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MINERAL COMPOSITION, PALATABILITY AND DIGESTIBILITY OF FREE RANGELAND GRASSES OF NORTHERN GRASSLANDS OF PAKISTAN

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Abstract

A study was conducted in the valley of Chagharzai in Bunair district lying in the north Trans-Himalayan moist zone occupying Malakand Division, North Western Frontier Province (NWFP), Pakistan to determine mineral composition, palatability and digestibility of locally available free rangeland grasses. The study area lies between 34.42 to 34.66 degree latitude and 72.62 to 72.78 degree longitude, having a humid subtropical to temperate environment. The annual precipitation varies from 600 to 1000 mm, mainly during summer and spring. Ten free rangeland grasses were identified for macro-minerals (Ca, P, K and Mg) and micro-minerals (Cu, Zn, Mn and Co). The mean percentage values for Ca, P, K and Mg at early bloom stage were 0.26±0.022, 0.025±0.004, 0.69±0.113 and 0.044±0.006, respectively. The mean ppm values for Cu, Zn, Mn and Co at early bloom stage were 22.75±2.671, 14.70±2.065, 10.12±1.770 and 0.023±0.003, respectively. The mean percentage values for Ca, P, K and Mg at maturity were 0.30±0.049, 0.031±0.006, 0.68±0.108 and 0.028±0.004, respectively. The mean ppm values for Cu, Zn, Mn and Co at maturity were 29.8±2.962, 8.96±2.0701, 6.14±1.034 and 0.029±0.005, respectively. In free grazing rangeland grasses the highest ($p<0.05$) potential intake rate (PIR) was observed for *Heteropogon contortus* (53.80±15.82 g/4 minute) and lowest for *Cymbopogon schoenanthus* (35.8±.12.16 g/4 minute). However, the highest ($p<0.05$) relative preference (RP) was noted for *Dichanthium annulatum* (81.15±0.61%) and lowest for *Cymbopogon schoenanthus* (19.33±1.84%). The mean *In vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME) of free rangeland grasses at early bloom stage were 55.3±1.86% and 7.57±0.25 MJ/kg DM, respectively, whereas, the mean IVDMD and ME at mature stage were 44.0±2.11% and 5.86±0.29 MJ/kg DM, respectively. The macro and micro mineral composition, IVDMD, RP and PIR values indicate that free grazing rangeland grasses be fed to livestock with some supplementation for different levels of production and types of livestock.

Introduction

Livestock grazing represents a system of land management in non-agricultural marginal areas, whereas, on rangeland livestock grazing represents the most suitable land use (Jones & Martin, 1994). Rangelands support 30 million herds of livestock, which contribute US $ 400 million to Pakistan’s annual export earnings (Anon., 2006). Past policies have often favored crops over livestock production, resulting in misuse of land having economically inefficient production potentials. Good pastures are being converted into cropland 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 110.30 million tons of crude protein (CP) and total digestible nutrients (TDN), respectively (Anon., 2006). However, present feed resources provide 40% CP and 75% TDN to the livestock (Younas & Yaqoob, 2005). The deficiency of nutrients leads to under nourishment, 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 and 1996 (Anon., 1996).

There is handsome 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 stored as hay. Grasses from fertile cropland sides and adjacent uneven areas are also cut several times during summer and fed to livestock. Free grazing at rangelands is 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 free rangeland grass species have never been explored. Therefore, this study was conducted to determine PIR, RP and IVDMD of free rangeland grasses of Northern grasslands of Pakistan.

Materials and Methods

Study area: The study was conducted in the valley of Chagharzai in Bunair district lying in the North Trans-Himalayan moist zone occupying Malakand Division, North Western Frontier Province (NWFP), Pakistan to determine PIR, RP and IVDMD of free rangeland grasses of Northern grasslands of Pakistan. The study area lies between 34.42 to 34.66 degrees latitude and 72.62 to 72.78 degree longitude, having 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.

Identification and sampling of grass species: A questionnaire was prepared and the farmers of various social groups at three elevations i.e., upper, middle and lower elevations were interviewed. They were asked about the names of grasses in local language (Pashtu), their season of use, location, elevations and aspects of their availability, species of animal fed and trends in their frequency. Ninety farmers (30 x 3, at each elevation) were interviewed in 9 villages (3 x 3, villages at each elevation). Based on the information generated by the farmers through the questionnaire, the samples of different grass species were collected and their specimens were sent to Pakistan Forest Institute, Peshawar, Pakistan for botanical identification. Ten available rangeland grass species were selected for detailed study. Samples of grass species harvested at early bloom and mature stages of growth were chopped to 2 - 3 cm in length, dried in air and stored in polythene bags for further analysis.

Mineral composition of free rangeland 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 free rangeland grasses: Four mature local sheep of 2.5 years age (average body weight 40 kg) were purchased from the local livestock market and were drenched for internal parasites. The experiments for palatability measurement were conducted at Civil Veterinary Dispensary, “Deewana Baba” in District Bunair of Malakand Division. The sheep were adapted to the grass hay, trained in the experimental procedure by offering the test samples to them alone or in pairs daily. It took about five weeks 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 800g /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 (NRC, 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 1 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 within 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 10 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 the 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).

$$\text{ME (MJ/kg DM)} = 0.15 \text{ IVDMD\%}$$
$$\text{IVDMD\%} = 0.98 \text{ IVDMD\%} - 4.8$$

The average values for chemical composition, structural constituents, IVDMD and ME were integrated to develop a matrix of correlation (Steel *et al*., 1997).

Results and Discussion

The free grazing rangeland grasses included *Heteropogon contortus*, *Chrysopogon aucheri*, *Panicum antidotale*, *Dichanthiurn annulatum*, *Chrysopogon gryllus*, *Cymbopogon jwarancusa*, *Chrysopogon montanus*, *Themeda anathera*, *Aristida adscensionis* and *Cymbopogon schoenanthus.* The *Chrysopogon aucheri*, *Panicum antidotale*, *Cymbopogon jwarancusa*, *Cymbopogon schoenanthus* and *Aristida adscensionis* were commonly available at lower and middle elevation. The *Chrysopogon gryllus* was characteristically a high elevation grass. The *Dichanthiun annulatum, Heteropogon contortus* and *Themeda anathera* were available at all elevations. Among the free grazing rangeland grasses found mainly on rocky slopes and shallow sites included *Heteropogon contortus*, *Chrysopogon aucheri*, *Chrysopogon gryllus*, *Chrysopogon montanus*, *Themeda anathera* and *Cymbopogon jwarancusa* whereas, the grass species found on less rocky and less shallow sites included *Panicum antidotale*, *Dichanthium annulatum* and *Cymbopogon schoenanthus*. The results of present study were in line with the findings of Leede (1998) who reported that in the subtropical zone of Leganai range (Bunair) of Malakand division, the free grazing rangelands grasses include *Cymbopogon jwarancusa*, *Heteropogon contortus* and *Chrysopogon aucheri*, in Topdarra range of Bunair, *Chrysopogon*, *Themeda* and *Heteropogon* 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 content. On the other hand *Themeda anathera, Chrysopogon montanus*, *Chrysopogon aucheri* and *Heteropogon contortus* were commonly found on shallow soil hill slopes (Hussain & Durrani, 2007; Khan *et al*., 2007; Sultan *et al.*, 2007; Sultan *et al.*, 2008; Inam-ur-Rahim *et al.*, 2008).

Mineral composition of free rangeland grasses: The DM content and macro and micro mineral composition of free grazing rangeland grasses at early bloom and maturity are presented in Tables 1 and 2. The DM content in free grazing rangeland grasses at early bloom varied from 30.4% (*Themeda anathera*) to 36.4% (*Cymbopogon schoenanthus)* and the average was 33.1±0.69%. At mature stage, the DM content in these grasses varied from 39.9% (*Chrysopogon gryllus*) to 47.5% (*Cymbopogon aucheri*) and the mean

Table 1. Dry matter (DM) content and mineral composition of free grazing rangeland grasses at early bloom stage.

Grass name	DM %	Ca %	P %	K %	Mg %	Cu ppm	Zn ppm	Mn ppm	Co ppm
Heteropogon contortus	34.4	0.28	0.022	0.78	0.048	37.5	14.0	10.2	0.009
Chrysopogon aucheri	32.2	0.20	0.016	0.40	0.024	20.0	11.5	8.0	0.010
Panicum antidotale	30.6	0.30	0.056	0.63	0.066	20.0	18.5	1.1	0.052
Dichanthium annulatum	33.7	0.14	0.024	0.54	0.032	30.0	8.0	28.0	0.043
Chrysopogon gryllus	32.7	0.30	0.012	0.76	0.076	35.0	14.0	6.2	0.009
Cymbopogon jwarancusa	34.7	0.26	0.013	0.39	0.030	20.0	16.5	9.7	0.024
Chrysopogon montanus	31.8	0.14	0.026	0.59	0.015	15.0	11.5	8.2	0.031
Themeda anathera	30.4	0.26	0.041	0.58	0.042	12.5	10.0	12.3	0.029
Aristida adscensionis	33.7	0.36	0.024	1.62	0.070	20.0	32.0	11.0	0.012
Cymbopogon schoenanthus	36.4	0.38	0.013	0.56	0.036	17.5	11.0	6.5	0.011
Mean ± SE	33.1 ±0.69	0.26±0.022	0.025± 0.004	0.69± 0.113	0.044 ±0.006	22.75 ±2.671	14.70 ±2.065	10.12 ±1.770	0.023 ±0.003

Table 2. Dry matter (DM) content and mineral composition of free grazing rangeland grasses at maturity.

Grass name	DM %	Ca %	P %	K %	Mg %	Cu ppm	Zn ppm	Mn ppm	Co ppm
Heteropogon contortus	42.2	0.20	0.043	0.70	0.040	39.5	12.0	4.0	0.029
Chrysopogon aucheri	47.5	0.32	0.038	0.55	0.0.21	27.5	9.2	9.5	0.031
Panicum antidotale	39.9	0.46	0.056	0.68	0.054	32.5	7.3	10.0	0.052
Dichanthium annulatum	41.8	0.13	0.026	0.72	0.030	41.2	4.5	11.6	0.038
Chrysopogon gryllus	39.9	0.32	0.027	0.63	0.041	38.5	11.5	2.3	0.061
Cymbopogon jwarancusa	44.5	0.29	0.020	0.62	0.020	30.0	10.9	5.7	0.009
Chrysopogon montanus	46.8	0.14	0.019	0.41	0.010	14.2	9.4	3.5	0.017
Themeda anathera	45.9	0.23	0.028	0.40	0.031	30.0	7.5	4.5	0.016
Aristida adscensionis	44.6	0.45	0.024	1.63	0.008	21.5	13.8	7.6	0.012
Cymbopogon schoenanthus	42.9	0.49	0.032	0.48	0.022	23.0	3.5	2.7	0.023
Mean ± SE	43.6 ±1.03	0.30 ±0.049	0.031 ±0.006	0.68 ±0.108	0.028 ±0.004	29.8 ±2.962	8.96 ±2.071	6.14 ±1.034	0.029 ±0.005

was 43.6±1.03%. The Ca concentration in free grazing rangeland grasses at early bloom varied from 0.14% (*Dichanthiun annulatum*; *Chrysopogon montanus*) to 0.38% (*Cymbopogon schoenanthus)* and mean was 0.26±0.022%. The Ca concentration at maturity varied from 0.13% (*Dichanthiun annulatum*) to 0.49% (*Cymbopogon schoenanthus)* and the mean was 0.30±0.49%. The findings of present study revealed that Ca content in free rangeland 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 (Skerman & Riveros, 1990; Gohl, 1981). The Ca contents determined in the free range grasses supported the findings of K *et al*., (2006) who reported that Ca contents of arid pastures were slightly higher than the minimum recommended levels in the diets of ruminants (Hussain & Durrani, 2007; Khan *et al*., 2007; Sultan *et al.*, 2007; Sultan *et al.*, 2008; Inam-Ur-Rahim *et al.*, 2008).

Phosphorus concentration in free rangeland grasses at early bloom stage varied from 0.012% (*Chrysopogon gryllus*) to 0.056% (*Panicum antidotale*) and the mean was 0.025±0.004%. The P content at maturity varied from 0.019% (*Chrysopogon montanus)* to 0.056% (*Panicum antidotale)* and the mean was 0.31±0.006%. The P content increased with age in free rangeland 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 depresses 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 free grazing rangeland grasses at early bloom varied from 0.39% (*Cymbopogon jwarancusa*) to 1.62% (*Aristida adscensionis*) and the mean was 0.69±0.113%. The K concentration in these grasses at maturity varied from 0.40% (*Themeda anathera*) to 1.63% (*Aristida adscensionis*) and the mean was 0.68±0.108%. 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 (Hussain & Durrani, 2007; Khan *et al*., 2007; Sultan *et al.*, 2007; Sultan *et al.*, 2008; Inam-Ur-Rahim *et al.*, 2008).

Magnesium concentration in free grazing rangeland grasses at early bloom varied from 0.015% (*Chrysopogon montanus)* to 0.076% (*Chrysopogon gryllus) and the mean was 0.044*±0.006%. The Mg concentration at maturity varied from 0.008% (*Aristida adscensionis)* to 0.054 % (*Panicum antidotale*) and the mean was 0.028±0.004%. The present study showed that Mg concentration decreased with plant age in free grazing rangeland 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 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 cat-ions and soil pH (Skerman & Riveros, 1990).

The Cu content in free rangeland grasses at early bloom varied from 12.50ppm (*Themeda anathera*) to 37.50ppm (*Heteropogon contortus*) and the mean was 22.75±2.671ppm. The Cu concentration at maturity varied from 14.20 ppm (*Chrysopogon montanus*) to 41.20ppm (*Dichanthium annulatum*) and the mean was 29.80±2.96ppm. The cu concentration increased with age in free grazing range land grasses. Cu content in all grasses were higher than the livestock requirements 6-12ppm of diet DM (Anon. 1975). Minson (1990) reported that increasing Molybdenum 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 was in line with those of Gohl (1981) who reported decreased Cu concentration with age of the plant.

The Zn concentration in free grazing rangeland grasses at early bloom stage varied from 10ppm (*Themeda anathera*) to 32.00ppm (*Aristida adscensionis*) and the mean was 14.70±2.065ppm. The Zn concentration at maturity stage varied from 3.5ppm (*Cymbopogon schoenanthus*) to 13.8ppm (*Aristida adscensionis*) and the mean was 8.96±2.071ppm. The concentration of Zn in grasses varied from 7 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. 47ppm) and Zn deficiency rarely occur in ruminant fed such forages. 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 free grazing rangeland grasses at early bloom stage varied from 1.10ppm (*Panicum antidotale*) to 28.0 ppm (*Dichanthium annulatum)*) and the mean was 10.12±1.77ppm. The Mn concentration at maturity stage varied from 2.3 ppm (*Chrysopogon gryllus*) to 11.60ppm (*Dichanthium annulatum*) and the mean was 6.14±1.34ppm. The Mn content increased with age in free rangeland 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 0.009ppm (*Heteropogon contortus*) to 0.052ppm (*Panicum antidotale*) and the mean was 0.023±0.003ppm. The Co concentration at maturity stage varied from 0.009 ppm (*Cymbopogon jwarancusa*)) to 0.061ppm (*Chrysopogon gryllus*) and the mean was 0.029±0.005ppm. 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. 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 K had no effect on Co concentration (Minson, 1990).

Palatability of rangeland 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 10 free grazing rangeland grasses are presented in Table 3. The average PIR (grams consumed during 4 minutes per sheep) was the highest for *Hetropogon contortus* (53.80±15.82 g/4 minute) followed by *Chrysopogon aucheri* (51.5±12.5 g/4 minute), while the lowest PIR value was observed for *Cymbopogon schoenanthus* (35.8±12.16 g/4 minute). The RP value was the highest for *Dichanthium annulatum* (81.15±0.61%) followed by *Panicurn antidotale* (80.22±1.41%). The lowest RP value was observed for *Cymbopogon schoenanthus* (19.33±1.84%).

Among the free grazing rangeland grasses, *Cymbopogon jwarancusa* 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 it might decrease the relative preference of the grass 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=0.86) 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 present study revealed that although the PIR and RP 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 integrated.

Kenney & Black (1984) reported that when effects of taste and odor are removed, sheep prefer diet having faster intake rates. The IVDMD is positively correlated with both RP and PIR across all the grasses (r=0.31, 0.04). These results supported the findings of Provenza *et al*., (1996) who reported that lambs preferred food having higher CP content. The CP content had positive correlation with RP (r=0.02) but negative correlation with PIR (r= -0.23). The macro and micro minerals under study showed positive correlation with RP and PIR, except Ca which showed negative correlation with RP (*r*= -0.37) and PIR (*r*= -0.19) (Table 5). Other factors like fibrousness reduces intake rate because of the associated reduction in bite size to properly sever 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; Hussain & Durrani, 2007; Khan *et al*., 2007; Sultan *et al.,* 2007; Sultan *et al.,* 2008; Inam-Ur-Rahim *et al.,* 2008).

Table 3. Potential intake rate (PIR) and relative preference (RP) of free grazing rangeland grasses of Northern grasslands of Pakistan.

S. No.	Grass name	PIR (g/4 minute) ± SE*	(%) RP±SE**
1.	*Heteropogon contortus*	53.8±15.82 [a]	72.38±0.93 [b]
2.	*Chrysopogon aucheri*	51.5±12.50 [a]	55.03±0.84 [c]
3.	*Panicum antidotale*	48.8±16.92 [ab]	80.22±1.41 [a]
4.	*Dichanthium annulatum*	48.5±12.47 [ab]	81.15±0.61 [a]
5.	*Chrysopogon gryllus*	45.3±11.66 [ab]	71.20±0.68 [b]
6.	*Cymbopogon jwarancusa*	44.3±10.22 [ab]	28.50±0.53 [e]
7.	*Chrysopogon montanus*	42.5±11.35 [ab]	57.78±1.08 [c]
8.	*Themeda anathera*	41.8±8.42 [abc]	44.97±1.82 [d]
9.	*Aristida adscensionis*	40.5±10.69 [abc]	42.53±2.287 [d]
10.	*Cymbopogon schoenanthus*	35.8±12.16 [bc]	19.33±1.84 [f]

SE = Standard error
*Figures having different letters are significant (p<O.05) within the same forage grass.
*Each figure represent mean (± standard error of the mean) of 4 samples.
*Figures having different letters are significant (p<O.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. *In vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME) of free grazing rangeland grasses of Northern grasslands of Pakistan.

S. No	Early bloom			Maturity	
	Grass name	IVDMD %	MJ/kg DM	IVDMD %	MJ/kg DM
1.	*Heteropogon contortus*	48.6	6.40	37.3	4.77
2.	*Chrysopogon aucheri*	58.5	7.87	43.5	5.69
3.	*Panicum antidotale*	49.4	6.53	38.9	4.98
4.	*Dichanthium annulatum*	51.4	6.82	39.5	5.11
5.	*Chrysopogon gryllus*	62.5	8.45	53.9	7.20
6.	*Cymbopogon jwarancusa*	50.4	6.70	35.0	4.44
7.	*Chrysopogon montanus*	57.2	7.70	48.5	6.40
8.	*Themeda anathera*	68.1	10.96	51.5	6.86
9.	*Aristida adscensionis*	58.3	7.87	52.6	7.03
10.	*Cymbopogon schoenanthus*	48.7	6.44	38.9	4.98
Mean ± SE		55.3 ±1.86	7.57 ±0.25	44.0 ±2.11	5.86 ±0.29

Table 5. Correlation matrix among relative preference, potential intake rate, digestibility, macro and micro mineral content of free grazing rangeland grasses of Northern grasslands of Pakistan.

.	PIR	IVDMD	Ca	P	K	Mg	Cu	Zn	Mn	Co
RP %	+0.86	+0.31	-0.37	+0.40	+0.36	+0.25	+0.53	+0.12	+0.29	+0.46
PIR	-	+0.04	-0.19	+0.25	+0.18	+0.47	+0.31	+0.20	+0.15	+0.20
IVDMD	-	-	+0.007	+.012	+0.01	+0.26	+0.07	+0.16	-0.05	-0.19

***In vitro* dry matter digestibility (IVDMD) and metabolizable energy (ME) of grasses:** The IVDMD for free grazing rangeland grasses at early bloom stage varied from 48.6 (*Heteropogon contortus*) to 68.1% (*Themeda anathera*) and the mean was 55.3±1.86% (Table 4). The ME value at early bloom stage varied from 6.40 MJ/Kg DM (*Heteropogon* *contortus*) to 10.96 MJ/Kg DM (*Themeda anathera*) and mean was 7.57±0.25 MJ/Kg DM. The IVDMD value of free grazing rangeland grasses at maturity varied from 35.0% (*Cymbopogon jwarancusa*) to 53.9% (*Chrysopogon gryllus*) and the mean was 44.0±2.11% (Table 4). The derived ME value at maturity had a range of 4.44 MJ/Kg DM (*Cymbopogon jwarancusa*) to 7.20 MJ/Kg DM (*Chrysopogon gryllus*) with a mean of 5.86 ± 0.29 MJ/Kg DM. The IVDMD was positively correlated with Ca (r=0.007), P (r=0.12), K (r=0.01), Mg (r=0.26), Cu (r=0.07), and Zn (r=0.16), and negatively correlated with Mn (r= -0.05) and Co (r= -0.19). 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).

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