7.99	43.5	5.69
6.	*Digiteria sanguinalis*	59.3	7.99	42.6	5.52
7.	*Saccharum spontaneum*	47.6	6.28	34.6	4.35
8.	*Rottboellia exaltata*	48.2	6.36	36.4	4.65
9.	*Arthraxon prionodes*	60.4	8.16	51.5	6.86
10.	*Cenchrus ciliaris*	58.6	7.91	36.6	4.65
11.	*Desmostachya bipinnata*	64.3	8.75	47.6	6.28
12.	*Andropogon squarrosus*	43.2	5.65	37.3	4.77
	Mean ± SE	**58.4±2.05**	**7.74±0.29**	**43.3±1.89**	**5.64±0.25**

IVDMD = *In vitro* dry matter digestibility ME = Metabolizable energy

Table 5. Correlation matrix (r) among relative preference, potential intake rate, digestibility, macro and micro mineral content of marginal land grasses of Trans-Himalayan Grasslands of Pakistan.

.	PIR	IVDMD	Ca	P	K	Mg	Cu	Zn	Mn	Co
RP %	0.84	+0.65	-0.29	-0.19	+0.31	+0.14	-0.51	-0.47	+0.20	+0.08
PIR	-	+0.43	-0.63	-0.27	+0.16	-0.29	-0.36	-0.55	+0.25	+0.06
IVDMD	-	-	+0.12	-0.11	+0.07	+0.05	-0.23	-0.24	-0.27	+0.023

Kenney & Black (1984) reported that when effects of taste and odor are removed, sheep preferred diet having faster intake rates. The IVDMD showed positive correlation with both RP and PIR across all the grasses (*r*=0.65, 0.43). The CP contents had positive correlation with RP and with PIR (Provenza *et al*., 1996), but CP contents were not determind in the present study. They also reported that lambs preferred food having higher CP contents. The macro minerals under study showed correlation with RP and PIR. Calcium and phosphorus showed negative correlation with RP (*r*= -0.29, *r*= -0.19) and PIR (*r*= -0.63, *r*= -0.27). Potassium showed positive correlation with RP (*r*= 0.31) and PIR (*r*= +0.16), whereas, Mg showed positive correlation with RP (*r*= 0.14) and negative correlation with PIR (*r*= -0.29) (Table 5). Other factors like fibrousness reduces intake rate because of the associated reduction in bite size to properly severe forage and the associated increase in chewing time necessary to adequately process the forage (Laca *et al*., 2001). Lignin and CP content interfered with the digestion of structural carbohydrates, the former by acting as a physical barrier to rumen microbial enzymes (Moore & Jung, 2001) and the later by limiting rumen microbial growth (Orskov, 1982). The factors affecting palatability need more investigation (Pratt *et al*., 1997).

***In vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME) of grasses:** The IVDMD for marginal land grasses at early bloom stage varied from 43.2 (*Andropogon squarrosus*) to 69.3% (*Pennisetum orientale*) and the mean was 58.4±2.05% (Table 4). The ME value at early bloom stage varied from 5.65 MJ/Kg DM (*Andropogon squarrosus*) to 9.25 MJ/Kg DM (*Setaria pumila*) and mean was 7.74±0.29 MJ/Kg DM. The IVDMD value of marginal land grasses at maturity varied from 36.4% (*Rottboellia exaltata*) to 55.4% (*Cynodon dactylon*) and the mean was 43.3±1.89% (Table 4). The derived ME value at maturity had a range of 4.35 MJ/Kg DM (*Saccharum spontaneum*) to 7.41 MJ/Kg DM (*Cynodon dactylon*) with a mean of 5.64 ± 0.25 MJ/Kg DM. The IVDMD was negatively correlated with Ca (*r*= -0.29), P (*r*= -0.19), Cu (*r*= -0.51) and Zn (*r*= -0.47), whereas, IVDMD was positively correlated with K (*r*=0.31), Mg (*r*=0.14), Mn (*r*=0.20), and Co (*r*=0.8). Many other factors like NDF, ADF, hemi cellulose and lignin may affect IVDMD. The IVDMD decreased with increasing maturity of the plants and similar findings were reported by Skerman & Riveros (1990) who found a fall of 0.1 to 0.2% DM digestibilities per day with maturity of pasture grasses. Buxton (1989) reported that the proportion of stem in a grass approaching maturity was the main morphological factor determining the digestibility. Gabrielsen *et al*., (1990) and Van Soest (1965) reported that NDF, ADF and lignin concentration increased with maturity while IVDMD and CP declined. Revell *et al*., (1994) reported a positive correlation between CP and digestibility, whereas, Cherney *et al*., (1990) observed negative correlation of IVDMD with NDF, ADF and lignin. It had been reported that cell wall component, NDF, ADF and lignin were negatively correlated with IVDMD in tree leaves (Mowatt *et al*., 1969, Kundu & Sherma,1988; Perveen, 1998). The macro and micro mineral profile, IVDMD, RP and PIR values of marginal land grasses suggest that these can be fed to livestock with some supplementation.

References

Anonymous. 1975. *Nutrient Requirements of Domestic Animals-Nutrient Requirement of Sheep*. (5^{th} revised Ed.) National Research Council. National Academy of Science, Washington, DC

Anonymous. 1984. *Energy Allowances and Feeding Systems for Ruminants*. Ministry of Agriculture Food and Fisheries, Her Majesty Stationery Office, London.

Anonymous. 1985. *Nutrient Requirements of Sheep*: Sixth Revised Edition. National Academy Press, Washington, DC.

Anonymous. 1996. *Pakistan census of livestock*. Agriculture census organization, Statistics Division, Islamabad, Pakistan.

Anonymous. 1998. *Background paper on the sustainable management of grazing lands in the NWFP*. IUCN, The World Conservation Union, Sarhad Program Office Pakistan.

Anonymous. 2006. *Economic Survey*. Government of Pakistan, Finance Division, Islamabad, Pakistan.

Bell, F.R. 1959. Preference thresholds for taste determination in goats. *J. Agric. Sci.,* 52:125-29

Buxton, D.R. 1989. *In Vitro* digestion kinetics of temperate perennial forage legume and grass stems. *Crop Sci*., 29: 213 -219.

Cherney, D.J.R., D.R. Mertens and J.E. Moore. 1990. Intake and digestibility by withers as influenced by forage morphology at three levels of forage offering. *J. Anim. Sci.,* 68(12): 4387-4399.

Fritz, J.S. and G.H. Schenk. 1979. *Quantitative Analytical Chemistry*. 4th Ed., Allyn and Bacon, Inc., Boston, Massachusetts.

Gabrielsen B.C., K.P. Vogel. B.E. Anderson and J.K. Ward. 1990. Alkali labile cell wall phenolics and forage quality in Switch grasses selected for different digestibility. *Crop Sci.,* 30(6): 1313-1320.

Georgievskii, V. I. 1982. Biochemical regions. Mineral composition of feeds. In: *Mineral Nutrition of Animals*. (Eds.): V.I. Georgievskii. B.N. Annenkov and V.I. Samokhin. Butterworths London.

Gohl, Bo. 1981. *Tropical Feeds. Feed information summaries and nutritive values.* FAO, Animal Health and Production Series No. 12. FAO, Rome, Italy

Heath, M.E., R.F. Barnes and D.S. Metcalfe. 1985. *Forages: The science of grassland agriculture*. Iowa State University Press. Ames, Iowa, USA .

Humphreys, L.R. 1984. *Tropical pastures and fodder crops*. Longman Group U.K. Ltd. Longman House, Burnt Mill, Harlow Essex CM 20 2J. E. England

Jones, G.E and Martin. 1994. *Eco zone suite of model, for FAO training service*. Eco zone Gough SAC Edinburgh Policy Analysis Division, Rome.

Kenney, P.A. and J.L. Black. 1984. Factors affecting diet selection by sheep I. Potential intake rate and acceptability of feed. *Aust. J. Agric*. Res., 35: 55 1-63

Khan, Z. I., M. Ashraf and E. E. Valeem. 2006. Forage mineral status evaluation: The influence of pasture. *Pak. J. Bot*. 38: 1043-1057

Kinzel, H. 1983. Influence of limestone silicates and soil pH on vegetation. III. Physiological plant ecology. In: *Encyclopedia of Plant Physiology*. (Eds.): O.L.P.S. Lang, Nobel, C.B. Osmond and H. Zieglers. Spriger-Verlag, Berlin.

Kundu, S.S. and V. Sharma. 1988. Chemical composition and *in vitro* dry matter digestibility of certain tree leaves. *Indian J. Anim. Nutr*., 5(1): 23-27.

Laca, E.A., L.A. Shipley and E.D. Reid. 2001 Structural anti-quality characteristics of range and pasture plants. *J. Range Manage.*, 54: 413-419.

Leede, B. 1998. *Vegetation production in hill-side plantation in Bunair and upper Swat*. Environmental Rehabilitation Project. Technical Report # 2.7 (WFP 4659)

Minson, D.J. 1990. The chemical composition and nutritive value of tropical grasses. In: *Tropical grasses FAO Plant Production and Protection Series*, (Eds.): P.J. Skerman and F. Riveros. No: 23. FAO Rome.

Moore, K.J., and H.G. Jung. 2001 Lignin and fiber digestion. *J. Range Manage*., 54: 420-430

Mowatt, D.N., M.L. Kwain and J.E. Wind. 1969. Lignification and *in vitro* cell wall digestibility of plant parts. *Can. J. Plant Sci.,* 49: 499-504.

Orskov, E.R. 1982 *Protein Nutrition in Ruminants*. Academic Press, London.

Perveen, S. 1998. Nutritive evaluation of some fodder tree leaves through *In vitro* digestibility techniques. Technical Paper, NWFP Agricultural University, Peshawar.

Pratt, D.J., F.L. Gall and C.D. Haan. 1997. *Investing in Pastoralism*. The International Bank of Re-construction and Development. The World Bank 1818 H Street, NW Washington, D.C. 20433,USA.

Provenza, F.D., C.B. Scott, T.S. Phy and J.J. Lynch. 1996. Preference of sheep for foods varying in flavor and nutrients. *J. Anim. Sci.,* 74(10): 2355-61.

Rehman, A. 1995. *The potential for the use of salt bush in sheep grazing systems during summer and autumn in a Mediterranean climate*. Ph.D. Thesis, University of Western Australia.

Revell, D.K., S.K. Baker and B.B. Purser. 1994. Estimates of the intake and digestion of nitrogen by sheep grazing a Mediterranean pasture as it matures and senesces. *Proc. Aust. Soc. Anim. Prod*., 20: 217-20.

Shah, S.M., W. Mohammed and M.M. Iqbal. 1986. Micro-nutrient status of the soils of the Frontier Regions. *Pak. J. Sci. Ind. Res*., 29(4): 288-90.

Skerman, P.J and F. Riveros. 1990. *Tropical grasses*. FAO Plant Production and Protection Series, No. 23. FAO Rome

Sprague, H.B. 1979. *Management of rangelands and other grazing lands of the Tropics and subtropics for support of livestock production*. Technical Series Bulletin No. 23, Agriculture Technology for Developing Countries, Office of Agriculture Development Support Bureau. Agency fir International Development, Washington DC, 20523

Steel, R.G.D., J.H. Torrie and J.H. Dicky. 1997. *Principles and Procedures of Statistics a Biometrical Approach*. 3rd Ed. McGraw Hill Book Co. Inc., New York, USA.

Tilley, J.M.A. and R.A. Terry. 1963. A two stage technique for *in vitro* digestion of forage crops. *Grass Forage Sci*., 18: 104-111.

Van Soest, P.J. 1965. Voluntary intake in relation to intake and digestibility. Symposium on Factors influencing the voluntary intake by ruminants. *J. Anim. Sci*., 24: 834-43.

Younas, M and M. Yaqoob. 2005. Feed resources of livestock in the Punjab, Pakistan. *Livest. Res. Rural Devel.* http://www.cipav.org.co/lrrd/lrrd17/2/youn17018.htm

(Received for publication 20 December 2007)