AN ABSTRACT OF THE THESIS OF

Abdul Wahid for the degree of Doctor of Philosophy in Rangeland Resources presented on August 29, 1990.

Title: Dietary Composition and Nutritional Status of Sheep and Goats Grazing Two Rangeland Types in Baluchistan, Pakistan.

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Abstract approved: ______________________
Douglas E. Johnson

The main objective of this research was to assess the nutritional status of sheep and goats grazing two rangeland types in Baluchistan, Pakistan. These types were Artemisia maritima/Haloxylon griffithii association represented by the Zarchi Field Station and Cymbopogon shoenanthus, found at the Tomagh Field Station. Seasonal above ground biomass production and variability in the quality of major plant species was determined at four phenological growth stages for two years. At the same time a relative palatability index of major plant species and preference of sheep and goats was also determined. The Analysis of Variance procedures (ANOVA) of Statistical Analysis System (SAS, 1985) were used to evaluate various null hypotheses.

Forage quality decreased with the advancement of phenological growth stages in all plants studied. On both study sites (Tomagh and Zarchi), spring forage samples were of higher quality than those of other seasons. Advance in season brought significant changes in the nutrient content

of plant species. Grasses were lower in crude protein concentration and higher in neutral detergent fiber (NDF) content than forbs and shrubs. Plant species were not statistically different in phosphorus concentration.

From March through October, sheep and goat diets varied in their botanical composition on both study sites. Grasses remained a major component of animal diets at Tomagh throughout the grazing seasons. However, sheep and goats consumed a higher percentage of shrubs with the passage of time while grazing Zarchi area. Across all the grazing seasons, the diets of both animal species were deficient in protein and phosphorus.

The lignin ratio technique was evaluated for its use in determining daily dry matter and apparent nutrient digestibility consumed by grazing animals. Highly variable digestion co-efficients of lignin (both positive and negative) were obtained by using sheep and goat rumen liquors. As much as 51.0% of forage lignin in samples was digested. Negative lignin digestion co-efficients were also obtained from forage samples. These ranged from -1.0% to -103.0%. Lignin biodegradation and/or complexing during *in vitro* digestion invalidated its use as an internal marker in digestion studies on these rangelands.

Dietary Composition and Nutritional Status of Sheep and Goats Grazing Two Rangeland Types in Baluchistan, Pakistan

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirement for the
degree of

Doctor of Philosophy

Completed August 29, 1990

Commencement June, 1991

APPROVED:

Redacted for Privacy

Professor of Rangeland Resources in charge of major

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Date thesis is presented August 29, 1990

Typed by researcher for Abdul Wahid

ACKNOWLEDGEMENTS

I would like to extent special gratitude to my friends and colleagues at Arid Zone Research Institute (AZRI), Pakistan Agriculture Research Council (PARC), Quetta, Pakistan. They are a fine group of good individuals. I must acknowledge the help and cooperation extended by Ahmed Gul, Javed Afzal, Bismillah Jan and the staff at both Tomagh and Zarchi research stations, during this study. I owe a debt of gratitude to my friend Mohammad Islam, who provided invaluable help in my laboratory analysis work. Laboratory assistants of AZRI laboratories were very cooperative and provided me complete help.

I feel highly obliged to Mukhtar Nadeem, Scientific Officer and Ayyaz Khan, Junior Scientific Officer of Animal Sciences Institute (ASI), National Agricultural Research Center (NARC), PARC, Islamabad, Pakistan. Their hospitality and cooperation in analyzing the plant and fecal samples in the animal nutrition laboratories of ASI were incredible.

I have had the honor and pleasure of being a graduate student in the Department of Rangeland Resources, where excellence in every aspect is a common mandate of both quality faculty and excellent group of graduate students. I would like to thank all faculty and graduate students of this department, who always provided me with both encouragement and full cooperation.

I have been very lucky to have an extremely outstanding graduate committee:

Dr. R. O. Crisman as Graduate School Representative has provided encouragement, valuable suggestions and a critical review of the manuscript.

Dr. D. R. Thomas has been very helpful with respect to experimental design and statistical analysis of data. His special interest in my program is appreciated.

Dr. M. Vavra, a wonderful guy, has provided not only encouragement, but very helpful suggestions in the planning of this study. His interest and inputs in the manuscript were excellent.

Dr. W. C. Krueger, a man of insight, is a credit to the Department of Rangeland Resources. His leadership reflects his national and international experience. I feel like his continuous inspiration and guidance filled the gaps in my professional personality.

Dr. D. E. Johnson, my major professor, is a unique personality. He is a credit to the Department of Rangeland Resources. His supervision and sincere guidance was very much appreciated. His enthusiastic and continuous support made it possible for me to complete a Ph.D. program in which I can have pride. He and his wife, Irene, have been helpful throughout all of the difficulties encountered during my studies. I wish to work with Douglas in future too.

These acknowledgments are incomplete if I do not mention the help and cooperation provided by my wife, Sughra. Her contributions to my Ph.D. program are beyond listing. She has helped both in the laboratory and on the computer. Without her support it would have been difficult for me to complete this program in the given time period. Finally, my very special thanks to our newly born, little son, Shaheer, who has been very patient with our insufficient attention.

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INTRODUCTION

About 70 percent of the geographical area of Pakistan is rangeland, i.e. 57.07 million hectares (Qureshi and Hunjra, 1969). These rangelands have been the main source of subsistence for native livestock. Little regard has been given to land planning or to range management until very recently. Local pastoralists continuously overgraze the ranges with little attention given to either the animals or the land. Consequently, rangelands suffer from overgrazing and carrying capacity has dropped to about 16.0 hectares arid/desert range per animal unit (Din, 1980). Today, these rangelands are supplying only about 15.0 percent of the annual livestock feed requirement (Gill et al., 1976). Deterioration in range condition continues and vegetative cover and species diversity is decreasing. The increasing human population has increased demand for animal origin protein and competition for grazing land. Currently Pakistanis consume approximately 16.0 g of animal protein rather than the recommended amount (about 30.0 g). This situation has placed much more pressure on the grazing areas of Pakistan. Improvement of pastoral ranges is recognized as necessary if starving livestock and the human population that depend on them are to be fed. Real and concentrated efforts have to be made for scientifically based range management planning; however, it must be based upon solid research to insure future success.

It is evident that our basic problem is to manage and improve the rangelands of Pakistan on scientific lines. However, successful range management and improvement requires knowledge of the forage calendar, nutritional value of range plant species (both qualitative and quantitative), and the cycle of nutritional requirements of the flocks in the region. Unfortunately, little research has been done on these subjects and this fundamental information is still lacking. This study generated some of this information by conducting research studies in two phases.

Phase I

The lignin ratio technique was evaluated for determining daily dry matter intake and digestibility of forage consumed by grazing animals. Based on the degree of lignin digestibility for different range plants at different phenological stages, correction factors were to be developed for adjusting the results of daily dry matter intake and its digestibility.

Phase II

The following parameters were estimated:

a) Seasonal forage production of two representative rangeland types of Baluchistan, Pakistan was measured.

b) Seasonal proximate nutrient content were determined for different seasons of the year by species.

c) Relative palatability and preference indices for principal range plants in selected areas were determined, enabling us to determine key plants and also nutrients available for grazing animals.

d) The above information was compiled to develop nutritional calendars for these representative rangelands.

e) Finally, a conceptual model was developed to improve and manage the rangelands of Baluchistan on scientific lines.

CHAPTER I

THE VALIDITY OF LIGNIN AS AN INTERNAL MARKER IN DIGESTION STUDIES ON RANGELANDS

INTRODUCTION

Non-carbohydrate components of plant tissues that resist digestion are usually lumped into the general category of crude lignin. Lignin is often assumed to be indigestible and recoverable in feces (Van Soest, 1982) and has been commonly used as an internal marker in digestion studies with ruminants. However, problems with incomplete recovery of this cell wall component still exist and many workers report lignin digestion. Most researchers conclude that changes occur in the lignin molecule with passage through the digestive tract of ruminants. They show that a large portion of the lignin consumed is converted to a soluble lignin-carbohydrate complex in the rumen, precipitated in the abomasum, and excreted in the feces of ruminants. Although many studies have been conducted, the mechanism of lignin digestion is still unknown. The character of lignin varies with plant species (Van Soest, 1982). Where the lignin ratio procedure would be used in digestion studies, some measure of apparent lignin digestibility would be necessary, particularly with immature forages. Thus, the main emphasis of this study was to evaluate sources of error in the lignin ratio method of determining the digestibility of forage consumed by grazing animals.

The objectives of this study were:

1. to determine the lignin content of several important range plants of Baluchistan at different stages of growth.
2. to determine lignin degradation rates for these species in sheep and goats ruminal fluid.
3. to study differences in lignin digestibility at different stages of growth in these range plants.
4. to examine variations in lignin digestibilities among sheep and goats.
5. to develop correction factors for adjusting fecal lignin values so that accurate estimates of apparent digestibility can be made.

LITERATURE REVIEW

Early research showed that lignin was not a totally inert part of animal diets; however, the composition of lignin remained obscure. Since then, the qualitative determination of lignin is basically empirical. Animal nutritionists have been concerned with the fate of lignin in the gastrointestinal tract of animals. A review of literature will establish a suitable foundation for the present study.

Lignin Assays and Discrepancies

Lignin is commonly measured by gravimetric methods. The lack of specific standards causes these methods to provide differing values upon analysis of the same materials. The 72% sulfuric acid detergent lignin (ADL) method measures cutin and maillard type browning as lignin while some of the true lignin will be destroyed (Georing and Van Soest, 1970). In theory permanganate lignin procedure overcomes some of the artifact lignin problems and should provide better lignin determinations over ADL. However, $KMnO_4$ lignin could contain tannins, pigments and/or proteins that resist solubilization in acid detergent but could be oxidized by permanganate treatment (Van Soest and Wine, 1968). Permanganate lignin values did not agree with the values determined by sulphuric acid method. Lignin concentration measured by the permanganate procedure were considerably lower than acid detergent lignin contents (Cymbaluk et al., 1973).

The acetyl bromide spectrophotometric lignin method (ABSL) possesses the sensitivity for detecting soluble lignin components. There was a negative correlation between the digestibility of ADL and ABSL methods of lignin determination (Fahey et al., 1979). However, the ABSL could not produce better results as compared to other gravimetric methods (Muntifering, 1982). The use of an appropriate lignin assay becomes critical because the lignin can be either very resistant to chemical treatment or very susceptible to degradation by the same treatment (Fahey et al., 1979; Muntifering et al., 1981a).

Lignin Digestion by the Ruminants

The possible digestion of lignin by animals is the most serious objection to its use as a marker in digestion studies. Hale et al. (1940) reported lignin digestibility varying from -5.1 to 23.7%. Use of lignin as a marker should be viewed with caution as incomplete recovery results in underestimation of a nutrient digestibility (Fahey and Jung, 1983). Dry matter digestibility values calculated on the basic assumption that lignin was indigestible, were about 30% underestimated (Wallace and Van Dyne, 1970). The digestion co-efficients for other nutrients were also below the actual measurements (Smith et al., 1965). Where the lignin ratio procedure was used, some measures of incomplete lignin recovery were required (Harris, 1968 and Wallace and Van Dyne, 1970). Good results could be obtained by correcting fecal lignin values for apparent lignin digestibility (Wallace and Van Dyne, 1970).

An ideal marker must be non absorbable and it must not affect or be affected by the digestion process (Fahey and Jung, 1983). The status of lignin as a valid marker is still questionable since remarkably high digestibility co-efficients for lignin have been reported by various workers. The digestion co-efficients of lignin were found to be measurable and variable ranging from 3.0 to 12.4% for different plant samples (Sullivan, 1955). Smith et al. (1956) reported positive lignin digestibilities by sheep and mule deer for most of their trials. The values varied from 9.3 to 42.1%. The low recovery of lignin seriously limited its use as an indicator by Elam and Davis (1961). Digestion experiments using beef steers indicated that an average of 12.9% of the lignin fed in the ration was digested. Individual co-efficients of lignin digestibility varied from 11.1 to 14.6% among the animals. Wallace and Van Dyne (1970) collected forage grazed by esophageal-fistulated steers in June, July, September and December. The grazed forage later was fed to sheep in conventional digestion trials. Apparent lignin digestion was 46.0, 42.0, 29.0 and 4.0% respectively.

The partial and variable digestion co-efficients of lignin invalidated it as reference substance for estimating the digestibility of other nutrients (Sullivan 1955). Porter and Singleton (1971) found that as much as 10.2% of the dietary lignin disappeared from the alimentary tract of sheep. Fahey et al. (1979) criticized the use of lignin as an inert marker in digestion studies. Both low quality and high quality roughages were fed to lambs, and except for wheat straw, an average of 24.6% acid detergent lignin (ADL) digestibility was observed. Several other researchers noticed that varying amount of lignin might be degraded in the ruminant's digestive tract. Among those are Crampton (1939), Louw (1941), McAnally (1942), Davis et al. (1947), Bondi and Meyer (1948), Pazur and Delong (1948), Ely et al. (1953), Johnson et al. (1964), Allinson and Osbourn (1970), Minson (1971) and Grant et al. (1974).

However, Crampton and Maynard (1938), Ellis et al. (1946), Forbes et al. (1946), Gray (1948), Swift et al. (1947), Forbes and Garrigus (1948), and Kane et al. (1950) concluded that lignin was indigestible. Balch (1957) suggested lignin as a promising marker for obtaining digestibility coefficient for the reticulo-rumen of cows.

High fecal lignin recoveries add another kind of discrepancy in the results obtained by the use of lignin as an internal marker. Forbes and Garrigus (1950) reported higher lignin recoveries averaging 105% for steers and 114% for wethers. Results presented by Elam and Davis (1961) also indicated about 103% lignin concentration in steers feces. Muntifering et al. (1981b) fed kenhy tall fescue to lambs and a 101% fecal recovery of ADL was obtained. They suggested that minimal digestibilities of lignin could be corrected to 100% assuming all lignin digestion occurs in the rumen. Allinson and Osbourn (1970) determined consistent negative acid detergent lignin digestibilities for sanfoin using mature wether sheep. The inconsistent positive and negative variations of the ADL digestibility for the regrowth and primary cuts of rye grasses were considered error of the determination due to the method used. Fahey et al. (1979, 1980) noted no particular patterns of lignin digestion by sheep. Mean negative ADL digestibilities for wheat straw and oak dust were 10.7% and 24.3% respectively.

The chemical evidences suggest that degradation of lignin takes place mainly in the stomach of ruminants (Porter and Singleton, 1971). The fecal lignin is attacked more readily by strong acids and weak alkalies than lignin separated from the grasses, an indication that lignin is modified in the digestive tract of sheep (Sullivan, 1955). A demethoxylation process in the stomach of sheep resulted in considerably low methoxyl content of fecal lignin (Bondi and Meyer, 1948; Porter and Singleton,1971), a 19.2% and 33.5% reduction resulted in the lignin of hay and straw diets respectively. Fecal lignin contained 16.0% less methoxyl content as compared to feed. It was suspected that occurrence of biological degradation of lignin was a result of rumen microflora (Porter and Singleton,1971). However, Csonka et al. (1929) claimed that demethoxylation of lignin could be undertaken by some agents other than bacteria, possibly an enzyme present in the gastric juice of the animals. Various workers like Csonka et al. (1929), Phillips et al. (1929), and Pazur and Delong (1948) observed higher excretions of hippuric acid related to higher amounts of lignin in the diet. It was believed lignin metabolism took place in the animal body (Fahey and Jung, 1983). Richards and Reid (1952) later discovered some of the digested methoxyl did not belong to lignin because methoxy groups do occur with hemicellulose and protein molecules (Van Soest, 1982). The relationship among anaerobic gastrointestinal tract microflora and lignin degradation has not been established very well (Fahey and Jung, 1983). Organic matter digestion in the alimentary tract of most animals is an anaerobic process. Anaerobic microbes have been known to degrade a variety of soluble aromatic compounds but not natural lignins (Bellam et al., 1979; Zeikus, 1980). Generally, it was conceived that anaerobic bacteria were not able to utilize lignin (Bellamy, 1974). However, Crawford and Crawford (1980) reported aerobic degradation of both simple phenolic monomers and lignin by fungi and bacteria in the soil. Akin (1976) discovered a filamentous microbe that attached sclerenchyma (a lignified tissue) in the leaf blades of the digesta removed from a cannulated steer, implying that attack on lignocellulose occurred under anaerobic conditions. Akin (1980) further studied the role of this filamentous microbe in the degradation of lignin. This facultative bacterium was isolated from rumen fluid and when grown under optimal conditions of pH (7.4 to 8.0) and temperature (39.0° C) was capable of degrading intact, lignified tissue. This demonstrated a unique role of this microbe. Although degradation of tissue was not extensive, pretreatment with this bacterium before digestion with rumen microflora disrupted unlignified and some lignified tissues and cell wall were more readily available to rumen microorganisms (Akin, 1980).

Lignin may undergo changes during the mastication and insalivation process (Heinemann and Evans, 1966; Conner et al.,1963) and could further enhance its degradation in the rumen. A large proportion of lignin consumed is converted to a soluble lignin-carbohydrate complex through the action of rumen microorganisms. These complexes were polymeric in nature (Gaillard and Richards, 1975). When lignin carbohydrate complexes were subjected to mild alkaline conditions, the lignin was degraded to lower molecular weight phenolic compounds (Morrison, 1974). Two of these phenolic degradation products ferulic acid and para-coumaric acid act as cross linkages between lignin and cell wall carbohydrates (Hartley, 1972). Most of the dissolved complexes precipitated in the abomasum and were present in the feces (Neilson and Richard, 1978).

Fahey et al. (1980) postulated that lignin and other plant phenolic compounds are degraded as they pass through the gastrointestinal tract. There could be six common lignin degradation products: p-coumaric acid, ferulic acid, vanillin, acetovanillone, p-hydroxybenzaldehyde and p-hydroxyacetophenone. These monomers decrease in concentration with passage through digestive tract sheep (Fahey et al., 1980). Low recoveries of p-coumaric acid, ferulic acid and vanillin are usual after fermentation and digestion by sheep (Jung and Fahey, 1983a and Fahey et al., 1980). There are several potential explanations for the apparent digestibilities of these phenolic monomers. In the case of positive digestion coefficients, phenolic acid monomers may be utilized as a source of energy by rumen microbes or released as soluble phenolic glycosides (Jung et al., 1983b). The possibility of metabolism of these monomers to non-aromatic products should be considered. The aromatic amino acid, phenylalanine and tyrosine, are catabolized to fumerate and acetate by the mammalian liver (Rodwell, 1979), suggesting that the aromatic ring of the phenolic monomers may be susceptible to oxidative cleavage by ruminants. Products such as fumerate and acetate can obviously be utilized as a source of energy (Jung et al., 1983b). Fahey et al. (1980) concluded that if these phenolics were the structural monomers of the lignin molecule, the apparent digestibility of lignin might be related to their disappearance.

In case of negative digestibilities, the bonding of phenolic monomers to the cell wall may be weakened by the fermentation facilitating the extraction of previously unextractable phenolic compounds (Jung et al., 1983a). It was further hypothesized that large negative digestibilities for certain monomers occurred due to increased extractable material by the action of digestive processes. It relates to no utilization of phenolic monomers by rumen bacteria as energy source and for the same reason lignin cannot be utilized (Jung et al., 1983a). Fahey et al. (1980) related the high negative lignin digestibilities to free phenolic monomers which were capable of binding to low molecular weight materials such as digestive end products of carbohydrates or nitrogenous compounds and were measured gravimetrically as lignin in fecal residues.

Fate of Lignin Across Fermentation Intervals

Allinson and Osbourn (1970) determined the changes occurring in the nature of lignin in various plant samples through 48 h *in vitro* fermentation with rumen liquor, and 48 h *in vitro* fermentation followed by another 48 h acid pepsin digestion. The spectras of *in vivo* residues and respective feed materials were different at 250 and 300 mu, whereas 350 mu peaks remained unchanged. Based on the differences they concluded that some of the simple non conjugated phenolic units in the lignin fraction were altered and conjugated phenols were not affected in the rumen. The spectrum obtained after the rumen liquor fermentation alone was closer to *in vivo* results. The spectrum obtained from residues of rumen liquor fermentation followed by acid pepsin digestion was similar to that obtained from fecal lignin material. The ADL estimates for two stage *in vitro* digestion and corresponding fecal samples were 147% and 176%, respectively. Following the *in vitro* 48 h digestion period alone the ADL content of the residue (5.9 +/- 0.24%) were very close to the original forage ADL value (6. 2 +/- 0.1%). This suggested a post ruminal addition of artifact lignin in the animal and was possibly an indigestible condensation product of some other plant fractions.

Cymbaluk et al. (1973) incubated maize stalk tissues in the rumen of a steer for 4.5, 9, 18 and 36 h. There had been a marked decrease in the amount of lignin extractable with dimethylformamide (DMF-lignin) after the first 4.5 h of incubation. Despite a constant digestion from 4.5 to 36 h, the DMF-lignin tended to rise slightly during this period against the expectation if the negative relationship existed. A decrease in the concentration of the aromatic aldehydes during the first 4.5 h of incubation and increase in the concentration of the aromatic acids after 18 h of incubation in the rumen led to the conclusion that changes in the composition of DMF-lignin had happened.

Jung and Fahey (1983a) observed the recoveries of phenolic monomers after 48 h of fermentation with rumen fluid of sheep. Rumen microorganisms were capable of substantial metabolism of phenolic monomers. Recoveries were exceedingly low for p-coumaric acid, ferulic acid , p-hydroxybenzoic acid, p-hydroxybenzaldehyde, syringic acid, syringaldehyde and vanillin. The presence of several identified compounds in the fermentation residues suggested extensive microbial metabolism of phenolic monomers.

Forage Type and Lignin Degradation

Unlike most other biopolymers, lignin is not a well described compound with systematically repeated bonds or units. A three dimensional lignin molecule is highly branched, heterogenous and made up of phenyl-propanoid units which are inter linked through numerous different bonds (Harvey, 1986). The phenylpropanoid precursors, phenylalanine and tyrosine, give rise to the three monomers that account for most of the lignin molecule: p-coumaryl, coniferyl and sinapyl alcohols (Harkin, 1973). Each of these alcohols contains a phenolic group (Harvey, 1986). Lignins from various sources differ mainly in the proportion of the three constituent alcohols. Gymnosperm lignins are comprised mainly of coniferyl alcohols, whereas angiosperm lignins comprise equal amounts of coniferyl and sinapyl alcohols. Gross lignins contain a high proportion of p-coumaryl alcohol in addition to coniferyl and sinapyl alcohols (Harkin, 1973; Harvey, 1986). The highly condensed polymer of cinnamyl alcohols possessing high molecular weight is referred to as "core" lignin (Gordon and

Neudoerffer, 1973; Griseback, 1981). The lignin core appears to be linked to the structural carbohydrates of the plant cell wall via carbohydrate esters of ferulic acid (Hartley, 1973) and generally has two or more covalent linkages between phenolic monomer units within the lignin molecule (Jung, 1989). Non-core lignins are comprised of p-coumaric acid and ferulic acid components (Gordon, 1975), which may act as cross linkage between lignin and structural carbohydrates, the non-core lignin monomers usually have only one covalent linkage of the phenolic compounds, usually a cinnamic acid, to either core lignin or hemicellulose. Alkali extraction of plant lignin yields p-coumaric, ferulic, diferulic , p-hydroxybenzoic acids and vanillin (Higuchi et al., 1976a; Hartley, 1972; Hartley and Jones, 1977). Nitrobenzene oxidation of grass lignin yields vanillin, syringaldehyde and p-hydroxybenzaldehyde (Higuchi et al., 1976a, 1976b).

Lignin contents of forages are quite variable, but a few patterns emerge (Allinson and Osbourn, 1970; Lindgren et al., 1980). The concentration of core lignin is greater in stem than leaf tissue (Morrison, 1980). Grasses are lower in core lignin levels than legumes (Mowat et al., 1969; Allinson and Osbourn, 1970; Van Soest, 1975). Tropical grasses possess higher lignin content than do temperate grass species (Van Soest, 1975, 1980). Lignin is the largest source of phenolics in the plant cell wall (Jung and Fahey, 1983b). The most concentrated phenolics in the forages are ferulic acid and p-coumaric acid (Hartley et al., 1976). The legume and grass differ in their phenolic and carbohydrate composition (Jung and Fahey, 1984). Ester-linked phenolics are routinely found in grasses (Hartley and Jones, 1977), while some workers were not able to find these phenolics in legumes (Hartley and Jones, 1977; Hartley and Haverkamp, 1984; Buxton and Fritz, 1985). The composition of lignin in various feeds varies greatly and is not related to amount of lignin present. Chemical and/or physical characteristics of lignin affect its degradation and need to be identified (Reeves, 1985b).

Apparent lignin digestibilities varied among different roughage sources (Fahey et al., 1979; Fahey et al., 1980; Muntifering et al., 1981a; Jung et al. 1983a; Jung et al., 1983b). It is plausible that lignin of one roughage is more easily degraded than lignin from other roughage sources (Fahey et al., 1980). There is considerable uncertainty about lignin chemistry and the nature of bonding that happens between lignin chemistry and the carbohydrate in plant cell wall (Morrison, 1974). This uncertainty could coincide with the difference in the lignin digestibility of various roughages. Ferulic acid in the legume was more digestible than ferulic acid in the grasses (Jung et al., 1983b). The digestibility of alkali-labile p-coumaric acid and ferulic acid was greater with lucerne diets than with tall fescue diets. Phenolic monomers differed in their digestibilities among forages and sections of gastrointestinal tract in the ruminants (Jung et al. 1983a, b; Jung and Fahey, 1984). Alkali labile phenolics represent relatively loosely bound compounds either to the cell wall or other cell constituents, while nitrobenzene oxidation products are regarded as very tightly bound material (Jung et al., 1983a). However, these monomers could reside in different structural environments within the cell wall. In the grasses ferulic acid was bound to cell wall polysaccharides in both unlignified cell walls and lignified cell walls. The p-coumaric acid served as the cross linking agents between lignin and structural carbohydrates (Burritt et al., 1984). If these phenolic monomers are the bricks of the lignin molecule, it appears that the apparent digestibility of lignin might be due to the loss of the phenolic monomers (Fahey et al., 1980). Jung et al. (1983b) reported the apparent digestion of lignin phenolics and their apparent absorption by ruminants resulted because of numerous interactions, both positive and negative between these compounds and the biological processes of ruminant digestion and absorption.

According to Jung et al. (1983a) apparent lignin digestion coefficients did not differ among forages. Forages differed in content of alkali-labile monomers and most compounds were found in both the cell soluble and cell walls. A significant proportion of a plant's phenolic monomer content could be the part of the cell solubles. The apparent digestion of phenolic monomers and lignin represents solubilization rather true digestion in the sections of gastrointestinal tract (Jung et al., 1983a), therefore it becomes difficult to differentiate between these groups and confusing to describe and interpret the results (Jung and Fahey, 1983a).

Lignin and Plant Growth

The concentration of core lignin increased in the forages with physiological maturity for both leaf and stem tissue (Morrison, 1980). The younger leaf blades contained more ferulic acid and p-coumaric acids than the older blades (Hartley and Jones, 1977). The ratio of guaicyl to syringyl monomeric units decreased with maturity in total herbage and the stem fraction (Jung et al., 1983b; Buxton and Fritz, 1985). Immature and mature lucerne hays did not differ significantly in their content of phenolic monomers. However, mature tall fescue hay had higher levels of p-coumaric acid, ferulic acid and p-hydroxybenzaldehyde than did immature tall fescue hay (Jung et al., 1983b).

Low apparent digestibility of lignin and increased lignin content were associated with advancing plant maturity (Wallace and Van Dyne, 1970; Jung and Fahey, 1983b). Results obtained by Allinson and Osbourn (1970) indicated negative lignin digestibilities for the regrowth and primary cuts of ryegrass. In good quality roughages like perennial ryegrass, the possibility exists that low molecular weight phenols originated in vacuoles of the plant polymerize under low pH conditions present throughout various sections of the alimentary canal of ruminants. Consequently, formation of phlobaphens appears as lignin artifact and causes a higher recovery of lignin in the feces. Fahey et al. (1979) and Jung, et al. (1983b) reported positive lignin digestibilities on overall digestive tract basis, while negative digestion coefficients for lignin regardless of the diet were noted in the small intestine only.

Recent Understanding of Lignin Biodegradation

Studies on the lignolytic fungi, so called "white-rot" fungi, led to the discovery of ligninase (Harvey, 1986). As summarized by Harvey (1986), ligninase was considered as an extracellular enzyme in the process of lignin biodegradation by *Phanerochaete chrysosporium*. Ligninase required H_2O_2 (hydrogen peroxide) for catalytic activity and was described as an H_2O_2-dependent oxygenase. Later, ligninase was recognized as a peroxidase, one of the same family of enzymes involved in lignin biosynthesis. Recently, the oxidation of lignin by ligninase with verateryl alcohol as a mediator has been suggested. Verateryl alcohol radical cations are generated by ligninase and mediate the oxidation of lignin by functioning as one-electron oxidant.

METHODS

Sample Collection

Plant sample collection was done on two rangeland types of Baluchistan, Pakistan between April, 1988 and September, 1988. Samples of commonly growing plants, two shrubs, two forbs, and two grasses were collected during the second week of April, last week of May or first week of June and first or second week of July. These sampling dates represented sequential phenological growth stages of the plants.

Sample preparations were done in the laboratories of Arid Zone Research Institute, Pakistan Agricultural Research Council, Brewery Road Quetta, Pakistan. Samples were oven dried at 55.0° C and were ground to pass a 1.0 mm screen using a wiley mill. These samples were shipped to the Department of Rangeland Resources Oregon State University, Corvallis, for further analysis. We were required by U.S. government regulations to treat all plant samples with 10.0% formalin prior to shipping. These treated samples were sealed in air tight plastic sacks and were shipped in air tight containers. Later plant samples were washed with ordinary tap water to remove formalin and were oven dried at 55·0° C. Researchers in the Department of Agricultural Chemistry, Oregon State University were contacted to inquire into the potential effect of formalin upon lignin digestibility. They did not suspect any effect by formalin on lignin or any other structural carbohydrates. However, a study has been planned to verify the effect of formalin on lignin and other structural carbohydrates.

Lignin Determinations

All laboratory analysis was done at the Department of Rangeland Resources, Oregon State University, Corvallis. Samples of each plant species at three phenological growth stages were analyzed for lignin content before and after *in vitro* digestibilities. Standard procedures described by Georing and Van Soest, (1970) and Waldern, (1971) were followed for acid detergent fiber (ADF) and lignin determinations. The ADF was used as a preparatory step for lignin determination. All samples were analyzed in duplicate.

Various assays have been applied for the determination of lignin. The lack of a specific standard causes these methods to provide differing values upon analyses of the same materials. In this study lignin was determined by permanganate method. Advantages of this method over 72-percent sulphuric acid method include a shorter procedure for lignin per se. The lignin reagents are much less corrosive and require no standardization. Lignin values are not subject to some inferences (cutin, soluble lignin, silanol water) which affect 72-percent sulphuric acid lignin. Values are less affected by heat damage artifacts and closer to true lignin content (Goering and Van Soest, 1970).

In vitro Digestibilities

All *in vitro* digestibilities were assayed according to the methods of Georing and Van Soest (1970). Fermentations were conducted in 100 ml beakers; 0.75 g of each oven dried plant sample, 30 ml McDougall's buffer and 18 ml inoculum were used.

In vitro digestion was completed in two separate lots. Lot separation was based on the randomly picked animal species (sheep or goat) as inoculum source. A goat was sacrificed to obtain rumen fluid for the first lot of *in vitro* digestibilities. Each sample of each of two shrubs, two forbs and two grasses at three phenological growth stages (vegetative, bloom and mature) was incubated in duplicate for 12, 24, 48 and 72 h. Within the lot a complete randomization in term of digestion time and kind of plant sample fermented took place. An alfalfa standard was included in the lot to check the procedures. After each fermentation period, samples were kept frozen until the residue of each digested sample was analyzed for lignin content. The lignin value of the digested sample was empirically adjusted for the original sample. The lignin digestibility was calculated by difference between the lignin values of digested and undigested plant sample. For the second lot, rumen liquor was obtained by killing a sheep and all above described procedures were repeated. Sheep and goats were fed alfalfa hay for a minimum of 10 days as an adaptation period before use.

Statistical Analyses

The analysis of variance procedures of the Statistical Analysis System (SAS, 1985) was used for response variable (lignin digestibility) to determine relationship among the three plant types (shrub, forbs, grasses); plant species within plant type; growth stages; digestion times, the two animal species (sheep and goat) and their interactions. Means were separated by protected LSD at an alpha of 0.05 level.

The interactions among most of the factors were extremely high and to get better understanding about the complexity of the interactions the data were analyzed on individual animal species basis. The model included plant types, plant species (plant type), growth stages, and digestion times. The 4-way interactions were used as an error term to test the significance. The interactions were still very complex in nature and the data were further analyzed for individual plant type separately within each animal species (sheep, goats). The model used was lignin digestibility as influenced by plant species, plant phenological growth stages and *in vitro* digestion times. The 3-way interactions were used as the error term.

RESULT AND DISCUSSION

Animal Species

Biological degradation of lignin occurs in the stomach of ruminants. *In vitro* digestion of plant material at 12 h, 24 h, 48 h, and 72 h intervals registered certain patterns in term of lignin digestibilities. Lignin biodegradation increased at longer digestion intervals with certain exceptions. Mean lignin coefficients of all plant types were positive at 72 h fermentation regardless of growth stage and animal species. Interactions between digestion times and plant phenological growth stage were highly significant in both sheep and goats. The relative p-values for all statistical significances are given in Table 4.

In goats, 12 h fermentation always gave negative digestion values (Figures 1 - 3). At vegetative stage of all plant types, a sharp increase in the negative digestibilities took place at 24 h fermentation (Figures 1 - 3). However, positive values with upward trend were obtained at 48 h and 72 h fermentations for forbs and grasses; shrubs possessed negative lignin digestion at 48 h but still lesser than both 12 h and 24 h fermentations. There was a positive linear relationship among lignin digestibilities and digestion times for the other two plant growth stages (bloom and mature). Forbs and grasses had similar lignin digestibility. Maximum lignin digestibility

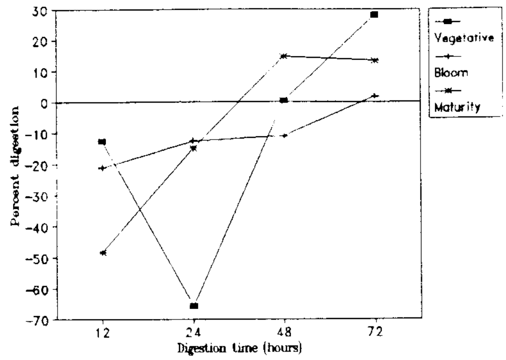

Figure 1. Lignin digestibility in grasses by goats.

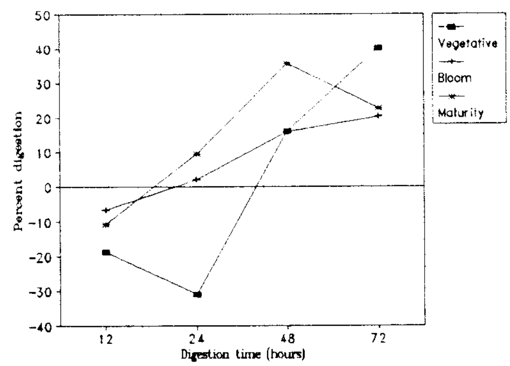

Figure 2. Lignin digestibility in forbs by goats.

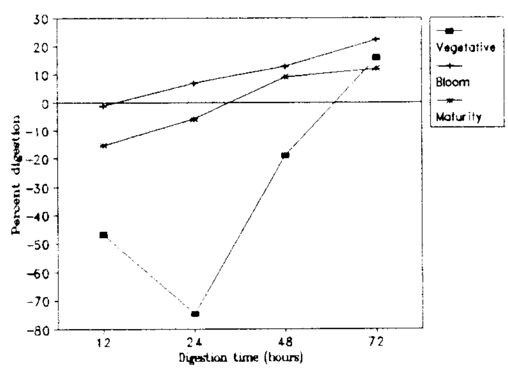

Figure 3. Lignin digestibility in shrubs by goats.

was observed at 72 h fermentation with digestion values of mature and bloom stages in descending order (Figures 1 and 3). The mature stage had positive and greater lignin digestion coefficients associated with it than the other two growth stages of forbs at 24 h and 48 h and of grasses at 48 h digestion across the fermentation interval. Shrubs exhibited a different pattern of lignin digestion from forbs and grasses. Figure 3 indicates that the data line for bloom stage takes top position and the vegetative stage holds bottom position on the graph except at 72 h fermentation.

With sheep rumen liquor, overall lignin digestion improved with long digestion times (Figures 4, 5 and 6). Highest lignin digestion coefficients were obtained at 72 h fermentation for forbs and grasses at vegetative growth stage and for bloom stage of shrubs (Figures 4 - 6). Forbs and grasses digested in sheep rumen had similar patterns to goats in their lignin digestibility curves but with different digestion levels. Within forbs and grasses lignin degradation was always greater at vegetative growth than bloom. Mature lignin was digested more than in the other two growth stages at 12 h and 48 h fermentation in forbs and only at 48 h in grasses. Lignin in forbs was digested positively across all fermentation times, while grasses had negative digestion values at 12 h fermentation for their bloom and maturity stages. Lignin of the shrubs at bloom

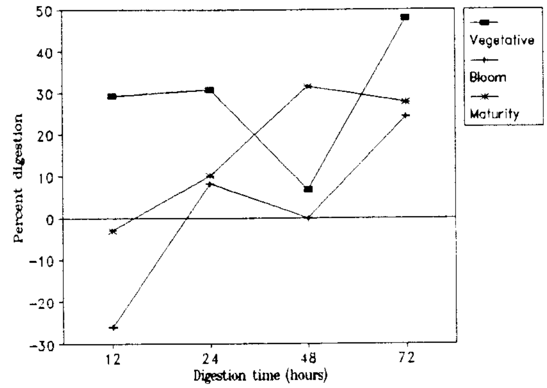

Figure 4. Lignin digestibility in grasses by sheep.

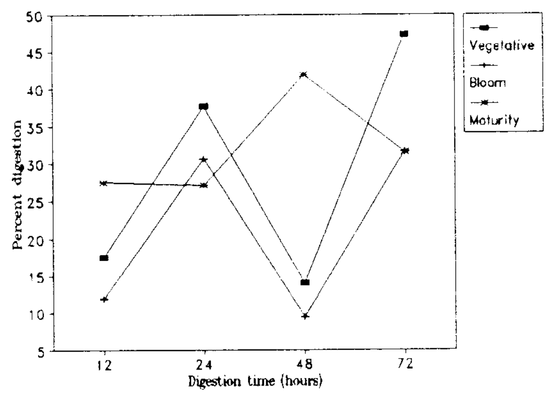

Figure 5. Lignin digestibility in forbs by sheep.

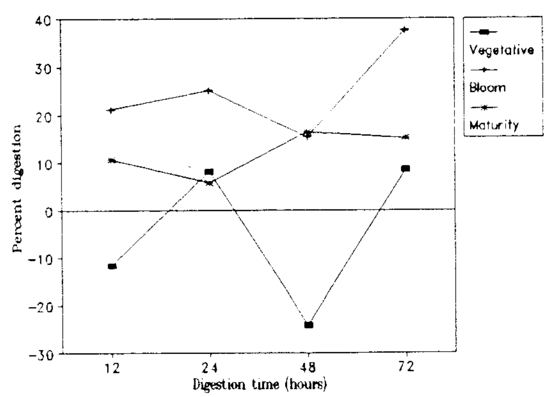

Figure 6. Lignin digestibility in shrubs by sheep.

stage was digested to a greater extent and its digestibility curve across all four digestion periods stayed higher than the other two curves (Figure 6). Negative digestibilities were mainly associated with vegetative stage at 12 h and 48 h fermentation. Mature lignin curve was about in the middle of bloom and vegetative data lines (Figure 6).

Lignin undergoes changes and its degradation takes place mainly in the rumen. The complexity of this phenomenon indicates involvement and interactions between various factors including animal species, kind of forage being consumed by animal species, the nature of plant material and its retention time in the alimentary tract of the animal. Organic matter digestion in the alimentary tract oi ruminants is an anaerobic process. The relationship among anaerobic gastrointestinal tract microflora and lignin degradation is not known (Fahey and Jung, 1983). Generally, it is believed that anaerobic bacteria are not able to utilize lignin (Bellamy, 1974). Gaillard and Richard (1975) reported that a large proportion of consumed lignin is converted to soluble lignin-carbohydrate complexes. In this study, high negative lignin digestibilities, particularly at 12 h and 24 h fermentation by goat rumen liquor and in some cases of fermentation with sheep rumen fluid, indicated the formation of lignin-carbohydrate complex mainly during the first 24 h of digestion. Lignin and other plant phenolic complexes can be degraded by the action of rumen microorganisms (Fahey et al., 1980. Bonding between lower molecular weight phenolic compounds (Morrison, 1974) and nitrogenous fragments occurred and has been measured as artifact lignin (Fahey et al., 1980). The water wasting of formalin treated plant material resulted in loss of cell soluble contents. Dry matter digestibilities were less than 10.0% on average at 12 h fermentation and were <20.0% on average at 24 h fermentation, because rumen microbes were mainly dealing with structural carbohydrates as substrate. High positive lignin digestion values by sheep particularly during the first 24 h fermentation strongly indicated the lignin degradation by microorganisms in the rumen. Their digestibilities could be attributed to the filamentous microbe reported by Akin (1980), which was isolated from steer rumen fluid and was capable of degrading intact lignified tissue. In his studies, pretreatment with this microbe disrupted unlignified and some lignified tissues and made the cell walls readily available to rumen microorganisms (Akin, 1980). High negative lignin digestion values by goats contrary to high positive values by sheep during the first 24 h fermentation supported the microbial degradation of lignin. Dry matter digestibilities were relatively higher in goats during the first 24 h of in vitro digestion. It indicated a faster dilution rate, which could have effectively eliminated (Van Soest et al., 1986) the slow growing and low in number filamentous microbes capable of lignin degradation (Akin, 1980). This could explain the sudden increase in negative lignin digestibilities associated with vegetative plant growth and 24 h digestion by goat rumen fluid. Immature lignification of young plant tissues favored the faster dilution rate and its subsequent conversion into lignin-carbohydrate complexes. In sheep a sudden decrease in lignin digestion rate at 48 h digestion time indicated that the unfavorable environment for the particular microbe took place much later and at a slower rate. This could account for the difference in lignin digestibilities among sheep and goats. These differences could be based upon the kind of fiber digesting microbes (Van Soest et al., 1986).

In both sheep and goats, after the sudden changes the lignin digestibilities improved at the following fermentation period and a normal linear relationship between digestion times and lignin digestibilities was regained relative to the shorter digestion periods. Subsequently, highest high lignin digestion coefficients were obtained at 72 h fermentation regardless of animal species and growth stages. It appears that lignin degrading microbes could adapt to the unfavorable environment within 24 h. Lignin degradation may be achieved by more than one kind of rumen microbe. Fungi appear to possess a full complement of enzymes (Orpin, 1981). Bauchop (1981) reported the attachment of rumen fungi to lignified vascular tissues. Fungi have been reported to degrade extensive amounts of sclerenchyma tissue (Akin, 1983) This fungi can attack the carbohydrate fraction in certain lignocelluloses containing dimethoxyl phenolic units that the rumen bacteria cannot readily degrade (Akin and Rigsby, 1985). The fungi can degrade lignin by the enzymatic activity of ligninase (Harvey, 1986). The results of this study indicate the presence of rumen lignolytic fungi. It is also plausible that the activity of ligninase is enhanced by co-culturing with facultative bacterium (Akin, 1980), as is the case with other fungal enzymes (Bauchop and Mountfort, 1981).

The other variations and inconsistencies in lignin digestibilities noted across all four fermentation periods and plant growth stages indicate the different natures of plant lignins.

Plant Types and Plant Species

The composition of lignin in various feeds varies greatly and is not related to amount of lignin present (Reeves, 1985). The differences in lignin digestibilities among the plant types (grasses, forbs and shrubs) and species were significant in both sheep and goats.

Apparent lignin digestibilities of all plant types were quite variable and unpredictable by both animal species. The results indicate that lignin from various sources differs in its chemical and/or physical characteristics. Gymnosperm lignins are comprised mainly of coniferyl alcohol, whereas angiosperm lignins comprise equal amounts of coniferyl and sinapyl alcohols. Grass lignins contain a high proportion of p-coumaryl alcohol in addition to coniferyl and sinapyl alcohols (Harkins, 1973; Harvey, 1986). The chemical and physical properties of lignin affect its microbial degradation and need to be identified (Reeves, 1985). It is plausible that lignin of one roughage is more easily degraded than the lignin from other roughage sources (Fahey et al. 1980).

Plant species within similar plant type (grasses, forbs, shrubs) could differ in their properties of lignification and lignin biodegradation. Plant species (plant types) were highly significant in their differences; however, plant species X growth stage interactions were also found highly significant for all plant types and in both animal species.

In goats, among grasses, Chrysopogon aucheri (grass 1) retained negative lignin digestibilities across all growth periods. Cymbopogon shoenanthus (grass 2) had positive lignin digestion coefficient only at vegetative growth (Figure 9). The lignin digestibilities of all plant species are given in Table 2. The lignin in forb 1 (Veronica seniola) was digested positively. Lignin biodegradation was greater in the later growth stages of forbs. Maximum digestion value was 18.20% (averaged across digestion times). Forb 2 (Centaurea spp.) differed from forb 1. Negative lignin recoveries were obtained for the first and second growth periods. The only lignin disappearance took place for the third growth stage (Figure 9). The

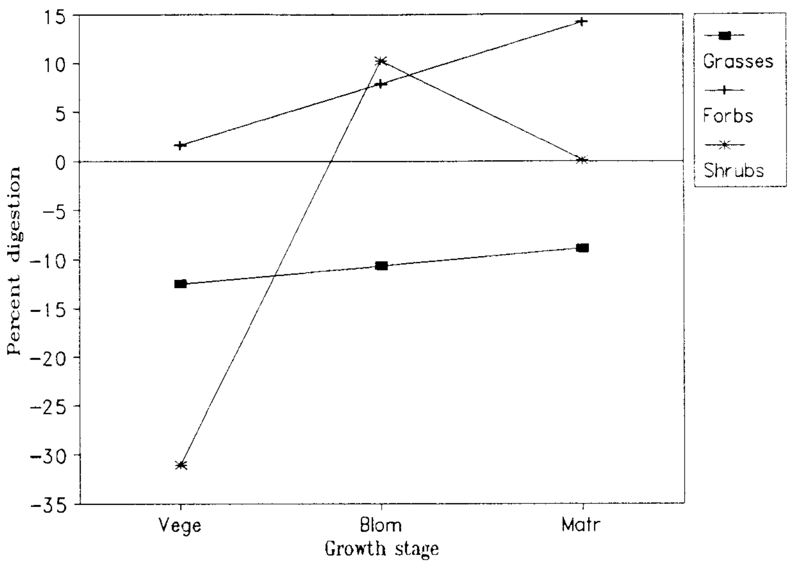

Figure 7. Lignin digestibility in plant types by goats.

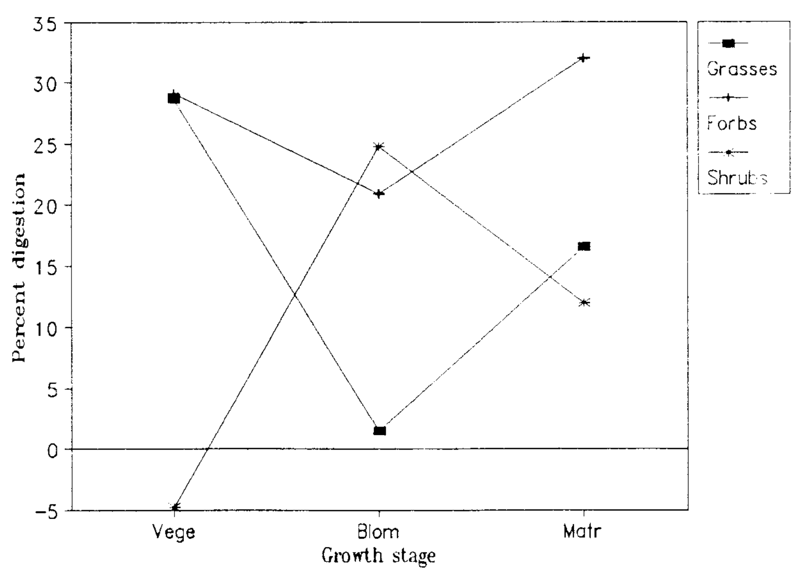

Figure 8. Lignin digestibility in plant types by sheep.

variability among shrub species was much greater. The highest negative lignin digestion coefficients (-57.23% at vegetative growth) and followed by highest positive digestion coefficient (19.87%) at bloom growth were measured in _Artemisia maritima_ (shrub 1); however, there was a relatively negligible lignin degradation at mature stage. The lignin digestion coefficients of _Cousinia stocksii_ (shrub 2) ranged from -4.99% to 1.33% (averaged across digestion times).

In sheep, both grasses had lower lignin digestion values at bloom relative to other stages. Lignin of _Chrysopogon aucheri_ was digested at the rate of 25.31%, 4.61% and 18.71% accordingly across the growth stages. Vegetative, bloom and mature stages of _Cymbopogon shoenanthus_ had lignin digestion values which were 31.96%, -1.50% and 14.45%, respectively. Forb species had positive and decreasing lignin digestion at the bloom growth stage. Unlike forb 1 lignin digestion of forb 2 was low throughout all growth stages (Figure 10). Shrub 1 (_Artemisia maritima_) had trends of lignin degradation very similar to those observed in goats. Shrub 2 (_Cousinia stocksii_) followed the trends of grasses and forbs (sheep) with consistently positive lignin digestion coefficients (Figure 10).

Results indicated that plant species within plant types (grasses, forbs, shrubs) did differ in their lignin degradation coefficients but the pattern of lignin digestion

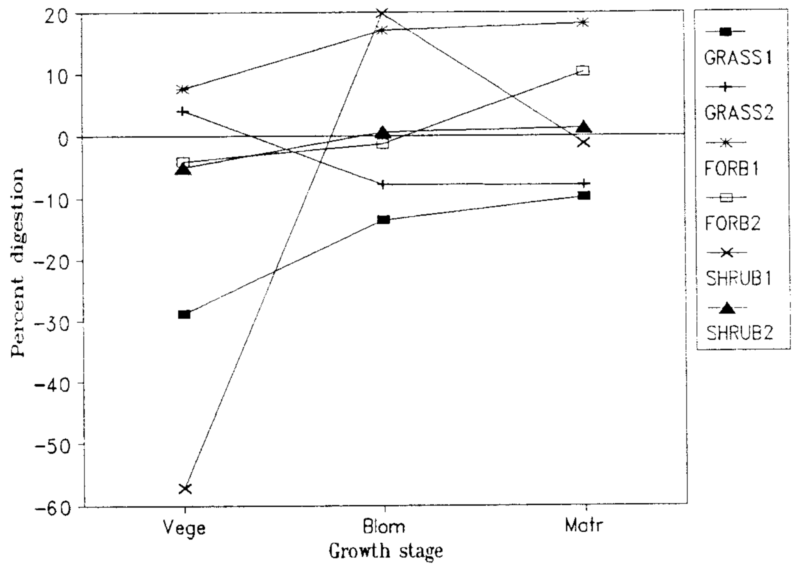

Figure 9. Lignin digestibility in plant species by goats.

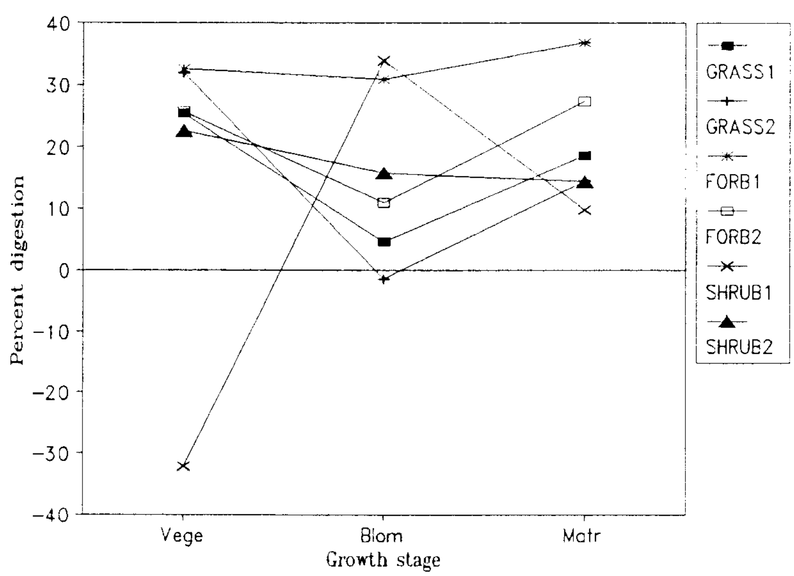

Figure 10. Lignin digestibility in plant species by sheep.

were relatively similar except in shrubs where Artemisia maritima showed enormous variability across the three growth stages. Variation in lignin digestion is related to the considerable variation in lignin structure and its bonding with other lignin fractions and carbohydrates of the plant cell wall (Morrison, 1974). Highly condensed polymers of cinamyl alcohols possessing high molecular weight are referred as "core lignin" (Gordon and Neudoerffer, 1973; Grisebach, 1981). Non-core lignins are comprised of p-coumaric acid and ferulic acid components which act as a cross linkage between lignin and structural carbohydrates. Ferulic and p-coumaric acids are relatively concentrated phenolics represent by relatively loosely bound components (either bound to cell wall or cell wall constituents) (Jung et al. 1983a). These monomers possibly reside in different structural environments within cell wall.

Many workers have reported the fate of these monomers in the digestive tract of ruminants. These monomers are known to inhibit microbial activity upon release from cell wall during digestion processes. Highly significant interactions between various factors were found in this study which could clarify the role of these phenolic monomers in lignin biodegradation. Figures 7 and 9 show consistent negative digestibilities of grasses. Grasses have been reported to contain higher concentrations of alkali labile phenolic monomers in their cell walls than legumes (Hartley and Jones, 1977; Jung et al., 1983b). In the case of negative lignin digestibilities in grasses, it is postulated that alkali labile monomers were solubilized during the first 12 to 24 h of fermentation. These phenolic acids are toxic to rumen bacteria and protozoa but are not to rumen fungi (Akin and Rigsby, 1985). Phenolic acids may however, inhibit the ability of rumen fungi to colonize and degrade plant fiber (Akin and Rigsby, 1985). Their ability to degrade lignified tissues in the rumen can also be depressed in the case of sulphur deficient forage (Akin et al., 1983). These phenolics would then have contributed the artifact lignin. This is a plausible explanation for the negative lignin digestibilities of grasses in goats. Jung and Fahey (1984) reported tall fescue accumulated little lignin during maturation but phenolic acid content increased dramatically. This effect may result in consistent negative lignin digestibilities of grasses across all growth stages. This contention is also supported by this study and the relatively low dry matter digestibilities of grasses across all fermentation intervals (Table 3). In the case of sheep, a considerable amount of lignin in grasses disappeared (Figure 8). There is no readily apparent explanation but it indicates animal species differences in the kind and nature of ruminal microbial populations. This is a possible reason why sheep have more complete digestion of lignin in all plant types at all growth stages.

The availability of sulfur for rumen microbes may also vary between forages (Akin et al., 1983) or plant types could be different in both phenolic and carbohydrate composition. Alfalfa increased markedly in lignin content with maturation, while phenolic levels remained constant. This may relate to the consistent positive lignin digestion values of forbs. Most probably higher sulfur and lower alkali labile monomers concentration in the forbs would have enhanced the lignin digestibilities. There is no possible explanation for the general decline in lignin digestibilities by sheep at bloom stage and highly variable digestion values of Artimesia maritima in both sheep and goats. In general better lignin degradation took place at plant maturity. It could be interpreted that less solubilization of phenolics at maturity did not affect the activity of lignolytic fungi and other microbes responsible for lignin degradation.

This hypotheses may explain the discrepancies in lignin digestibilities among plant types, plant species within plant types, growth stages and their interactions. Further research is needed to establish the relationship between lignin digestion of various plants and their sulfur and phenolic acid contents.

Lignin is not an inert substance and consequently, use of lignin as an internal marker in digestion studies will produce invalid results. Highly variable, both positive and negative digestion coefficients of lignin were obtained. Lignin digestibilities are presented in Tables 1 and 2. As much as 51.45% lignin was digested in some samples yet negative digestion coefficients in others ranged from -1.15% to -103.37%. Animal species were significantly different in their lignin digestibilities. Most of the negative digestion values in the data were from goats. Sheep exhibited relatively consistent and positive digestion coefficients. These results supported the findings of numerous workers who reported varying lignin digestibilities for different animals. Smith et al. (1956) mentioned that sheep were apparently able to digest a greater percentage of lignin than were deer. Results of this study indicate that sheep can degrade forage lignin to a greater extent than goats.

Muntifering et al. (1981b) suggested that ruminal digestibilities of lignin could be corrected to 100.0%. Wallace and Van Dyne (1970) obtained good results by correcting fecal lignin values for the apparent digestibilities of lignin. However, Allinson and Osbourn (1970) found inconsistent positive and negative variation of acid detergent lignin for the regrowth and primary cuts of rye grass. There were no particular patterns of lignin digestion in sheep (Fahey et al., 1979, 1980). The present study revealed very complex interactions between animal species, digestion times, plant types (grasses, forbs, shrubs), plant species within each plant type and phenological plant growth stages. The complex nature of these interactions provide lignin digestibility results with no strictly predictable patterns. The fabrication of certain correction factors for apparent lignin digestibilities as a marker and their use in adjusting the digestibility results is therefore difficult or impossible. On the basis of the results of this study, it must be concluded that there is no basis to use the lignin ratio technique to determine daily dry matter intake or digestibility of forage consumed by sheep and goats grazing rangelands in Baluchistan.

Table 1. Lignin digestibilities of plant types by sheep and goats.

Digestion Time(Hrs)	Goats (%) Lignin digested Growth stage Vege	Blom	Matr	Avg	Sheep (%) Lignin digested Growth stage Vege	Blom	Matr	Avg
Grasses								
12	-12.61	-21.12	-48.41	-27.38	29.21	-26.03	-3.02	0.05
24	-65.59	-12.51	-14.94	-31.02	30.72	8.13	10.15	16.34
48	0.31	-10.96	14.63	1.33	6.72	-0.07	31.60	12.75
72	28.17	1.88	13.30	14.45	47.38	24.20	27.60	33.23
Avg	-12.43	-10.68	-8.36		28.63	1.56	16.53	
Forbs								
12	-18.74	-6.71	-10.78	-12.07	17.52	11.90	27.50	18.98
24	-30.86	2.00	9.42	-6.48	37.73	30.67	27.16	31.85
48	16.10	15.86	35.53	22.50	14.05	9.48	41.88	21.80
72	40.24	20.42	22.74	27.80	47.23	31.63	31.54	36.80
Avg	1.69	7.39	14.23		29.13	20.92	32.02	
Shrubs								
12	-46.73	-1.23	-15.25	-21.07	-11.69	21.16	10.69	6.72
24	-74.67	6.92	-5.61	-24.45	3.20	25.14	5.85	13.06
48	-19.00	12.99	9.18	1.06	-24.13	15.36	16.41	2.53
72	15.95	22.37	12.03	16.73	3.52	37.56	15.10	20.39
Avg	-31.11	10.27	0.09		-4.79	24.80	12.01	

Table 2. Lignin digestibilities of plant species by sheep and goats.

Digestion Time(Hrs)	Goats (%) Lignin digested Growth stage Vege	Blom	Matr	Avg	Sheep (%) Lignin digested Growth stage Vege	Blom	Matr	Avg
Chrysopogon aucheri (Grass1)								
12	-22.08	-22.91	-46.65	-30.55	25.02	-2.55	12.51	11.66
24	-103.4	-17.04	-13.45	-44.62	25.26	8.66	8.62	14.18
48	-9.77	-14.17	10.42	-4.51	3.94	-6.73	31.46	9.55
72	19.84	0.10	10.38	10.11	47.04	19.08	22.27	29.46
Avg	-28.35	-13.50	-9.83		25.31	4.61	18.71	
Cymbopogon shoenanthus (Grass2)								
12	-3.15	-19.33	-50.18	-24.22	33.41	-49.52	-18.55	-11.55
24	-27.82	-7.98	-16.43	-17.41	36.19	7.61	11.68	18.49
48	10.39	-7.74	18.83	7.16	9.50	6.60	31.74	15.95
72	36.49	3.66	16.23	18.80	48.73	29.32	32.92	36.99
Avg	3.98	-7.85	-7.89		31.96	-1.50	14.45	
Veronica seniola (Forb1)								
12	-14.23	-2.18	-8.43	-8.28	19.46	19.73	38.87	26.02
24	-25.52	8.95	7.78	-2.93	40.66	41.55	29.48	37.23
48	24.88	29.57	39.45	31.30	18.89	18.77	43.03	26.89
72	44.96	31.86	33.99	36.94	51.45	43.62	35.73	43.60
Avg	7.52	17.05	18.20		32.61	30.92	36.78	
Centaurea spp. (forb2)								
12	-23.25	-11.24	-13.12	-15.87	15.59	4.08	16.13	11.93
24	-36.20	-4.94	11.07	-10.02	34.30	19.79	24.34	26.48
48	7.32	2.15	31.62	13.70	9.21	0.19	40.74	16.71
72	35.53	8.98	11.48	18.66	43.01	19.64	27.34	29.99
Avg	-4.15	-1.26	10.26		25.65	10.92	27.26	
Artemisia maritima (Shrub1)								
12	-77.31	12.57	-13.77	-26.17	-49.18	30.66	6.18	-4.11
24	-83.35	17.26	-7.39	-24.49	-16.13	31.59	5.06	6.84
48	-55.01	19.27	7.37	-9.46	-54.27	25.10	14.12	-5.02
72	-13.26	30.36	9.18	8.76	-9.13	48.20	13.36	17.48
Avg	-57.23	19.87	-1.15		-32.18	33.89	9.68	
Cousinia stocksii (Shrub2)								
12	-16.15	-15.02	-16.72	-15.96	25.80	11.66	15.20	17.55
24	-65.98	-3.42	-3.84	-24.42	32.53	18.68	6.60	19.27
48	17.01	6.72	10.99	11.57	5.92	5.62	18.70	10.08
72	45.16	14.38	14.88	24.81	26.16	26.93	16.84	23.31
Avg	-4.99	0.67	1.33		22.61	15.72	14.34	

Table 3. *In vitro* DM digestibilities of plant species by sheep and goats.

Digestion Time(Hrs)	Goats (%) Dry matter digested Growth stage Vege	Blom	Matr	Avg	Sheep (%) Dry matter digested Growth stage Vege	Blom	Matr	Avg
				Chrysopogon aucheri (Grass1)				
12	7.06	5.95	5.28	6.10	3.83	0.61	2.38	2.27
24	7.06	5.30	5.38	5.91	2.87	0.91	2.68	2.16
48	12.36	12.63	19.55	14.85	12.40	6.41	15.71	11.51
72	5.97	7.47	22.98	12.14	33.09	14.11	25.45	24.22
Avg	8.11	7.84	13.30		13.05	5.51	11.56	
				Cymbopogon shoenanthus (Grass2)				
12	6.70	5.01	5.63	5.78	5.01	3.55	1.46	3.34
24	7.25	5.65	3.82	5.57	4.16	3.74	7.97	5.29
48	7.13	12.49	18.63	12.75	8.58	21.07	17.11	15.59
72	15.33	9.57	23.99	16.30	26.73	23.66	35.05	28.48
Avg	9.10	8.18	13.02		11.12	13.01	15.40	
				Veronica seniola (Forb1)				
12	10.73	13.15	10.85	11.58	6.11	6.51	3.44	5.35
24	16.50	20.89	19.35	19.08	19.77	21.23	22.22	21.07
48	40.96	35.48	34.51	36.98	42.53	38.30	32.37	37.90
72	30.32	33.99	38.06	34.12	43.33	38.16	34.47	38.32
Avg	24.63	25.88	25.32		28.06	26.05	23.25	
				Centurea spp. (forb2)				
12	10.37	9.36	9.53	9.92	5.96	4.01	4.21	4.73
24	15.71	15.21	14.19	15.04	19.67	5.40	16.31	13.80
48	36.85	20.43	31.37	29.72	41.37	26.09	35.73	34.56
72	39.49	14.19	11.55	21.74	41.03	27.01	26.91	31.65
Avg	25.61	14.92	16.78		27.13	15.63	20.79	
				Artemisia maritima (Shrub1)				
12	12.63	9.13	8.33	10.03	7.53	6.92	3.07	5.34
24	20.73	10.05	7.63	12.80	15.17	5.39	5.30	8.79
48	16.65	11.88	12.00	13.51	31.62	22.91	10.67	21.73
72	29.63	16.26	14.31	20.06	22.13	22.49	9.59	18.07
Avg	19.91	11.83	10.57		19.11	14.43	7.28	
				Cousinia stocksii (Shrub2)				
12	15.17	11.26	11.89	12.77	11.83	10.64	8.69	10.38
24	19.61	13.53	10.75	14.63	17.58	12.47	10.69	13.58
48	31.74	25.80	20.17	25.90	40.95	27.93	16.74	28.54
72	44.29	14.99	23.18	27.48	8.28	26.83	18.42	17.34
Avg	27.70	16.39	16.50		19.56	19.47	13.63	

Table 4. P-values for sources of variation for lignin digestion.

Source	Lignin Digestibilities %
Animal species	0.0001
Plant types	0.0001
Goats-forbs:	
Species	0.0005
Growth stages	0.0043
Species*growth stages	NS
Digestion times	0.0001
Species*digestion times	NS
Growth stages*digestion times	0.003
Goats-grasses:	
Species	0.0105
Growth stages	NS
Species*growth stages	0.0291
Digestion times	0.0001
Species*digestion times	NS
Growth stages*digestion times	0.0017
Goats-shrubs:	
Species	0.0404
Growth stages	0.0002
Species*growth stages	0.0005
Digestion times	0.0004
Species*digestion times	NS
Growth stages*digestion times	0.0308
Sheep-forbs:	
Species	0.0005
Growth stages	0.0133
Species*growth stages	0.0493
Digestion times	0.0032
Species*digestion times	NS
Growth stage*digestion times	0.0093
Sheep-grasses:	
Species	NS
Growth stages	0.0127
Species*growth stages	NS
Digestion times	0.0144
Species*digestion times	NS
Growth stage*digestion times	NS
Sheep-shrubs:	
Species	0.0066
Growth stages	0.0001
Species*growth stages	0.0001
Digestion times	0.0097
Species*digestion times	NS
Growth stage*digestion times	0.0366

SUMMARY AND CONCLUSIONS

The overall purpose of phase 1 was to evaluate the lignin ratio technique for its use in determining daily dry matter intake and apparent digestibility of forage consumed by grazing animals. Various points of interest are summarized below:

1. Highly variable, (both positive and negative) digestion coefficients for lignin were obtained from *in vitro* digestion trials, regardless of any other factor. As high as 51.0% lignin was digested in some samples, while negative digestion co-efficients ranged from -1.0% to -103.0% in others.
2. Sheep and goat rumen liquor digested plant lignin differently. Sheep liquor was apparently able to digest a greater percentage of lignin than goat. Most of the negative lignin digestion values appeared in plant samples digested with goat liquor.
3. *In vitro* digestion of plant material at 12 h, 24 h, 48 h, and 72 h intervals did not register strong pattern of lignin digestibilities. Lignin biodegradation generally increased at longer digestion intervals, however, there were exceptions. Mean lignin coefficients of all plant types were positive at 72 h fermentation.
4. Apparent lignin digestibility of all plant types were quite variable and unpredictable by both animal species.

Plant species within similar plant type (grasses, forbs, shrubs) also differed in the extent of lignin decomposition.

5. Negative lignin digestibilities were mainly associated with vegetation stage at 12 h and 24 h fermentation, indicating that lignin is complexed with other by products of rumen decomposition.

6. This study revealed very complex interactions between animal species, digestion times, plant types (grasses, forbs, shrubs), plant species within each plant type and phenological plant growth stages. The complex nature of these interactions made it impossible to correct fecal lignin values for apparent digestion of lignin. Lignin coefficients had no strictly predictable patterns.

Biological alteration and degradation of lignin occurs in the stomach of ruminants. The complexity of this phenomenon indicates involvement and interactions between various factors like animal species, the kind of forage being consumed by animal species, the nature of plant material and its retention time in the alimentary tract of the animal. Lignin degradation occurred to such a great extent in this study which indicate that there is lignolytic enzymatic activity by atleast some rumen microbes.

There is no basis for using lignin ratio technique with the plant species tested. Use of lignin as an internal marker in digestion studies on these plant species will produce invalid results. The fabrication of certain correction factors for apparent lignin digestibilities as a marker and their use in adjusting the digestibility results is difficult or impossible.

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CHAPTER II

DIETARY COMPOSITION AND NUTRITIONAL STATUS OF SHEEP AND GOATS GRAZING TWO RANGELAND TYPES IN BALUCHISTAN, PAKISTAN

INTRODUCTION

The geographical area of Pakistan is 79.35 million hectares; 34.73 million of these make up Baluchistan (Gill et al., 1976). The unfavorable topographic, edaphic and climatic conditions in this province have limited cultivation practices, and about 93.4 percent of the area is rangeland (Gill et al., 1976). Sheep and goats are the preferred livestock for the topography of the region. However, the productivity of these small ruminants is far below their potential due to limited forage on rangelands which providing about 70.0% of feed requirements.

These rangelands have never been managed on a scientific basis. Traditional grazing induces overstocking, as well as intense and frequent use regardless of season. Consequently, the productivity of native pastoral ranges has been adversely affected, in general they are producing 10 to 50.0% below their potential (Din, 1980). The trend of retrogression is still in progress due to unwise range practices.

Along with other management problems, overstocking of animals is widespread on native rangelands. Inappropriate stocking rates have not only affected the forage production, but a dramatic change in the vegetation composition is also gradually taking place. There has been a continuous decrease in the number of desirable forage species due to reduction in their vigor and ability to compete and reproduce. An increase in the number of noxious plant species and deterioration in the watershed stability are other basic results of these traditional practices.

No comprehensive studies have been conducted, and no research information is available about the effects of stocking rates on pasture and animal production from rangelands in this region. The purpose of this study is to classify the rangelands of Baluchistan on a quantitative basis and establish stocking rate guidelines for domestic small ruminants on these lands.

<u>Objectives</u>

1) To measure the production of forage on rangelands of Baluchistan.

2) To estimate the seasonal standing crop of vegetation on these rangelands by species.

3) To determine the seasonal chemical (nutritional) composition of major range plant species.

4) To determine the relative palatability and preference of range plants by sheep and goats.

5) To develop computer analysis techniques necessary for rapidly developing grazing management plans.

LITERATURE REVIEW

Forage Quality

Range animal productivity is based on a common goal of optimum economic gains through proper utilization of range forages. Efficiency of livestock production is mainly associated with the amount and nutritive quality of available vegetation to meet the daily nutritional demands of grazing animals. The daily nutrient demand can fluctuate with the physiological functions of the grazing animal, such as maintenance, gestation, growth, fattening and lactation (Cook and Harris, 1977).

It is difficult to regulate precisely the daily nutrient intake by range animals, since their forage consumption results from individual grazing efforts. Yet, the amount of feed consumed on any given range is influenced by the physiological state of the animal, the plant species available, phenological plant stage, forage diversity and abundance, and general climatic attributes (Cook and Harris, 1977). Therefore, to achieve the goal of optimum economic returns, a knowledge of range animal nutritional requirements and the nutritional calendar in a given range ecosystem is essential.

While evaluating forage species for livestock production, forage quality and quantity should be considered. If forages are used for maintenance requirements, maximum forage yield may be first priority (if digestibility is 50% or greater). However, if forages are providing feed for growing, pregnant or lactating animals, then forage quality may be more important than forage yield (White and Weight, 1984). White and Weight (1984) found that forage quality was inversely proportional with forage yield. The dry matter digestibility decreased between 1.5 and 2.3 % for every 1,000 Kg/ha increase in forage yield.

The nutritive value of range plants can be influenced directly or indirectly by various environmental factors such as weather, soil, plant competition and grazing. Laycock and Price (1970) summarized the effects of environmental conditions upon the quality of forage plants. The most obvious direct effect was considered to be leaching of nutrients from plants by rain. As quoted by Laycock and Price (1970) "leaching of herbaceous plants as a result of exposure to rain causes large losses in protein, phosphorus, ash and carotene contents (Guilbert et al. 1931: Guilbert and Mead, 1931; Watkins 1937, 1943); however, older leaves are more susceptible to leaching than are younger leaves." Many environmental factors bring changes in the phenological development of plants which indirectly affects the chemical composition of plants. Temperature determines the rate of development, phenology and total yield of many plants and indirectly influences the nutritive value of plants. In various plants, protein and phosphorus contents increase as soil and ambient temperature increase up to 80° F. Lack of adequate light has direct and indirect impacts on plants. Laycock and Price (1970) have reported the results of several studies indicating the effects of light on plants. They concluded that shaded plants generally produce less forage yields, total carbohydrates and nitrogen free extract than plants growing under open sunlight. The depth, texture and nutrient status of the soil determines the chemical composition of range plants. However, these are correlated with both climate and plant kind. Grazing alters form or state of development, which affects its nutrient contents. Many studies indicate that the presence or absence of plants possessing nitrogen-fixing nodules influenced the fertility and growth of associated plant species.

It is very important to determine the comparative nutrient value of available forage resources during the various seasons and the ability of those resources to meet the animal requirements for optimum livestock production (Cook and Harris, 1977). A multiplicity of factors is responsible for the rate of change in nutrient composition with advancing plant development and maturity stages (Kilcher, 1981). As a result, variations in animal performance when consuming various forages or the same forage at different growth stages have been documented (Beaty and Engel, 1980). The seasonal trends in the chemical composition of plant species are used to identify periods of maximum and minimum nutritional quality. Herbage quality typically declines with advancing maturity (Hart et al., 1983; Sanderson and Wedin, 1989). Precise description of the relationship between fluctuation in herbage quality and phenological growth would be of great practical significance (Sanderson and Wedin, 1989) in the proper management of livestock on rangelands.

General trends in nutritive contents of range plants may serve as guidelines. The protein content of shrubs and forbs usually exhibits greater consistency than grasses. Grasses are higher in protein content in the spring at the vegetative stage, however, protein is lesser in grasses than in either shrubs or forbs at mature stage (Bohman and Lesperance, 1967). Grasses generally show great reduction in their nutrients through development stages (Hart et al., 1983; Kilcher, 1981; Sims et al., 1971). Their threshold level for adequate nutrients for grazing animals is reached soon and for much of the year they are deficient which necessitates supplementation to avoid reduced animal production levels (Kilcher, 1981). In Georgia, Lewis et al. (1975) reported grass crude protein of only 10.0% in April which then fell to less than 4.0% by October. Forbs declined from 16.0% to 6.0% and shrubs declined from 12.0% to 6.0% during the same period.

Calcium, potassium., zinc, copper, and phosphorus decline with the advancement of plant phenology (Rauzi et al., 1969). Phosphorus is critical to animal growth and productivity and its deficiency is universal in grasses at later phenological growth stages. However, some or few grasses do have adequate levels of P (0.17 to 0.23%) for animal needs (Kilcher, 1981). In their Utah studies, Cook and Harris (1977) found phosphorus content of both grasses and forbs decreased as the season advanced, whereas browse gained a slight increase in its phosphorus content. Grasses remained decidedly lower in phosphorus than either forbs or browse during all periods of summer. Rauzi (1975) observed a significant decline in the phosphorus concentration of herbage with maturity. Phosphorus concentration of crested wheatgrass at early bloom and full bloom stages of growth were 0.27% and 0.16%, respectively. Murray (1984) reported phosphorus content of crested wheatgrass as low as 0.08% in mid September.

Dabo et al. (1988) reported neutral detergent fiber concentration of various grass cultivars. Differences among cultivars were statistically significant, generally of small magnitude and not consistent over harvest dates, plant parts or years. No definite trends were apparent. Sanderson and Wedin (1989) observed that alfalfa stem concentrations of NDF increased quadratically with increasing phenological stages, as did alfalfa herbage. However, red clover petioles, stems and herbage each increased linearly in NDF concentration with increasing phenological stage.

Concentrations of ADF were strongly affected by maturity in whole plant, stem, and leaf samples. Changes in ADF concentrations in all plant parts with advancing maturity were best explained by quadratic equations. Cultivar differences were statistically significant (Dabo et al., 1988). Hart et al. (1983) reported that the concentration of ADF in Western wheatgrass increased more rapidly than that of other species. However, ADF of all plant species increased significantly. Sedges registered a slower increase in their ADF content than other species. The increase in ADF was faster than NDF in all species, which indicated an increase in cellulose and a decrease in hemicellulose, pentosans and other more digestible "fiber fractions" as the plants matured.

Individual forage classes are inherently different in their nutrient contents. Grasses have the lowest protein and phosphorus content but are highest in energy yielding cellulose (Cook and Harris, 1977). Mean crude protein concentration of five grasses was significantly lower than crude protein content of non-grasses (Meyer and Brown, 1985). Nutrient content among grass species varies greatly depending upon the length of time required to reach maturity (Cook and Harris, 1977). Buxton and Marten (1989) reported that among grass species, CP concentration was consistently higher in reed canarygrass than in tall fescue. However, Holechek et al. (1989) observed no differences in CP concentrations of wheatgrass species. Mean NDF concentrations of the grasses were higher than non-grasses all the time, whereas phosphorus content did not differ among grasses, forbs and shrubs (Meyer and Brown, 1985). In conclusion, if the diet is largely grass, phosphorus and digestible protein may be markedly deficient (Cook and Harris, 1977). A rapid decline in CP and P and an increase in fiber components of grasses with advancing maturity requires special management techniques to maintain grasses in actively growing juvenile state for best animal performance (Dabo et al., 1988).

Browse and forbs furnish ample protein and phosphorus, even late in the season, but provide relatively less energy supplies (Cook and Harris, 1977). Bohman and Lesperance (1967) considered forbs as the most nutritious forage class of range plants. Cook and Harris (1977) believe browse plants are highest in protein and lowest in cellulose. Forbs stay intermediate among three major forage groups in most respects. Malechek and Leinweber (1972c) concluded that shrubs tended to be more stable in their protein content because of their deeper root system. However, even though CP remains relatively high throughout the season, increasing lignin reduces digestibility (Bohman and Lesperance, 1967; Kilcher, 1981).

As a general conclusion, browse plants fulfill the protein requirements of pregnant animals and are high in carotene. However, their phosphorus level may be slightly below the animal needs and they are decidedly low in energy yielding constituents. Therefore, a mixture of browse and grass will balance the animals diet better than areas possessing mainly one forage class alone (Cook and Harris, 1977).

Diet Selection

Animal husbandry is the most productive use of arid and semiarid areas of the world. Rangelands of these areas produce forage which can be utilized by more than one kind of livestock. Animal production can be maximized on the rangelands by common-use grazing with more than one kind of animal (Merrill and Miller, 1961). However, ranges do deteriorate when improperly used. Improper use can stem from grazing during unsuitable seasons, grazing by the wrong kind of livestock or grazing by too many animals. Obvious results are changes in the plant community in terms of plant density and species composition (Cook et al.,1962).

Not all forage species are equally palatable and nutritious. Huss (1971) divided them into three categories: desirable, less desirable and undesirable. It is a fact that desirability of the plants varies with the kind of animal species interacting with them. Each class of livestock exhibits certain dietary preferences when grazed on a diverse plant community. The number of desirable plant species in a particular plant community is often determined by grazing. Continued overgrazing eliminates desirable forage species. When one plant is eliminated, it is replaced by another less desirable, undesirable or invading plant species. Cook and Harris (1950) found that forage remaining on good ranges following grazing was lower in nutrient content than originally present and that continued use caused still greater reductions in nutrient value. Increased intensity of grazing reduced daily forage intake and digestibility of nutrients (Cook et al., 1953; Pieper et al., 1959). However, this process could be reversed by management directed towards the establishment of desirable plant species (Huss, 1971).

The goal of any management system should be establishment of vegetation dominated by desirable plant species and which is naturally beneficial to both the plant and animal. To achieve this goal, knowledge of plant species commonly selected by grazing and browsing herbivores at different times of the year is a prerequisite. It is also desirable to evaluate the potential competition between livestock species as indicated by the extent to which they select the same plant species under common use grazing (Squires, 1982).

Sheep

The composition of an animal's diet is affected by many factors including forage availability, animal preference, animal anatomy, forage presentation and interspecific and intraspecific competition (Rector, 1983). Sheep maintained a higher quality diet than either cattle or goats (Squires, 1982). Sheep were mainly monocot consumers. Grasses and sedges were the major food of sheep. In a study in Southeastern Montana, forty seven plant species were identified in sheep pellets. These included 22 monocots, 14 forbs, 9 shrubs and 2 trees (Alexander et al., 1983). In East Africa, sheep diets usually consist of more than 50% grasses during all seasons. The shrub component of their diets tends to increase during dry seasons, caused by a decrease in grass availability (Migongo-Bake and Hansen, 1987). However, when the amounts of green herbage offered are low, sheep do not continue to select a diet containing a high proportion of green plant material. They then eat considerable quantities of dead herbage (Hamilton et al., 1973). Many workers have reported that sheep are consistent in their use of grasses and normally consume small amounts of trees and shrubs. Bryant et al. (1979), in a study conducted on a grassland steppe area on the Edwards Plateau, Texas, determined the contribution of forage classes to the diets of sheep, Angora goats, Spanish goats and white-tailed deer, averaged across 12 months. In sheep diets, grasses were highest (60%) followed by browse (22%) while forbs contributed 18% of the total diet. Sheep diets reported by Kothmann (1968) were not different and consisted of 55% grasses, 28% browse and 16% forb component on poor condition range. However, on good condition range, forbs dominated the sheep diets (55%) and were important to winter diets. Wilson et al. (1975) also regarded sheep as grass eaters and in most of their collections the proportion of tree and shrub species eaten was quite small. Other herbaceous plants were eaten by sheep when they were present. Ellis et al. (1977), Bryant et al. (1979) and MacCracken and Hansen (1981) agreed with the findings of others. They generalized that sheep would usually rely on grasses as their major diet component while forbs might be selected opportunistically. Van Dyne and Heady (1965) found that a single plant species may frequently compose 50% or more of the sheep diet for a short time.

Sheep will shift their diet among the forage classes as the season progresses. During the growing season, grasses and forbs normally dominated the diet. When grasses and forbs become mature, browse can replace the herbaceous components of the diet (Bryant et al., 1979). The data by Rector (1983) on sheep dietary components suggest that addition of other species of animals to range will change sheep diets. Sheep will consume alternate forages, grasses are replaced with sedges in the absence of forbs in the winter.

Goats

Goats are energetic, inquisitive and versatile in the art of food gathering (Huston, 1978). Goats differ fundamentally from sheep and other livestock in their physiological and several morphological traits that allow them to be well adapted to a broad variety of environments (Malechek and Provenza, 1981). They tend to be more highly selective in their diet (Fraps and Cory, 1940; Malechek and Provenza, 1981). The primary advantage of goats over sheep lies in their dietary amplitude. Goats utilize a wider range of plants than sheep. They are capable of shifting their diets from herbaceous broad-leaved plants to shrubs (Maher, 1945; Scifres, 1980; Wilson et al., 1975). Goats are highly flexible in their feeding behavior and are apparently more tolerant to secondary phytochemicals particularly tannins in the plants (Malechek and Provenza, 1981).

Goats are famous for their ability to utilize browse, and numerous studies indicate that goats consumed large quantities of browse. Wilson et al. (1975) determined the diets of feral goats in Australia consisted of 50% browse. The browse component of the diet ranged from 70% to 90% when goats grazed the area following sheep. Goat diets reported by Ahmed et al. (1981) from Cleaveland National Forest, San Diego, varied in their shrub component from 70% to 80% whereas grasses and forbs remained reasonably constant at about 20%. Warren et al. (1984a), in a study conducted on the Walker Ranch, a shallow sandy loam range with mixed-brush complex vegetation, found that most of the time in Spanish goat diets browse was more important than grasses. Spanish goats ate a number of native shrubs, contributing over half the diet in summer, autumn and winter. Overall browse made up half to three-fourths of the diets of Spanish goats.

Results obtained by Migongo-Bake and Hansen (1987); Pfister and Malechek (1986) and Villena and Pfister (1989) categorized goats as intermediate feeders. Angora and Spanish goat diets contained about equal proportions of grass and browse (Bryant, 1977). However, other reports indicated that goat utilized considerable amounts of grass. Warren et al. (1984b) determined that grasses made up about 80% of the diets of Angora goats and 68% of the diets of Spanish goats during the month of February. Malechek and Leinweber (1972b) included grass as an especially important item for goats from June to October. Diets of goats rarely contained more than 30.0% browse or 15.0% forbs.

Goats do exhibit important temporal dietary variations. Even under similar pasture conditions, annual climatic variations can cause major shifts in dietary trends.

Seasonal dietary shifts can be abrupt, particularly in areas having distinct wet and dry seasons. Malechek and Provenza (1981) reviewed several dietary studies which showed important temporal variations, either seasonally or monthly. The patterns of variations differed greatly from study to study, because of the differences in prevailing forage conditions. Lopes and Stuth (1984) observed significant seasonal shifts in the selection of grasses and browse by Spanish goats.

Dietary Interrelationships

An understanding of the forage needs of domestic ungulates and the competitive interrelationship is important for proper management of rangelands resources (Hanley, 1982). The sheep and goat, although competitors for some herbaceous plants, were partly complementary, indicating that annual production could be enhanced by grazing them together on renewable resources (Wilson et al., 1975). Bryant et al. (1979) found a keen dietary competition among sheep, Angora goats, Spanish goats and whitetailed deer when there was little high quality grass available. There was probably no competition for dry grass because of its abundance. They also observed greatest dietary competition for forbs in winter. However, critical competition occurred in March when forb utilization apparently equaled net primary production. Sheep were found more competitive with deer for forbs than Angora or Spanish goats. Trends of percent browse in diets were most similar among sheep and Angora goats, while trends of deer and Spanish goats were close. Warren et al. (1984b) reported similar findings.

There was relatively little dietary overlap between Angora and Spanish goats. The diets of Rambouillet sheep and Spanish goats were the least similar, while the diets of Barbado sheep and Angora goats overlapped to a greater extent.

The degree of dietary overlap between sheep and goats is probably greatest in dry season because of limited forage availability. A reverse trend would be noticed during the wet season (Pfister and Malechek, 1986).

Nutritional Status

A good knowledge of dietary composition and nutritive content of diets of grazing animals is a prerequisite for sustained livestock production on rangelands. Different kinds of animals grazing together often have different forage preferences. They differ in their nutrient requirements and therefore, require management to obtain optimum production. Livestock diets on excellent condition ranges contain levels of crude protein (CP) acceptable for maintenance and production (Bryant et al., 1980). On heavily stocked ranges animals have to consume more fibrous plant parts which results in lower dietary crude protein and digestibility (Malechek et al., 1978). Quality of the animal diets may be associated with seasonal changes (Van Dyne and Heady, 1965). Crude protein values of all forage species declined throughout the grazing periods (Bedell, 1970). The seasonal changes in the nutritive components of the diet were primarily due to similar changes in the plants in the pasture and not due to changes in preference (Buchanan et al., 1972).

The quantities of various forages available on ranges do not indicate the amount of each in the animal diet. The changes in the nutrient content of the animal diets result from the selective behavior of the animals for plant species and their portions (Cook et al., 1962; Bryant et al., 1980). Sheep select better quality diets than either cattle or goats. Percent dietary nitrogen (1.26%) was highest in sheep (Squires 1982). Generally sheep diets contain more crude protein than cattle diets (Van Dyne and Heady, 1965; Bedell, 1971). Most researchers report that crude protein content of sheep diets was not limiting to animal production (Arnold et al., 1966); Wilson, 1976; Bryant et al., 1980). However, when Wilson et al. (1975) compared sheep and goat diets, on eight occasions the nitrogen content of the goat diets was higher than the sheep diets. They concluded that goats appeared to eat a wider range of the available vegetation than do sheep and would make better use of the vegetation as a whole. Taylor and Kothman (1990) found that crude protein content of Spanish and Angora goats varied seasonally from a high of 18.0% in April to 9.0% in October. Generally, higher CP values tended to be associated with larger amounts of browse and forbs in their diet. They found that even though nutrient intake of Angora goats remained at acceptable levels before and during the breeding season, kid production was less than optimum. Poor reproductive performance was attributed to factors other than diet quality or quantity.

Nutritive value of the diets on good and poor condition ranges depends upon the species composition and the intensity of utilization. Animal diets containing a large percentage of browse would generally be high in protein, ash, lignin and ether extract; but when grasses appear as a major diet component, the nutrient intake would generally be higher in cellulose, other carbohydrates and metabolizable energy (Cook et al., 1962). Data gathered by Bryant et al (1980) from Texas show that energy appears to be the major limiting nutrient on excellent condition rangelands. Diets selected by sheep were higher in Digestible Energy (DE) than those of goats and deer most of the time. It was attributed to the higher percentage of grasses in the sheep diets. Energy supply was marginal at times during summer and early autumn and deficient during late autumn and winter for all four kinds of livestock. It was suggested that Angora goats would require additional energy during late gestation

(December, January and February) to improve kid crops and overall reproductive performance, especially during winters when goats eat large amounts of Plateau oak.

METHODS

Site Description

Tomagh (Loralai)

Tomagh Range-Livestock Research Station of Arid Zone Research Institute, PARC, Quetta, Baluchistan, Pakistan, lies between latitudes 30° 21' north and longitudes 68° 36' east and is situated on 4,000 ha of Tomagh State Forest 15 km west of Sanjawi, Pakistan at an elevation zone of 1800 m to 2000 m (ICARDA, 1989). The topography of the area is undulating and uneven. Steep slopes are intersected by deep stream gorges. Mountainous peaks and steep hills are also present. Pastures used in this study had slopes ranging between 30.0% to 40.0%. The soils of the area have not been described properly. The color of soil ranges from brown to reddish brown with loamy clay texture locally containing rock fragments. Most of the soils are homogenized and humified, with stable structure and good porosity conducive to plant growth.

The mean annual precipitation is approximately 300 mm distributed approximately 60.0% and 40.0% between winter and summer rainfall periods, respectively (ICARDA, 1989). Winter rain and snow are caused by Mediterranean disturbances whereas the summer rains are brought about by monsoons from the Arabian Sea. Droughts occur every 3 to 5 years (Baig, 1981). The records of a recently installed weather station indicate winter temperatures may fall as low as -5.1° C. However, summers are relatively comfortable and maximum ambient temperature recorded was 35.8° C (during the month of June, 1989).

It is difficult or impossible to describe the climax vegetation of the site. Tremendous disturbance from fuel wood cutting and continuous heavy grazing in the past have brought significant ecological changes. In the past medium sized woody trees such as _Olea ferruginea_ were an important component of the vegetation, but these trees are very rare today. Retrogression of climax plant communities (like _Chrysopogon aucheri_) to disclimax types (like _Cymbopogon shoenanthus_) is widespread. Plant species encountered during this study, though not climax, are used to describe the vegetation of the Tomagh research site.

Grasses are the dominant component of the site vegetation. Commonly encountered grass species are in order of abundance; _Cymbopogon shoenanthus_, _Chrysopogon aucheri_ and _Tetrapogon spp._. _Saccharum spp._ and _Cynodon dactylon_ are mainly found within dry channel beds and riparian boundaries. Shrubs and trees present on the site are _Ebenus stellatus_, _Ephedra intermedia_, _Salvia cabulica_, _Convolvulus spinosus_, _Perwoskis artiplicifolia_, _Olea ferruginea_, _Prunus padus_, _Rehmnus persica_ and _Pterophyrum olivieri_ . The presence of forbs is closely related to precipitation patterns. Phlomis stewartii, Veronica seniola, Centaurea spp., Astragalus spp. and some other unidentified forbs were collected from the area.

Zarchi (Kalat)

Zarchi Range-Livestock Research Station of Arid Zone Research Institute, PARC, Quetta, Baluchistan, Pakistan lies at latitude 29° 07' north and longitude 66° 24' east and is located on 4,000 ha of privately controlled land 20 km west of Kalat, Pakistan, at an elevation of 1800 m (ICARDA, 1989). The topography of the site is relatively level and contains several flat channelled stream beds. Slope on this site varied from 7.0% to 13.0%. Since this station has been established recently on privately owned land, there is not information available about the soil characteristics. However, the color of the soil varies from light brown to sometimes yellowish brown. The soils are well drained, homogenized, mainly sandy silty loam and low in organic matter content.

Average annual precipitation at Zarchi station is 200 mm, 90.0% of which is received in winter and early spring (ICARDA, 1989). Fairly persistent and desiccating winds blow during greater part of the year, coming from north and north-west. The potential evapotranspiration exceeds the mean annual rainfall. The water balance shows a continuous water deficit during the months of December to February

(Baig, 1981). Weather records of the previous two years indicate that winters are cold and the air temperature may fall as low as -8.6° C. Summers are dry and pleasant. Normally, daily maximum temperature is below 35.0° C.

Zarchi has desert shrub type range dominated by Artemisia maritima and Haloxylon griffithii. Indications of past disturbances are less prominent. This vegetation type is considered to be at mid seral to late seral stage. Common shrubs are Artemisia maritima, Haloxylon griffithii, Cousinia stocksii, Acantholimon longiflorum, Acantholimon munroanum, Convolvulus leiocalycinus, Astragalus stocksii, Sophora mollis and Hertia intermedia. Napeta juncea and Gallonia eriantha are perennial forbs and Tulipa montana, Scorzonera pusilla, Alyssum desertorum, Malconia torulosa are annual forbs. There have been some other short lived unknown forbs. Perennial grasses are rare on this study site. Poa siniaca is present in small amounts. Cynodon dactylon and Saccharum spp. were noticed growing around the water springs and the places high in soil moisture. Annual grasses (Hordeum marinum and Bromus spp.) appear early in the growing season and quickly reach maturity (as soil moisture becomes depleted).

Determination of Seasonal Above Ground Biomass of Principal Plant Species and Their Relative Composition on the Study Sites.

Herbage production and relative species composition was determined on each study site for 1988 and 1989, during the first week of April, last week of May or first week of June, first or 2nd week of July and last week of September or first week of October. Forage production on each site was estimated within 10.0% of the mean by double sampling using randomly located 1 m^2 rectangular quadrats clipped at ground level. Total number of quadrats required to sample within 10.0% of the population mean were calculated by using the following formula;

$$n = \frac{t^2 s^2}{(\text{sample mean} \times 0.1)^2} \quad \text{(Pieper, 1978).}$$

Where n = total number of quadrats required to sample.

t = table t value.

s = standard error of the sample mean.

The species weight of the current year herbage in each of the first four quadrats was estimated and the 5th quadrat was first estimated for species current year biomass and then clipped. Harvested forage material of each quadrat was sorted out into grasses, forbs and shrubs and later was oven dried at 55.0° C for at least 48 h. Separate regression equations were developed for each sampling period to describe the relationship between estimated and clipped herbage weights. The clipped weights of each sampling period were corrected by using the proper regression equation. Total as well as species forage production/ha was calculated on dry matter basis. Relative plant species composition was also determined on dry weight basis to monitor the magnitude of change in plant composition across seasons.

Permanent transects 300 to 400 m long were installed across the range area. A 0.10 x 0.10 m rectangular quadrat was examined at every 5th step on the transect during the last week of April and percent frequency of individual species was determined. Photographic records of the permanent transect are being maintained from a permanent reference point.

Determination of Variability in the Chemical Composition of Major Plant Species at Four Phenological Stages of Growth (Vegetative Stage, Bloom Stage, Maturity Stage and Dormant Stage).

The growing season for most of the plant species starts in the 2nd week of March on both study sites. Samples of 15 principal plant species for the year 1988 and 20 principal plant species for the year 1989 were collected at Tomagh study site during the first week of April (vegetative stage), last and first week of May (bloom stage), first and

2nd week of July (maturity stage) and last week of September and first week of October (dormant stage). From Zarchi study site, 13 commonly growing plant species in 1988 and 19 major plant species year 1989 were sampled across the periods described for Tomagh research site. The year 1988 was abnormally dry and relatively few plant species were encountered on both sites. All plant samples were transported to the laboratories of Arid Zone Research Institute, PARC, Quetta, Baluchistan, Pakistan for further chemical analysis. Duplicate samples of individual plant species from both research sites were subjected to dry matter, ash content, phosphorus, crude protein, neutral detergent fiber (NDF), and acid detergent fiber (ADF) determinations in the laboratory. However, all plant samples of 1989 were only analyzed for their phosphorus and crude protein contents because of finance problems.

Dry Matter Determination

Each sample in duplicate was dried in the oven at 55.0° C for 50 h (AOAC, 1980) and percent dry matter was calculated by the following equation;

$$\text{DM \%} = \frac{\text{wt. of dried sample}}{\text{wt. of fresh sample}} \times 100$$

$$\text{Moisture \%} = 100 - \text{DM \%}$$

Ash Contents

Dried samples were ground to pass 20 to 30 mesh (1 mm) screen by a wiley mill. One to 2 g of ground sample were ignited in the Muffle furnace at 600.0° C for at least 8 h and ash contents of the samples were determined (AOAC, 1980) as follows:

$$\text{Ash\%} = \frac{\text{wt. of ash}}{\text{wt. of sample}} \times 100$$

Crude Protein Determination

Nitrogen in each sample was determined in duplicate by micro Kjeldahl procedures (AOAC 1980). Each sample weighing 1 g was digested in sulfuric acid (Copper sulphate, two standard tablets was used as a catalyst; and 20-30 ml of concentrated H_2SO_4 was added to each digestion tube). The sample was digested by placing digestion tubes on a heating block and digestion was continued until color of the solution was clear. Nitrogen in the digested sample was collected in 4.0% boric acid solution by distillation . Boric acid was titrated against .02 N standardized H_2SO_4 by a semi automatic titrator. Crude protein in the sample was calculated by the following formula:

$$CP\% = \frac{(\text{ml } H_2SO_4 - \text{blank}) \times N \times 100 \times 6.25 \times 14.01}{\text{Sample weight} \times 1000}$$

Neutral Detergent Fiber (NDF)

One g of previously dried and ground sample was placed in a glass container suitable for refluxing. One hundred (100) ml of cold neutral detergent solution and 2 ml of decalin were added. The solution was then boiled for 5-10 m and refluxed for 60 m. Later, it was filtered through a previously-tared, sintered glass crucible using light suction. The filtered mat was broken up and washed twice with hot water. It was further washed with acetone and crucibles were dried at 100.0°C for 8 h and weighed (Van Soest, 1964). NDF was calculated as follows:

$$NDF\ \% = \frac{\text{wt. after treatment}}{\text{sample wt.}} \times 100$$

Acid Detergent Fiber (ADF)

One g of already processed sample was taken into a beaker suitable for refluxing. One hundred (100) ml cold acid detergent solution and 2 ml decahydronapthalene was added. The acid detergent solution was heated to boiling then refluxed for 60 m. The sample was then filtered on a previously tared gooch crucible, the filtered mat was broken up with rod and washed with hot water twice then with acetone until the affluent was clear. After that, the filterate was dried at 100.0° C for 8 h and weighed. Acid detergent fiber was calculated as follows:

$$\text{ADF }\% = \frac{(W^{o} - W_{t})}{S} \times 100$$

Where:

W^{o} = wt. of oven dry crucible including fiber

W_{t} = tared wt. of oven dried crucible

S = oven dried sample wt.

(Van Soest, 1963)

Phosphorus Determination

Phosphorus in the sample was determined by spectrophotometric analysis. A standard phosphorus solution (50 g of P per ml) was prepared. This standard phosphorus sample with a reagent blank was run through a spectrophotometer and a standard curve was prepared by plotting phosphorus concentration against percent light transmission. Then the sample solution was run to determine the ppm of P in the solution from the respective standard curves, and finally percent phosphorus in the sample was calculated in the following manner (Jackson, 1958):

$$\text{ppm in 50 ml} = \frac{\text{std ppm}}{\text{std absorbance}} \times \text{sample absorbance}$$

$$\text{ug of P in sample} = \text{ppm in 50 ml} \times \text{50 ml}$$

$$\text{ppm P in sample} = \frac{\text{ug P}}{\text{sample wt. (gm)}}$$

$$\text{P\%} = \frac{\text{ppm P}}{10{,}000}$$

<u>Determination of Relative Palatability of Major Plant Species and Preference of Sheep and Goats at Different Phenological Stages.</u>

Tomagh and Zarchi ranges are being grazed freely by sheep and goats in mixed herd forms. However, about 50.0 ha of representative area were protected from grazing on both sites to determine the seasonal forage production of these Baluchi rangelands. The grazing season starts in the first week of April and lasts through October. During both years, dietary composition of sheep and goats was determined during the second week of April, the last week of May, the first week of July and the last week of September or first week of October at both study sites. Each time, five animals were randomly drawn within each class of animals. Total fecal output by individual animal was determined by fecal collection bags worn for 48 h. Feces of each of the five sheep and five goats were dried separately in the oven at 55.0° C till constant weight was achieved. Dried feces were ground to 1 mm particle size using a Wiley mill.

During 1988, subsamples of individual fecal output were shipped to Colorado State University, Fort Collins, where they were subjected to microhistological analysis. The dietary components for each of five sheep and five goats across all four seasons were described by using methods of Sparks and Malechek (1968). About 1 g of fecal sample was soaked in household bleach (sodium hypochlorite) for 20-30 m to remove pigments. Two slides per individual fecal sample were prepared and studied under the microscope. Twenty fields were systematically located on each slide and were examined at 100X magnification using a phase contrast microscope. Different plant fragments in the fecal sample were identified under the microscope by comparing them with the reference slides of plant species from both study sites. Frequency conversion techniques were employed in obtaining estimates of the percentages of different plant species in the animal diets (Sparks and Malechek, 1968).

During 1989, the diets of the sheep and goats were observed by using bite count method. The bite count data were collected for two consecutive days on two sheep and two goats randomly selected from rest of the flock across the four grazing periods mentioned above. Daily, one animal of both animal species was observed for the number of bites made on each plant species twice a day, one hour in the morning at the onset of grazing and one hour in the afternoon (5.00 P.M.). Percent bites on each plant species were used to determine the preference pattern by both sheep and goats.

Total fecal production of individual sheep and goats was used to estimate the relative daily forage intake by both classes of animals. Lignin was used as an internal indicator and daily intake was calculated by the following formula:

$$\text{Total feed intake} = \frac{\text{kg feces}}{\text{day}} * \frac{\text{1 g I.I.}}{\text{kg feces}} * \frac{\text{kg forage}}{\text{1 g I.I.}}$$

Subsamples of individual fecal samples were analyzed to determine lignin concentrations in the feces of both sheep and goats. Animal diets were composed for both years and were analyzed for their lignin contents. Later, absolute amounts of each plant species consumed by each class were estimated and compared to the total production.

Statistical Analysis

The Analysis of Variance procedures (ANOVA) of Statistical Analysis System (SAS, 1985) were used to test the following null hypotheses related to plant species chemical composition.

i) There were no differences in the mean chemical composition of individual plant species at four phenological growth stages.

ii) There was no difference among plant species in their chemical composition.

iii) Good quality forage was available on the Baluchi rangelands year round to meet the nutritional requirements of sheep and goats.

Data of plant nutrient components for 1988 were analyzed to test the effects of season of a year and different plant species upon each nutrient separately as a dependent variable. The model used was 'dry matter (DM) Ash crude protein (CP) phosphorus (P) neutral detergent fiber (NDF) acid detergent fiber (ADF) = plant species season'. However, data regarding crude protein and phosphorus components of plant species for both years (1988 and 1989) were statistically analyzed together to measure the differences in these components among years, seasons within years and plant species. The stated model included 'crude protein (CP) phosphorus (P) = year season (year) plant species year x plant species'. Data regarding the botanical composition of sheep and goats diets for both years was analyzed on percentages basis.

Development of Grazing Management Guidelines for Area by Computer Analysis Techniques.

The above collected information was compiled by computer using spreadsheets. A nutritional calendar for sheep and goats grazing Baluchi rangelands was outlined. The nutrient supplies were compared with sheep and goats' nutrient requirements through the annual production cycle. The acute deficiencies of various nutrients which handicap the sheep and goats' productivity during different periods of a year were defined. The use of spread sheets enabled the following parameters which provide very basic grazing management guidelines for the area to be estimated.

i) Seasonal dry matter production, Kg/hectare on the range area, was calculated. This information was also subdivided into seasonal dry matter production of grasses, forbs and shrubs.

ii) Overall and species crude protein (CP), phosphorus and other proximate nutrients production was determined for different seasons of the year.

iii) Relative palatability and preference indices for individual plant species enabled estimation of the proportion of each of the proximate contents of individual plant species available from the total production at different seasons of the year.

iv) Based on the physiological states of sheep and goats, across different seasons their nutrient requirements were defined.

v) Rangelands of the area were classified on a qualitative basis and carrying capacity of these ranges was estimated.

vi) Periods of acute nutrient shortage for sheep and goats throughout the year were pointed out and concentrate supplementation was suggested to restore animal production potentials.

vii) To ensure year long nutritious and persistent forage supply to sheep and goats on Baluchi ranges, valuable plant species were ranked for their future propagation by looking through the dietary reference indices of both classes of animals.

viii) Chemical composition of plant species at both study sites was roughly compared to determine any variability in proximate contents due to site differences.

RESULTS AND DISCUSSIONS

Weather Conditions

The climatic conditions between the years were sufficiently dissimilar to cause differences in the growth and productivity of the vegetation on both sites. There was a large difference in the amount of annual precipitation; however, distribution patterns were approximately similar (Figure 11 and 11a). The year 1988 was much drier and total annual rainfall did not exceed 212 mm and 64 mm at Tomagh and Zarchi, respectively. At Tomagh, 1989 was about average with total annual precipitation of 315 mm; however, 1989 remained below normal with precipitation of 119 mm at Zarchi site (Appendix C). Ambient temperatures for both years are incomplete because of inexperienced local technicians and problems with automatic weather stations. Based on available temperature records, 1988 was warmer than 1989. Mean monthly temperatures of both sites are given in appendices A and B.

At Tomagh air temperature gradually decreased after 15th of November. The daily minimum temperatures went below 0.0° C after December 20th. Daily minimum air temperature remained close to 0.0° C until the first week of March. A change in the weather conditions took place approximately in the second week of March when both daily maximum and minimum temperatures started rising gradually. The average daily air temperatures were 11.9° C and 10.0° C for 1988 and 1989, respectively. Mean daily maximum and minimum temperatures kept increasing until June when they reached 26.5° C and 24.0° C for 1988 and 1989, respectively. Temperatures were relatively stable during the months of July, August and September with mean daily air temperature around 24.0° C during 1988. The second half of July, 1989, was cool and daily minimum temperatures dropped below 0.0° C.

At Zarchi, the daily air temperatures started declining in the last week of September and mean daily air temperature was -0.3° C during November, 1989. Unfortunately, daily temperatures during December through March were not recorded for both years. During 1988 the weather station was not installed and during 1989 it remained out of order. However, the mean daily air temperature during April, 1988, was 10.5° C which indicated an increase in daily temperatures, most probably in the third week of March. The temperature kept increasing until July when mean daily temperatures were 27.8° C and 22.8° C for the years 1988 and 1989. Both daily maximum and minimum temperatures remained relatively stable till the first half of September.

On both sites, and in both years, precipitation occurred during the same months but differed in amounts. At Tomagh, rainfall was mainly received during January; through April, however, there was no rainfall in April of 1988 or February of 1989. Precipitation during this period was

59.0% and 74.0% of the total annual rainfall occurred for 1988 and 1989, respectively. Precipitation was 6.96, 12.96 and 104.58 mm respectively for January, February and March in 1988. The remaining rainfall of this year was distributed over the first three summer months (June through August). Similar to 1988, maximum rainfall of 204.72 mm was received in March, 1989. Precipitation for January and April, 1989 was 18.3 and 10.4 mm respectively. Rainfall in June and July amounted to 70.40 and 10.72 mm respectively.

At Zarchi, 79.0% of the total annual rainfall was received between January and April, 1988, while these months totaled 67.0% in 1989. Precipitation was 11.3, 8.0, 29.0 and 2.0 mm, respectively, in January, February, March and April of 1988, whereas it was 20.5, 9.3, 3.0 and 44.1 mm, respectively, for the same months in 1989. There was 13.0 and 38.7 mm rainfall, respectively, in July of 1988 and 1989. There was no precipitation recorded in other months of 1988 and 1989, except a trace of rainfall in November for both years.

Above Ground Biomass Yields

Optimum use of natural resources like rangelands depends on the accurate understanding of the amount and dynamics of seasonal phytomass production. It is generally accepted that climatic fluctuations influence above ground phytomass yields. Herbage yield dynamics studied on two kinds of rangelands of Baluchistan, Pakistan, will be discussed separately.

Tomagh

Herbage yield varied among years for the four sampling periods. During the vegetative period, above ground biomass production on dry matter basis for 1988 was 2.4 times more than per hectare dry matter production in 1989 (Figure 12). In 1989, both air and soil temperatures were lower, particularly during the second half of March. Consequently, grasses did not respond to the increase in precipitation, which constituted about 72.0% of the total per hectare dry matter yield (Table 5). Standing crop peaked at second period (Bloom), when 473.67 and 509.69 Kg of dry matter/ha, respectively, were produced in 1988 and 1989. A one hundred millimeter increase in rainfall over 1988 produced only 36 Kg/ha of additional dry matter. The sampled area was protected from grazing since 1987. In 1988, a relatively below average precipitation accompanied with warmer temperature during March turned the previous year tillers into green rather than building additional structural carbohydrates through new tillers. However, this area was slightly grazed in the early winter of 1988 which removed some amounts of previous years growth. The grasses' regrowth in the spring of 1989 resulted from lot of new

Table 5. Forage production, relative plant species composition and suggested stocking rates.

Site	Year	Growth st	Grasses	Forbs	Shrubs	Total	AUM's /ha*	Ha/5.0 sheep or goats**	%composition Grasses	Forbs	Shrubs
Tomagh	1988	Vege	167.65	0.00	94.47	262.12	0.49	2.06	66.75	0.00	33.25
		Blom	408.83	2.34	62.50	473.67	0.88	1.14	84.43	0.43	15.14
		Matr	393.81	7.32	75.78	476.91	1.32	0.75	80.16	0.00	19.84
		Dorm	225.13	8.16	17.89	251.18	0.70	1.43	86.66	3.16	10.18
		Average	298.86	4.46	62.66	365.97	0.85	1.35	79.50	0.90	19.60
	1989	Vege	72.46	0.34	36.86	109.66	0.20	4.92	71.71	0.55	27.74
		Blom	439.31	12.89	57.49	509.69	0.94	1.06	85.55	2.61	11.84
		Matr	347.04	4.62	71.33	422.99	1.17	0.85	82.75	0.59	16.66
		Dorm	488.68	0.65	25.71	515.04	1.43	0.70	94.57	0.09	5.34
		Average	336.87	4.63	47.85	389.35	0.94	1.88	83.65	0.96	15.40
Zarchi	1988	Vege	1.64	0.64	70.82	73.10	0.14	7.39	2.35	1.21	96.44
		Blom	0.00	10.53	98.51	109.04	0.20	4.95	0.00	10.92	89.08
		Matr	0.00	14.31	88.47	102.78	0.29	3.50	0.00	17.08	82.92
		Dorm	0.00	1.87	53.83	55.70	0.15	6.46	0.00	2.83	97.17
		Average	0.41	6.84	77.91	85.16	0.19	5.58	0.59	8.01	91.40
	1989	Vege	3.33	15.08	89.30	107.71	0.20	5.01	2.67	14.85	82.48
		Blom	1.75	7.53	232.58	241.86	0.45	2.23	0.38	2.69	96.93
		Matr	0.50	4.61	266.23	271.34	0.75	1.33	0.23	1.82	97.95
		Dorm	0.61	1.83	204.56	207.00	0.58	1.74	0.22	1.10	98.68
		Average	1.55	7.26	198.17	206.98	0.49	2.58	0.88	5.12	94.01

* = AUM's calculated based on 50% utilization of total dry matter/ha produced.

** = basic assumption - 5.0 sheep or 5.0 goats constituted 1.0 AUM.

Table 6. Plant species frequency data on both sites during 1988.

Site	Plant Species	Frequency (%)
Tomagh	Cymbopogon shoenanthus	36.36
	Chrysopogon aucheri	16.36
	Ebenus stellatus	9.09
	Convolvulus spinosus	4.55
	Sophora mollis	4.55
	Lawaghon	0.91
	Ephedra intermedia	0.91
	Phlomis stewartii	2.73
	Bare ground	24.55
Zarchi	Artemisia meritima	30.17
	Astragalus stocksii	2.59
	Haloxylon griffithii	6.03
	Gallonia erientha	2.59
	Acantholimon longiflorum	1.72
	Bare ground	56.90

Table 7. Seasonal qualitative inventory of forage resources on the Tomagh and Zarchi sites.

			Ash/ha(kg)				CP/ha(kg)					
Site	Year	Growth Stage	Grasses	Forbs	Shrubs	Total	Grasses	Forbs	Shrubs	Total	AUM's /ha*	Ha/5.0 shee or goats**
Tomagh	1988	Vege	13.55	0.00	5.05	18.60	17.47	0.00	9.57	27.04	0.43	2.33
		Blom	24.11	0.18	5.92	30.21	27.06	0.22	4.64	31.92	0.51	1.97
		Matr	28.93	1.72	5.37	36.02	15.69	0.44	5.00	21.13	0.56	1.79
		Dorm	17.36	1.53	1.95	20.84	2.80	0.28	1.28	4.36	0.12	8.67
	1989	Vege	6.08	0.07	2.63	8.78	7.82	0.07	2.57	10.46	0.17	6.02
		Blom	26.36	1.48	4.63	32.47	29.68	1.36	4.16	35.20	0.56	1.79
		Matr	26.71	0.44	4.80	31.95	14.33	0.12	3.85	18.30	0.48	2.07
		Dorm	38.93	0.12	1.69	40.74	6.36	0.02	1.16	7.54	0.20	5.01
Zarchi	1988	Vege	0.15	0.07	7.61	7.83	0.23	0.11	12.13	12.47	0.20	5.05
		Blom	0.00	1.54	9.35	10.89	0.00	1.23	16.83	18.06	0.29	3.49
		Matr	0.00	1.22	5.29	6.51	0.00	0.66	3.55	4.21	0.11	8.98
		Dorm	0.00	0.09	4.63	4.72	0.00	0.03	3.58	3.61	0.10	10.47
	1989	Vege	0.29	1.63	9.99	11.91	0.29	2.04	16.88	19.21	0.30	3.28
		Blom	0.13	0.75	22.32	23.20	0.08	0.61	37.54	38.23	0.61	1.65
		Matr	0.11	0.32	21.23	21.66	0.03	0.19	13.95	14.17	0.37	2.67
		Dorm	0.09	0.12	15.62	15.83	0.03	0.05	11.07	11.15	0.29	3.39

* = AUM's calculated based on 50% utilization of total crude protein/ha produced.

** = basic assumption - 5.0 sheep or 5.0 goats constituted 1.0 AUM.

Table 7. (continued)

Site	Year	Growth Stage	P/ha(kg) Grasses	Forbs	Shrubs	Total	NDF/Ha(kg) Grasses	Forbs	Shrubs	Total	ADF/Ha(kg) Grasses	Forbs	Shrubs	Total
Tomagh	1988	Vege	0.230	0.000	0.120	0.350	110.84	0.00	37.93	148.77	59.13	0.00	24.52	83.65
		Blom	0.610	0.002	0.068	0.680	269.70	1.04	32.85	303.59	151.10	0.67	23.15	174.92
		Matr	0.217	0.008	0.085	0.310	266.39	4.10	37.90	308.39	160.87	3.29	29.17	193.33
		Dorm	0.120	0.009	0.021	0.150	154.84	4.50	10.15	169.49	93.99	3.48	8.81	106.28
	1989	Vege	0.104	0.001	0.026	0.130	49.80	0.28	11.62	61.70	26.57	0.21	9.16	35.94
		Blom	0.660	0.016	0.084	0.760	294.10	6.84	29.63	330.57	164.90	4.54	22.42	191.86
		Matr	0.240	0.002	0.028	0.270	243.92	1.19	31.86	276.97	147.04	0.96	25.41	173.41
		Dorm	0.260	0.001	0.029	0.290	347.41	0.37	13.04	360.82	211.11	0.28	11.45	222.84
Zarchi	1988	Vege	0.003	0.002	0.126	0.130	1.09	0.39	21.79	23.27	0.60	0.32	17.08	18.00
		Blom	0.000	0.019	0.211	0.230	0.00	5.14	42.54	47.68	0.00	4.05	30.25	34.30
		Matr	0.000	0.005	0.015	0.020	0.00	10.79	48.87	59.66	0.00	8.98	37.70	46.68
		Dorm	0.000	0.002	0.048	0.050	0.00	1.06	27.97	29.03	0.00	0.86	22.41	23.27
	1989	Vege	0.005	0.027	0.188	0.220	1.54	6.86	27.26	35.66	0.84	5.80	20.99	27.63
		Blom	0.001	0.007	0.492	0.500	0.53	2.89	105.62	109.04	0.32	2.57	77.08	79.97
		Matr	0.000	0.002	0.058	0.060	0.36	2.95	142.81	146.12	0.25	2.34	106.34	108.93
		Dorm	0.001	0.002	0.178	0.180	0.40	1.11	110.48	111.99	0.31	0.93	91.61	92.85

* = AUM's calculated based on 50% utilization of total crude protein/ha produced.

** = basic assumption - 5.0 sheep or 5.0 goats constituted 1.0 AUM.

tillering activity, probably because of equal herbage yields for both years. It should also provide another basis for comparatively low yields for 1989 at the vegetative sampling stage. The standing crop starts declining after peak (Sims et al., 1971). Dry matter production at maturity stage (Figure 11 and 11a) per hectare yields were slightly higher for 1989. Grasses dried up rapidly in 1988, which made it difficult for us to separate current year's growth from last year's growth. It caused an over estimation of grasses component of total yield. There were 251.18 and 515.04 Kg of dry matter/ha, respectively, estimated in the first weeks of October, 1988 and 1989. The yields of 1989 were about two times higher than yields for 1988. Above 40.0% of the total annual rainfall was very well distributed over June, July and August of 1988, compared to 25.0% of total per annum precipitation in 1989 received primarily in the month of June (early summer). Favorable and properly distributed precipitation in the summer of 1988 was reflected in considerable green flush of grasses. Dried tillers of grasses even from the current year could have been regarded as last growth. This resulted into what appeared to be very low per hectare herbage production at the fourth sampling period of 1988. Increased yields in 1989 at the same sampling stage could be an over estimation of dried up grasses, because of the problem of differentiating among current and old grass growth. It also indicated important

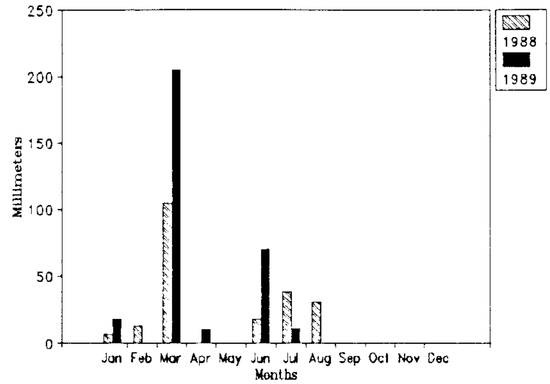

Figure 11. Rainfall patterns at Tomagh station.

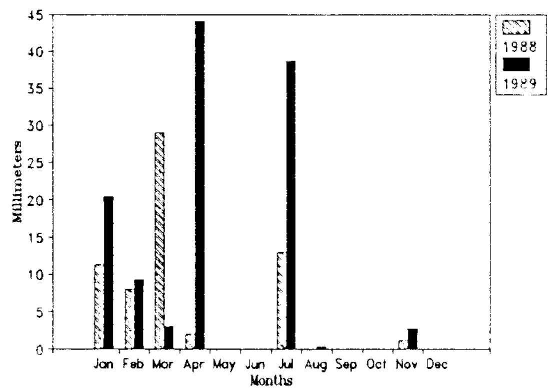

Figure 11a. Rainfall patterns at Zarchi station.

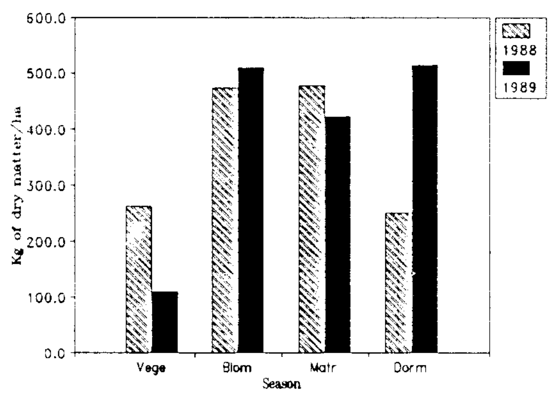

Figure 12. Standing crop dynamics during 1988 and 1989 at Tomagh station.

problems related to sampling of grasses for current year herbage yields at different phenological stages.

Zarchi

Dry matter yield varied greatly among years for the four sampling periods. There were 73.10 and 107.71 Kg of above ground biomass, respectively, estimated on moisture free basis at vegetative stage for both 1988 and 1989 (Table 5). Shrub component of total yield was 96.44% and 82.48%, respectively, for both years. It reflected the vegetation (particularly forbs) response to late winter and early spring rain showers in 1989. Evapotranspiration was less because of lower temperatures (Baig, 1981). Big differences in per hectare dry matter yields were noticed among years on bloom and maturity sampling periods (Figure 13). Yields of 1989 were 2.2 and 2.6 times, respectively, greater than yields of 1988 for both these sampling times. In 1988, herbage yield did not increase much as season advanced. Low soil moisture in combination with higher evapotranspiration rates produced little twig growth and deciduous shrubs dropped their leaves off rapidly accompanied with a decrease in dry matter production in dormant season. Favorable precipitation during late winter through late spring was reflected in high herbage yields for all sampling dates of 1989. Deep rooted shrubs took advantage of subsoil moisture

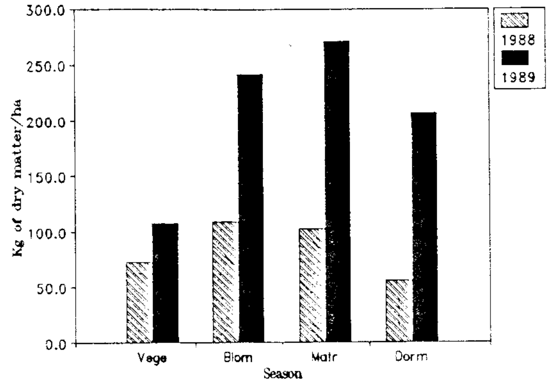

Figure 13. Standing crop dynamics during 1988 and 1989 at Zarchi station.

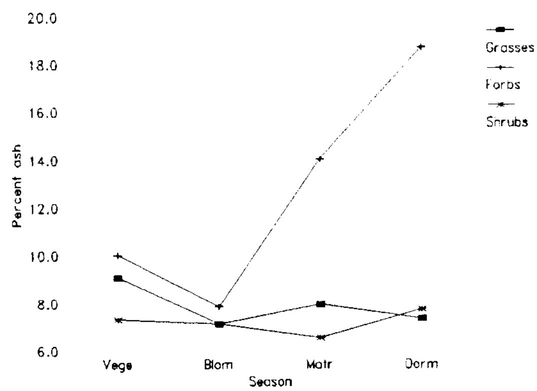

Figure 14. Ash content of forage classes druring 1988 at Tomagh station.

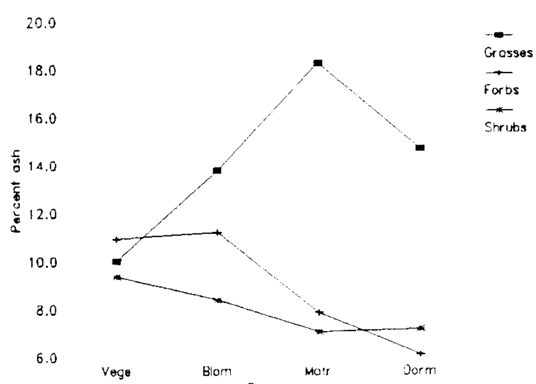

Figure 15. Ash content of forage classes during 1988 at Zarchi station.

and kept producing new twigs, branches and leaves until early summer. A 124.0% increase in per hectare herbage yield took place during the vegetative and bloom periods and a 12.0% increase in herbage production was estimated between bloom and maturity periods. After the standing crop peaked in the first week of July, herbage biomass declined about 24.0% through October 1989 (Figure 13). Total, as well as species wise dry matter yields are given in Table 5.

Relative Plant Species Composition

Relative species composition on both study sites is shown in Appendices D and E. Grasses were the dominant forage class in the Tomagh area both years. On average their proportion was 79.5% and 83.64% in 1988 and 1989, respectively. In both years, the grass percent composition increased as the season advanced and was highest in the Fall. Among grasses, *Cymbopogon shoenanthus* was the most abundant. During 1988 and 1989, it constituted 73.54% and 75.67%, respectively, of all plant biomass. *Cymbopogon shoenanthus* is not preferred by sheep and goats. It has invaded a majority of the grazing areas of northwestern Baluchistan. Its complete dominance on the rangelands of Baluchistan indicates the severity and intensity of past livestock grazing. Among palatable perennial grasses *Chrysopogon aucheri* is still found on grazed rangelands. In both 1988 and 1989, its average fraction into total plant composition was 5.96% and 7.92%, respectively. It appears that Chrysopogon aucheri has responded to a release from grazing pressure and expanded its population. Data indicate that Chrysopogon aucheri responded more to summer precipitation than early spring rains (Appendix D). Percent contribution by other grasses like Tetrapogon spp. was negligible. Future planning is necessary to save these species from becoming extinct. The second important forage class on Tomagh study site was shrubs. Mean percent shrub composition for both years was almost equal (Table 5), however, the relative percentage of individual shrub species varied across the sampling periods. Only Ephedra intermedia and Olea ferruginea were evergreen. Variations in percent composition by species across sampling periods could have been the result of random sampling and their deciduous characteristic. Annual forbs were rare during 1989. Phlomis stewartii, a perennial forb was encountered and its contribution remained negligible throughout the year. In 1989, some annual forbs did grow but could not out compete the dense stands of Cymbopogon shoenanthus. Their total composition was below 1.0% except at bloom stage (2.61%).

Zarchi is a shrub dominated range area. On average, shrub biomass was 91.0% and 94.0% for 1988 and 1989, respectively. Their contribution in total plant composition was relatively stable across the phenological seasons (Table 5). Among shrubs Artemisia maritima constituted the highest percentage while Haloxylon griffithii was second during both years. Average percent composition of Artemisia maritima was 54.0% and 60.0%, respectively, for 1988 and 1989. In both years the percent composition of Artemisia maritima remained fairly stable (Appendix E). Variations in the percent composition of Haloxylon griffithii were mainly correlated with the appearance of other shrub species during random quadrats sampling. Forbs were the second highest plant group in the Zarchi area. In 1988, percent contribution by annual forbs was negligible; however, percentage of forbs shown in Table 5 for bloom and maturity stages could mainly be attributed to two perennial forbs, Napeta juncea and Gallonia erientha (Appendix E). The diversity of annual forbs was greater during 1989 (Appendix E). These forb species complete their life cycle rapidly usually within a few weeks. Annual forb composition was 14.85% the first sampling period but dropped suddenly below 3.0% for the other three periods (Table 5). The perennial forbs were not encountered much during 1988, and grasses had a negligible contribution to the standing crop on this range. Their percent composition remained close to zero except at vegetative stage. During that period the surrounding hills where Chrysopogon aucheri was found growing were sampled. In 1989, Poa siniaca was seen commonly growing under the shrub plants; however, its productivity was extremely low. Its percent composition in spring was 2.67% and remained less than 0.50% for the last three periods (Table 5). Frequency data of various plant species (1988) for both sites is presented in Table 6.

Baluchi Ranges Nutrition and Deficiencies

Nutrient Requirements

Late winter or early spring lambing/kidding is a common practice on rangelands of Baluchistan, Pakistan. This is when rapid spring growth commences with warming conditions. The forage in this period is generally considered nutritionally adequate and abundant enough for all physiological states of sheep and goats. Tables 8 and 9 indicate physiological states of sheep and goats and animal nutrient requirements on Baluchi ranges. Considering the physiological states of sheep and goats, we can divide the whole year into four periods. Period 1 includes all the months of a year when animal requirements are at maintenance levels. Usually June, July, August and September constitute this period. The nutrient needs of animals remain minimal until the second half of September, when breeding normally begins. The second period is from October through December when ewes are in early to mid gestation. During this period, the fetus grows, the female gains some additional weight, and nutrient demand is slightly higher than maintenance. After December, a female enters a most

Table 8. Nutritive quality of forage classes at Tomagh station.

Forage	Season	Ash%*	CP%*	CP%**	P%*	P%**	% of required Sheep	% of required Goats	NDF%*	ADF%*
Grasses	Vege	9.06	11.14	15.89	0.15	0.180	63.85	72.17	65.04	34.98
	Blom	7.08	7.33	13.80	0.13	0.117	48.14	54.42	69.84	39.16
	Matr	7.92	3.53	10.70	0.07	0.060	32.04	30.52	71.71	42.53
	Dorm	7.33	2.69	5.50	0.07	0.022	23.75	22.62	71.24	44.79
Forbs	Vege	10.00	12.44	15.48	0.15	0.136	55.59	62.84	47.80	36.83
	Blom	7.83	9.28	13.27	0.13	0.087	42.00	47.47	51.43	36.35
	Matr	14.00	4.52	10.29	0.09	0.053	35.61	33.91	51.27	41.54
	Dorm	18.67	4.11	6.45	0.10	0.030	31.14	29.66	59.65	47.42
Shrubs	Vege	7.27	11.06	16.85	0.13	0.186	60.85	68.79	42.60	29.17
	Blom	7.08	7.47	14.68	0.11	0.117	43.22	48.85	48.35	35.14
	Matr	6.53	5.79	11.67	0.06	0.070	32.58	31.03	46.67	35.09
	Dorm	7.72	6.47	5.94	0.11	0.030	33.63	32.02	41.23	33.83

* = data for 1988
** = data for 1989

Table 9. Nutritive quality of forage classes at Zarchi station.

Forage	Season	Ash%*	CP%*	CP%**	P%*	P%**	% of required Sheep	% of required Goats	NDF%*	ADF%*
Grasses	Vege	10.00	10.01	13.69	0.16	0.225	73.94	83.59	53.38	29.10
	Blom	13.75	8.55	11.08	0.12	0.130	47.12	53.26	56.04	33.86
	Matr	18.25	4.12	6.61	0.05	0.080	31.38	29.88	57.04	39.69
	Dorm	14.67	4.34	5.08	0.08	0.031	26.38	25.12	65.02	50.34
Forbs	Vege	10.89	12.90	14.89	0.17	0.203	70.74	79.96	42.65	36.23
	Blom	11.17	9.54	12.57	0.12	0.117	45.96	51.96	45.35	40.14
	Matr	7.83	4.27	9.70	0.05	0.058	27.67	26.35	56.18	45.71
	Dorm	6.08	2.57	7.06	0.09	0.022	26.67	25.40	61.17	52.19
Shrubs	Vege	9.32	18.17	14.27	0.19	0.199	75.16	84.96	33.45	27.57
	Blom	8.36	11.30	12.11	0.12	0.128	47.98	54.24	50.91	35.74
	Matr	7.03	4.82	7.69	0.03	0.064	23.49	22.37	53.59	42.23
	Dorm	7.14	6.17	5.20	0.08	0.023	26.53	25.26	52.59	42.96

* = data for 1988
** = data for 1989

important period, when 70.0% to 80.0% of the fetal growth occurs. In addition, she gains weight in preparation for the coming lactation (fourth) period. In this period, nutrient requirements are fairly high compared to the preceding two periods (Tables 12 and 13). Lambing/kidding starts sometimes in March, when females experience the most stressful period. Besides nursing their kids, farmers require them to produce milk for human consumption. The nutritional requirements of the female are at the peak and the risk of inadequate nutrition is great. Energy requirements are fairly high and adequate protein, minerals and vitamins are especially important because of the increased levels of milk production. Lactation can end in May with lambs/kids weaning. However, it is often delayed due to continuous milking by the farmers, or delayed weaning of the young. After the termination of lactation, animals are in maintenance until breeding again in September. After the fourth period, the main concern of a Baluchi flock owner should be the young lamb/kid crop. They will be actively growing and to build their skeleton and muscles, rapid changes in their nutrient requirements take place. A failure to meet their nutritional needs results in poor weight gain and delayed puberty.

Nutrient Supplies

Ash

Ash content of forage progressively declines with advancing maturity (Kilcher, 1981). In this study some plant species did decline in their ash content with advance of season (Appendices G and F). However, most plant species did not follow a defined trend. Seasons' effect upon ash content of plant species during 1988 was not statistically significant (Table 10). On Tomagh site, the average ash content of both grasses and shrubs was relatively stable across the four seasons. High mean ash contents of forbs at bloom and mature stages are shown in Figure 14. Samples of *Phlomis stewartii* were contaminated with soil (Appendix F) and its added effect appeared in forbs mean ash content. Zarchi plants declined in their ash content with growing seasons (Figure 15) except *Hordeum murinum* (only grass) whose ash content was higher for the three later growth stages. *Hordeum murinum* , a shallow rooted annual grass, is easily pulled out with root when sampled. Soil particles on its roots may have increased the ash content of plant samples. Our results are in close accordance with Bedell (1971) who found no decline in the ash value of the total forage with the advance of season. On both study sites, highly significant differences (p=0.0002 and 0.0001)

Table 10. Significance levels for sources of variation for different nutrients in plant species during 1988.

Source	Dry Matter%	Ash%	Phosphorus%	Crude Protein%	ND Fiber%	AD Fiber%
Tomagh:						
Plant species	0.01	0.01	0.01	NS	0.01	0.01
Seasons	0.01	NS	0.01	0.01	0.05	0.01
Zarchi:						
Plant species	0.05	0.01	NS	0.01	0.01	0.01
Seasons	0.01	NS	0.01	0.01	0.01	0.01

Table 11. Significance levels for sources of variation for protein and phosphorus in plant species during 1988 and 1989.

Source	Crude Protein%	Phosphorus%
Tomagh:		
Year	0.01	0.05
Season(year)	0.01	0.01
Plant species	NS	NS
Year x Plant species	0.05	0.01
Zarchi:		
Year	NS	NS
Season(year)	0.01	0.01
Plant species	0.05	NS
Year x Plant species	NS	NS

occurred among plant species in their ash content (Table 10). However, at Tomagh, means of grass species were not significantly different from each other at 0.05 alpha level. The mean ash content of grass species ranged between 7.29% to 8.37%. Forbs did not differ from each other except Phlomis stewartii. Mean ash values of forbs were similar to grasses (alpha = 0.05). The means of shrubs exhibited a wide range of values. Salvia cabulica had the highest mean ash value of 12.0% whereas Convolvulus spinosus possessed the lowest (4.0%). Means of all plant species (including forbs and grasses) were found within this range (except Phlomis stewartii). Among Zarchi plant species, Hordeum murinum and Haloxylon griffithii possessed the highest mean ash content which was 14.16% and 13.81%, respectively. Both were significantly different (Alpha=0.05) in their mean ash content from all other plant species. Among forbs, Gallonia erientha contained the lowest mean ash content of 7.41% than other forbs and was significantly different. Mean ash values of shrub species were not statistically different except Hertia intermedia and Haloxylon griffithii. Both these plant species were significantly different from forbs in their ash values.

Phosphorus

On both study sites, the phosphorus concentration of the herbage declined significantly with maturity (p=0.000).

The phosphorus content of plant species among 1988 and 1989 differed significantly (p=0.053) only in Tomagh study area (Table 11). This was probably because of the amount and distribution of precipitation and its confounded effect with temperature during both years. In 1989, phosphorus values of plants at both study sites were higher at vegetative stage. However, a rise in phosphorus contents of all three forage classes occurred after the summer of 1988 on both sites (Figure 16 and 18). This is probably due to fall regrowth of herbage since there was late summer precipitation this year. Our results agreed with Rauzi (1975) who found a significant decline in the phosphorus concentration of herbage with maturity. Cook and Harris (1968) found that grasses were decidedly lower in phosphorus concentration than either forbs or browse during all periods of summer. Surprisingly, during both years, data in this trial disagreed with Cook and Harris. On both sites, plant species were not statistically different in phosphorus concentrations. Grasses were as equal as shrubs or sometimes little higher in their phosphorus. Our findings partially agreed with Rauzi (1975) who noticed no significant difference in the phosphorus concentration of herbage between second and fourth harvests. Mean phosphorus values of three forage classes are shown in Tables 8 and 9 and phosphorus content of individual plant species are given

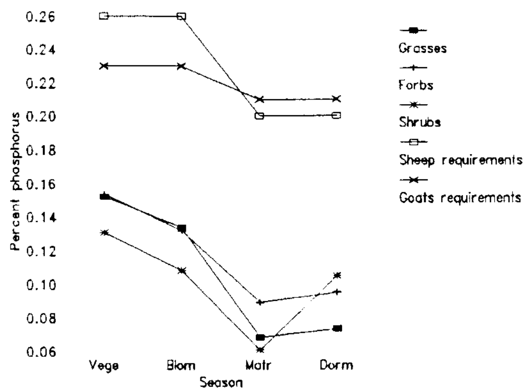

Figure 16. Phosphorus availability and animal requirements during 1988 at Tomagh station.

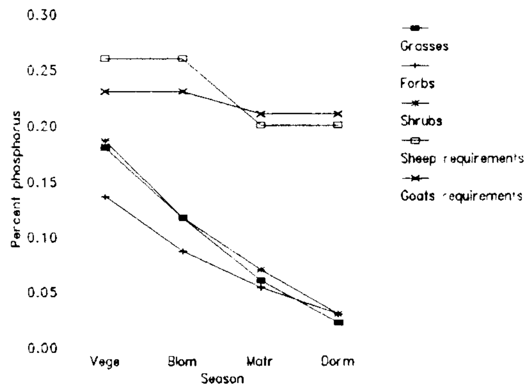

Figure 17. Phosphorus availability and animal requirements during 1989 at Tomagh station.

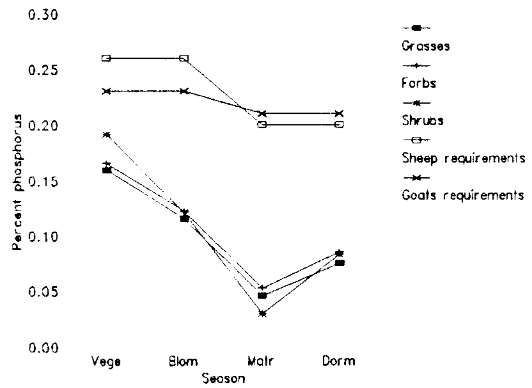

Figure 18. Phosphorus availability and animal requirements during 1988 at Zarchi station.

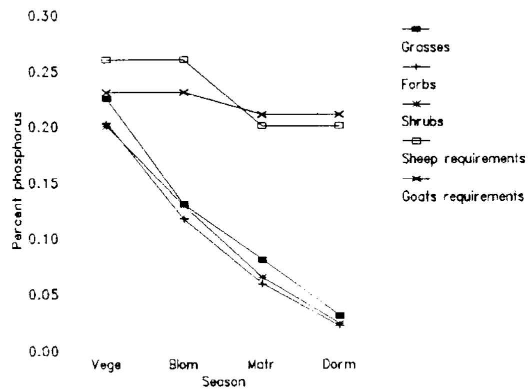

Figure 19. Phosphorus availability and animal requirements during 1989 at Zarchi station.

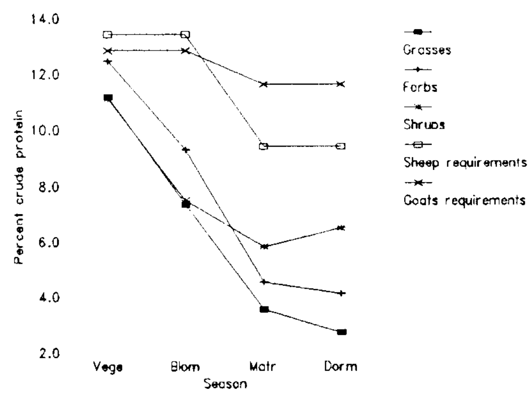

Figure 20. Crude protein availability and animal requirements during 1988 at Tomagh station.

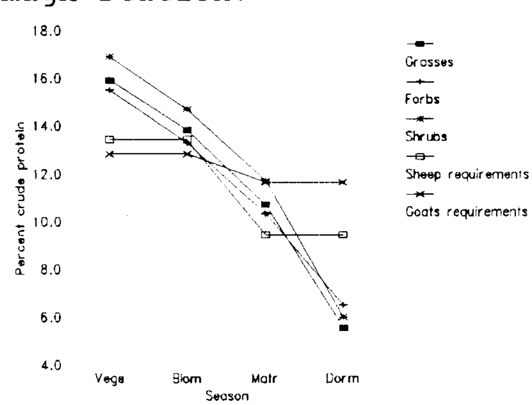

Figure 21. Crude protein availability and animal requirements during 1989 at Tomagh station.

in Appendices F and G. On both sites, the average P content of all three forage classes (grasses, forbs and shrubs) were well below the animal requirements across all the seasons during both years (Figures 16 - 19). Maximum availability of P was during spring season when plants were lush green and at vegetative stage. In spring, all three forage classes provided only about 64.0% and 78.0% of the phosphorus needs of lactating females (sheep and goats) with young on Tomagh and Zarchi sites, respectively. Tables 4 and 5 indicate P availability of different forage classes and its percent share to meet animal needs across seasons. It appears from Table 9 that animals grazing Zarchi area may not face P deficiency during spring since they can improve their dietary P content through diet selection and better use of shrub species. However, at Tomagh during the same period it could be difficult for animals to improve dietary P levels 28.0% - 38.0% (Table 8) by a diet selection process because all forage classes indicated inherent low P concentration (Appendix F). It appears that animals grazing Baluchi ranges experience severe P deficiencies for other periods of the year. All three forage classes on average supply enough P for 23.0% to 50.0% of animal needs. Phosphorus supplementation on these Baluchi ranges is mandatory throughout the year except early to mid spring. Otherwise severe P deficiency can result in imbalance of Ca and P ratio in the animals body. Mineral reserves of

Table 12. Nutrient requirements of sheep.

Months	Physiological Stage	DM%*	TDN%*	CP%*	P%*
September	Maintenance	2.00	55.00	9.40	0.20
October	Early gestation	2.40	55.00	9.40	0.20
November	Early gestation	2.40	55.00	9.40	0.20
December	Mid gestation	2.40	55.00	9.40	0.20
January	Late geststion	3.20	59.00	10.70	0.23
February	Late geststion	3.20	59.00	10.70	0.23
March	Lactation	4.20	65.00	13.40	0.26
April	Lactation	4.20	65.00	13.40	0.26
May	Lactation	4.20	65.00	13.40	0.26
June	Maintenance	2.00	55.00	9.40	0.20
July	Maintenance	2.00	55.00	9.40	0.20
August	Maintenance	2.00	55.00	9.40	0.20

* = percent of ration

Table 13. Nutrient requirements of goats.

Months	Physiological Stage	DM%*	TDN%*	CP%*	P%*
September	Maintenance	4.3	60.00	11.60	0.21
October	Early gestation	4.3	60.00	11.60	0.21
November	Early gestation	4.3	60.00	11.60	0.21
December	Mid gestation	4.3	60.00	11.60	0.21
January	Late geststion	5.9	63.00	11.70	0.19
February	Late geststion	5.9	63.00	11.70	0.19
March	Lactation	6.16	67.00	12.80	0.23
April	Lactation	6.16	67.00	12.80	0.23
May	Lactation	6.16	67.00	12.80	0.23
June	Maintenance	4.3	60.00	11.60	0.21
July	Maintenance	4.3	60.00	11.60	0.21
August	Maintenance	4.3	60.00	11.60	0.21

* = percent of ration

reproducing females will be depleted, which can cause infrequent conception and low fertility rates in flocks. Reduced birth weights, weaning weights and a decline in daily weight gains by growing lambs and kids will cause delayed puberty. As a consequence, animal production is limited on these rangelands. Cook and Harris, 1977 reported that some workers obtained increased wool yield and lamb crop for sheep and increased calf weights by supplementing phosphorus and protein in combination.

Crude Protein

Crude protein values of all forage species declined throughout the grazing seasons in both years (Table 8 and 9). Differences among seasons were highly significant (p=0.000). A slight increase in protein content of herbage was observed during fall of 1988 on both sites (Figures 20 - 23). It was caused by summer precipitation and consequent regrowth. The CP concentrations of plant species in 1988 were lower than in 1989. The differences among years were highly significant (p=0.000) only for Tomagh site (Table 10 and 11). In both years, CP concentrations of plants at the vegetative stage were higher than that of other growth periods. Vegetation initiated growth in early spring (sometimes in March), at which time CP content of plant

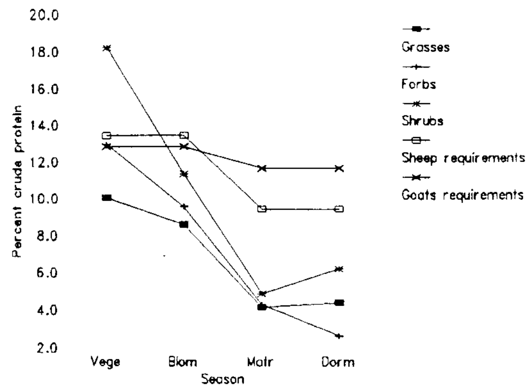

Figure 22. Crude protein availability and animal requirements during 1988 at Zarchi station.

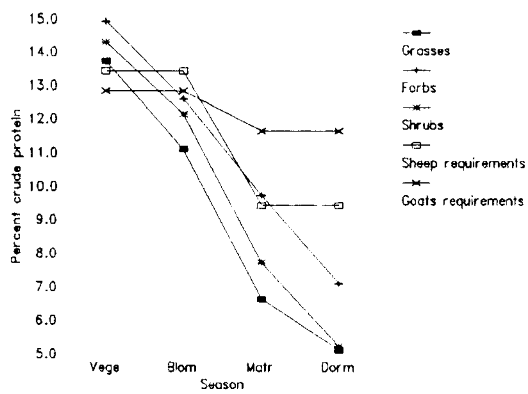

Figure 23. Crude protein availability and animal requirements during 1989 at Zarchi station.

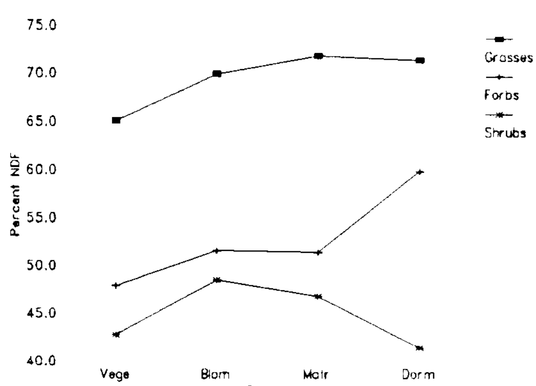

Figure 24. Neutral detergent fiber of forage classes during 1988 at Tomagh station.

species was at peak. However, CP concentration closely followed the growth periods (Figure 20 - 23). At the dormant stage (First week of October), CP concentrations reached lowest levels. It is suspected that a further decline in CP content of herbage after reaching maturity (1st week of July) is attributed to leaching by rainfall (Laycock and Price,1970).

On both sites, plant species did not differ significantly in their CP contents. In 1988, a sharp decline in the CP content of plant species was observed after the first period on Tomagh site. Grasses were most rapid and their CP content declined from 11.14% to 2.69%. Forbs registered a decrease from 12.44% to 4.11%. Shrubs were relatively consistent after a rapid decline of CP. Mean CP of shrubs ranged from as low as 6.47% to maximum 11.06%. During 1989, all plant species were more consistent in their CP levels. The mean CP concentrations were above 10% until the first week of July, the CP content dropped suddenly at dormant stage for all forage classes (Table 8).

At Zarchi, grasses presented CP content as high as 10.0% and as low as 4.4%. The CP concentrations of forbs varied from 12.90% to 2.57%. Shrubs had a more consistent CP content than the other two groups with CP concentration ranging from 18.17% to 4.82% during 1988 (Table 9). In 1989, forbs and shrubs were very close in their CP concentration. Both forage classes were slightly higher in their CP concentration than grasses. Shrubs were lower in CP contents in 1989 than 1988. It is hypothesized that spring rains caused more leaching in shrubs than other forage classes.

In spring, sheep and goats need respectively 13.40% and 12.80% protein in their diets (Tables 8 and 9). Plant groups growing on Tomagh range had CP slightly below the animal requirements, however, deficiencies were not serious. Animals would have managed it by a selective behavior during spring (Figure 20). However, animals would have faced severe protein deficiencies for all other seasons of 1988. The CP content of all three forage groups were well below the animal needs. Grasses provide bulk of animal diets on this range. Those contained 2.69% CP at dormant stage compared to animal requirement of about 10% CP. In 1989, all three plant groups met the animals CP needs till the first week of July (Figure 21). Animals therefore would need CP supplementation after the third week of July. It indicated that in a normal rain year, CP deficiencies are not critical to animal production at Tomagh. Although animals would definitely require protein supplementation during winter when dried dead plant material is all that is available to animals on ranges.

In the Zarchi area, shrubs and forbs met the animals CP requirements at vegetative stage during 1988 (Figure 22). During May (bloom stage) only, shrubs were relatively consistent in their CP values. Shrubs maintained slightly lower CP contents than the animals required, however, I believe animals will select higher quality forage and can cope with this problem. All forage classes were decidedly lower in their CP levels for the rest of the year. In 1989, CP deficiencies were severe after the late spring (Figure 23). It indicated that deciduous shrubs like Artemisia maritima dropped their leaves rapidly after the last week of May. On this type of range, protein supplementation in combination with P would be necessary to sustain animals during most of the year.

In general these findings were in agreement with others like Bedell, 1970; Rauzi, 1975; Meyer and Brown, 1984; Pinchak et al. 1990, and Cook and Harris, 1977. These researchers observed a decline in protein for all classes of forages from the beginning of the grazing season until grazing ceased.

Detergent Fibers

Concentrations of neutral detergent fiber (NDF) and acid detergent fiber (ADF) were strongly affected by maturation (Dabo et al., 1988). Advance of season brought highly significant (p=0.057 for NDF at Tomagh; others p=0.000) changes in detergent fiber content of plant species on both sites (Table 10). Detergent fiber of plant species and its phenological stage had a strong positive linear

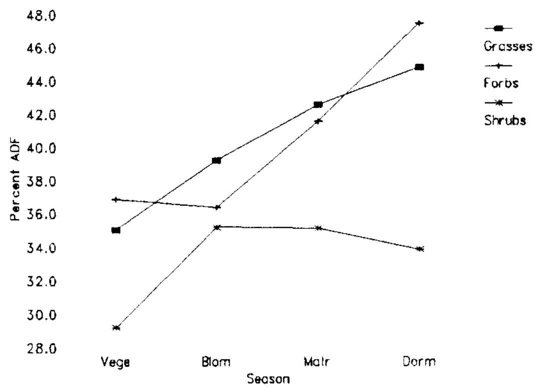

Figure 25. Acid detergent fiber content of forage classes during 1988 at Tomagh station.

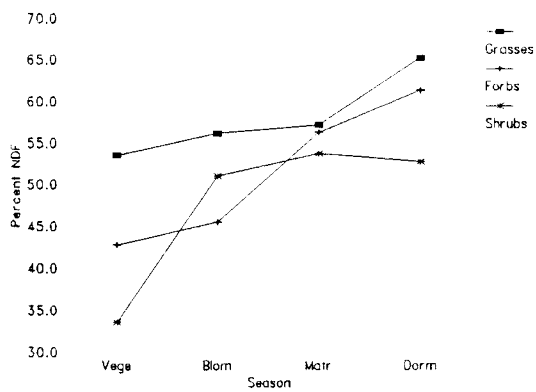

Figure 26. Neutral detergent fiber content of forage classes during 1988 at Zarchi station.

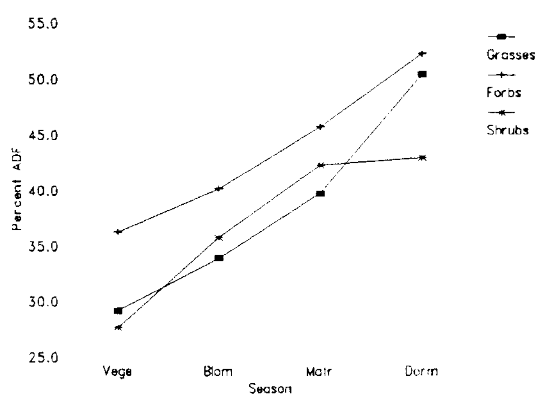

Figure 27. Acid detergent fiber content of forage classes during 1988 at Zarchi station.

relationship (Figures 24 to 27) except in the case of shrubs on Tomagh range, where the seasonal trends in DF concentrations were less distinct. Mean NDF content reached 48.35% at bloom stage compared to 42.60% at the beginning of growth season. The NDF concentrations declined afterwards and reached a low of 41.23% at maturity. The ADF concentrations of Tomagh shrubs increased to 35.14% at bloom stage and were relatively stable for the remaining periods. This is logical since shrubs are rather deeply rooted at this site and keep their leaves throughout the summer (until the onset of winter). Shrubs of Zarchi did show a minor decline in their DF contents after maturity (Figures 26 and 27). This is caused by regrowth after light summer rains.

On both sites mean NDF concentrations of the grasses were higher than the non-grasses during all seasons (Tables 8 and 9). Hart et al. (1983) and Meyer and Brown (1984) reported similar results in their studies. Forbs were second highest and shrubs had lowest NDF concentration throughout all seasons, in both areas. At the Tomagh site shrubs were always lowest in their ADF contents (Table 8), however, forbs were similar to grasses in ADF concentration at various growth stages (Table 8). Among plant groups in Zarchi, Forbs had highest ADF concentrations during all the seasons and their average concentration increased from initial 36.23% to 52.19% at dormant seasons. Shrubs had maximum ADF content at maturity and dormant stages (42.23%

and 42.96%, respectively). The mean ADF concentration of shrubs were lowest (27.57%) in the early growing season. <u>Hordeum</u> <u>murinum</u>, the only annual grass had 29.10%, 33.86%, 39.69% and 50.34% ADF concentrations, respectively, for four growth seasons. Our results regarding detergent fibers of plant species closely agree with those obtained by Dabo et al. (1988). Cellulose, hemicellulose and lignin constitute the NDF component of plant cell walls. NDF is a better measure of forage quality than is the more frequently reported ADF because, ADF presents hemicellulose as a completely digested fraction. This can be erroneous as hemicellulose is actually less digested than cellulose in various plant species (Van Soest, 1982). Grasses are the highest in energy yielding cellulose (Cook and Harris, 1977). Since grasses made up 67.0% to 95.0% of the total herbage at Tomagh across all seasons during both years, energy deficiency may not be a constraint to better animal production on grass dominated Baluchi ranges like Tomagh (provided the grasses produced are palatable). Browse plants are lowest in cellulose (Cook and Harris, 1977). On the Zarchi range, shrub contribution to total forage production ranged between 83.0% to 99.0% across all seasons of both years. Their low NDF (>50.0%) throughout the year indicated severe energy deficiency problems for sheep and goats . Supplementation with energy rich feeds or reduced stocking density may increase animal production.

Table 14. Sheep and goat diets during 1988 at Tomagh station.

		Season				
	Plant species	Vege	Blom	Matr	Dorm	Overall
Sheep	Phlomis stewartii	2.84	0.95	2.32	15.20	5.45
	Other forbs	0.20	0.56	0.00	0.78	0.33
	Total forbs	3.03	1.50	2.82	15.98	5.84
	Saccharum spp.	77.90	55.20	73.26	71.80	69.54
	Chrysopogon aucheri	2.86	21.90	4.03	1.53	7.58
	Cymbopogon shoenanthus	10.29	6.06	4.30	1.02	5.42
	Cynodon dactylon	4.14	6.51	6.71	1.00	4.59
	Other grass	0.94	2.35	7.75	5.93	4.24
	Total grasses	96.13	92.02	96.05	31.28	91.37
	Perwoskis artiplicifolia	0.00	1.14	0.39	1.69	0.93
	Other shrubs	0.45	2.13	0.00	0.97	0.39
	Ebenus stellatus	0.00	2.90	0.00	0.00	0.72
	Pteropnyrum olivieri	0.00	0.33	0.24	0.00	0.14
	Total shrubs	0.45	6.50	1.13	2.65	2.63
Goats	Phlomis stewartii	2.93	1.33	2.28	17.92	6.12
	Other forbs	0.00	4.63	0.21	3.77	2.15
	Total forbs	2.93	5.97	2.49	21.69	8.27
	Saccharum spp.	74.30	51.04	68.03	57.23	62.79
	Chrysopogon aucneri	5.37	12.77	3.23	0.93	5.70
	Cymbopogon shoenanthus	8.00	6.38	1.35	0.61	4.21
	Other grass	0.86	2.07	7.34	2.37	3.41
	Cynodon dactylon	2.84	0.27	4.28	0.96	2.09
	Total grasses	92.37	72.52	85.29	62.59	73.19
	Perwoskis artiplicifolia	0.94	2.39	2.76	11.06	4.29
	Other shrubs	1.25	7.67	0.92	3.74	3.40
	Ebenus stellatus	2.50	9.37	0.24	0.62	3.18
	Pteropnyrum olivieri	0.00	2.08	8.30	0.00	2.60
	Total shrubs	4.70	21.51	12.22	15.42	13.46

Table 15. Sheep and goat diets during 1989 at Tomagh station.

	Plant species	Season Vege	Blom	Matr	Dorm	Overall
Sheep	Phlomis stewartii	0.00	0.00	3.37	0.10	0.87
	Cymbopogon shoenanthus	89.17	62.64	20.57	24.98	49.34
	Other grasses	0.00	0.07	39.95	33.48	18.38
	Chrysopogon aucheri	3.48	20.03	13.99	18.72	14.05
	Tetrapogon spp.	2.87	10.66	9.51	10.46	8.37
	Total grasses	95.53	93.39	84.03	87.63	90.14
	Ebenus stellatus	0.00	6.57	0.37	5.91	3.21
	Perwoskis artiplicifolia	0.00	0.00	6.32	5.36	3.04
	Other shrubs	2.37	0.00	0.98	0.43	0.95
	Olea ferruginea	0.00	0.00	3.12	0.00	0.78
	Ephedra intermedia	1.3[illegible]	0.04	0.00	0.08	0.36
	Caraguna ambuguea	0.00	0.00	0.45	0.00	0.11
	Rhamnus persica	0.00	0.00	0.00	0.00	0.00
	Total shrubs	3.68	6.61	11.25	12.27	8.45
Goats	Phlomis stewartii	2.35	4.35	5.21	0.00	3.10
	Cymbopogon shoenanthus	52.46	24.10	12.24	17.27	26.52
	Other grasses	5.04	0.00	18.25	34.35	14.41
	Chrysopogon aucheri	6.11	17.39	4.52	14.72	10.68
	Tetrapogon spp.	0.00	3.52	0.59	1.30	1.48
	Total grasses	63.60	45.01	35.59	68.14	53.09
	Ebenus stellatus	27.66	18.54	17.28	10.40	18.47
	Caraguna ambuguea	0.32	0.93	13.28	12.56	6.77
	Olea ferruginea	0.00	8.50	6.70	6.68	5.47
	Perwoskis artiplicifolia	0.00	0.00	17.06	1.07	4.53
	Rhamnus persica	0.00	9.42	0.81	0.00	2.56
	Ephedra intermedia	0.00	8.02	0.58	0.68	2.32
	Other shrubs	4.94	0.00	0.20	0.49	1.41
	Total shrubs	32.92	45.42	55.90	31.87	41.53

Botanical Composition of Animal Diets

Tomagh-Sheep

In 1988, percent contribution of forage classes to the diets of sheep averaged across all four seasons was highest for grass (91.0%) followed by forbs (6.0%) and shrubs (3.0%). Overall sheep diets during 1989 comprised of 90.0% grasses, 9.0% shrubs and a forb component about 1.0% (Figures 28 and 29). Botanical composition of sheep diets reported by Kothman (1968) and Bryant et al. (1979) consisted of grasses, shrubs and forbs in quite similar order. A shift in the order of forb and shrub components of sheep diets happened between years 1988 and 1989. The year 1988 was dry. Grasses growing on the range area dried up rapidly and consequently sheep were searching for green herbage in the dry stream beds where plant species remained green for longer periods. *Phlomis stewartii*, a perennial forb usually found on the places high in soil moisture, was preferred over the browse species. This contention is also supported by a very high consumption of *Saccharum spp.* (69.53%) by sheep which was found only in stream beds (Figure 28). In general, sheep consumed less browse and forbs during both years. Possibly, the increased availability and variety of grasses in this area encouraged sheep to select more grasses than non-grasses (Bryant et al., 1979). Our results also agreed with the findings of

MacCracken and Hansen (1981) who generalized that sheep would usually rely on grasses as their major diet component, while forbs might be selected opportunistically.

Through years, sheep were consistent in their use of grasses and across times grasses made up more than 80.0% of the sheep diet. In 1988, sheep grazed mostly in riparian zones where they heavily utilized the _Saccharum spp._ throughout the year (Table 14). Sheep also selected _Cynodon dactylon_ which was growing in stream channels in extremely low quantities. The percentage of _Cynodon dactylon_ in sheep diets ranged from 1.0% to 7.0% throughout the seasons. Sheep diets during 1988 were consistently low in _Cymbopogon shoenanthus_ which was most abundant on Tomagh rangeland. Since riparian plants were green, this indicates strong preference by sheep for green herbage over dry and more mature plant tissues which is contrary to the findings reported by Hamilton et al. (1973). They concluded that when the amounts of green herbage on offer were low, sheep did not continue to select a diet containing a high proportion of green plant material. The proportion of _Chrysopogon aucheri_ , a palatable perennial grass, in the sheep diets during 1988 was highest in May (22.0%). It appeared that the selectivity for _Chrysopogon aucheri_ by sheep was related to its availability on the range. Shrubs were not an important component of sheep diets in 1988. On average their proportion was less than 3.0% (Table 14). A seasonal botanical composition of sheep diets during 1988 is shown in Figure 30.

During an average year, like 1989, sheep can heavily utilize Cymbopogon shoenanthus at vegetative stage when grass tillers are tender and succulent. However, its proportion in the sheep diets declines sharply as the plants get coarser (Table 15). Other grasses like Saccharum spp. and Cynodon dactylon would replace Cymbopogon shoenanthus in sheep diets during later seasons of the year (Figure 31). On average, sheep diets consisted of less than 9.0% shrub species during 1989 at Tomagh. Percentage of shrubs in the diets increased when grasses, mainly Cymbopogon shoenanthus became mature in the later seasons (Table 15). Bryant et al. (1979) also found that browse began to replace the herbaceous component of sheep diet when grasses and forbs were mature. The annual forbs were not frequently encountered on this range. Therefore, forbs contribution into sheep diets remained negligible.

Tomagh-Goats

In 1988, goat diets were approximately similar to sheep diets. Overall, grasses made up 78.0% of the total diet. Among grasses Saccharum spp. was heavily and consistently selected by the goats. On average Phlomis stewartii contributed about 6.0% of the total diet. It indicated that goats also mainly walked within the stream passages in

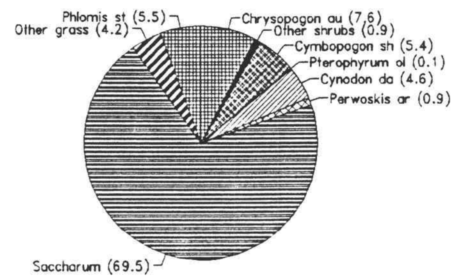

Figure 28. Overall sheep diets during 1988 at Tomagh station.

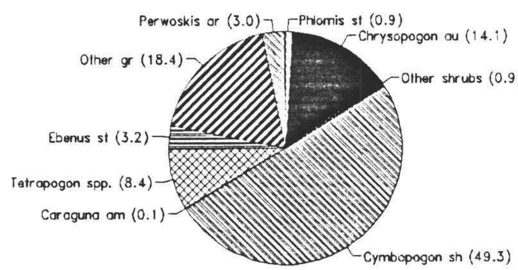

Figure 29. Overall sheep diets during 1989 at Tomagh station.

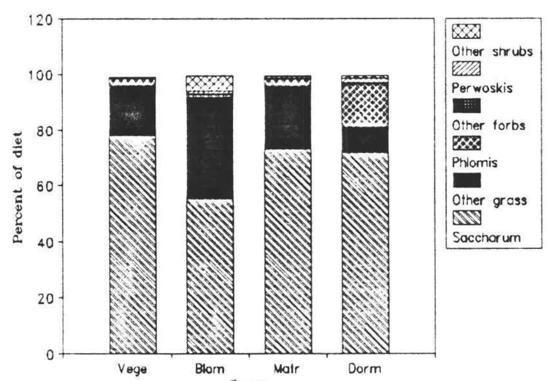

Figure 30. Sheep diets during 1988 at Tomagh station.

search of green food material. The average shrub percentage of the diet was higher (13.46%) which indicated goats greater ability to utilize browse normally unapproachable by sheep. Based on our results, it is concluded that Saccharum spp. could be a potential forage source for sheep and goats under drought conditions. However, special management tools like cutting down the old growth would be required to improve its acceptability by maintaining green growth for longer periods.

Malechek and Provenza (1981) reported that goats select more browse than do sheep, but often utilize considerable amounts of grass particularly during the height of the growing season. In our study, grasses represented 92.37% of the goats diets during the spring of 1988. Grasses remained major dietary components throughout the year. However, grass portion of the diet declined (62.54%) in fall of 1988 when an increase in forb component (21.69%) began. Considerable amounts of Phlomis stewartii was consumed (Table 14). Probably, any regrowth of this perennial forb attracted goats. Goats neglected Cymbopogon shoenanthus throughout all seasons. Its percentage in goat diets was negligible relative to its amount on Tomagh range. Goats did like Chrysopogon aucheri in spring but its percentage declined in later seasons (Table 14), possibly because goats spend more time in riparian zones. Among shrubs Ebenus

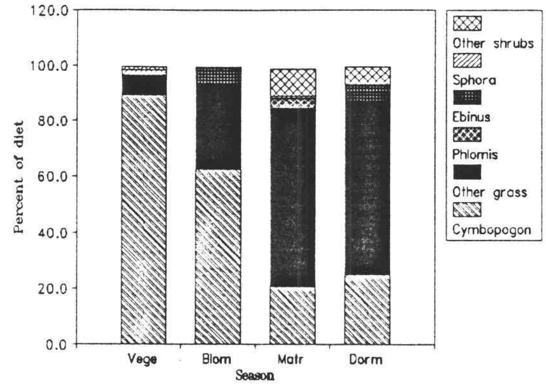

Figure 31. Sheep diets during 1989 at Tomagh station.

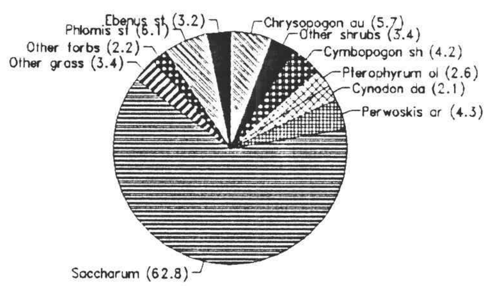

Figure 32. Overall goat diets during 1988 at Tomagh station.

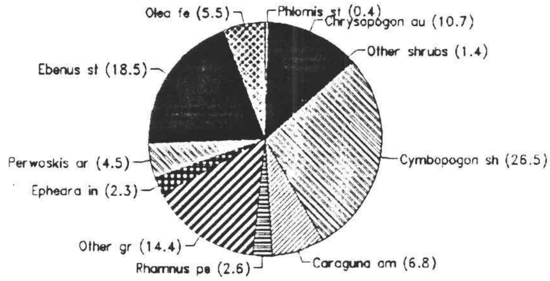

Figure 33. Overall goat diets during 1989 at Tomagh station.

stellatus, a deciduous bush was important for goats at bloom stage when it still had plenty of leaves and flowers. Pfister and Malechek (1986) found that fruits and flowers were seasonally important in animals diets. Various other studies (as quoted by Pfister and Malechek, 1986) indicated that these plant parts may be crucial to animals survival at times of nutritional stress. Perwoskis artiplicifolia was another shrub which was a component of goat diets throughout the seasons. Its highest contribution (11.0%) was in fall probably because of its succulent regrowth. The amounts of other browse species like Olea ferruginea and Pterophyrum olivieri were variable.

Bite count data of 1989 revealed that the most preferred forage class by goats was grass (53.0%) followed by shrubs (41.53%) and forbs (3.10%). More than 50.0% of goat bites were made on Cymbopogon shoenanthus during early growing season in April. Figure 25 indicates a remarkable decline in goat bites for Cymbopogon shoenanthus during other seasons. A consistent use of Chrysopogon aucheri indicated its preference by goats (Table 15). Among shrubs Ebenus stellatus was a consistently preferred plant species by goats followed by Caraguna ambuguea, Olea ferruginea, Perwoskis artiplicifolia and other shrubs (Table 15). It appeared that goats travelled longer distances across the range area which resulted in diverse shrub selection. The goat bites data is different from those reported and quoted

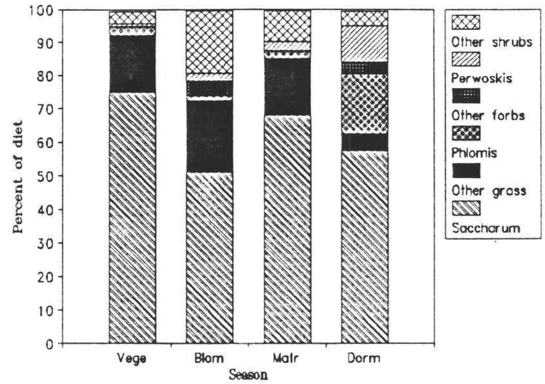

Figure 34. Goat diets during 1988 at Tomagh station.

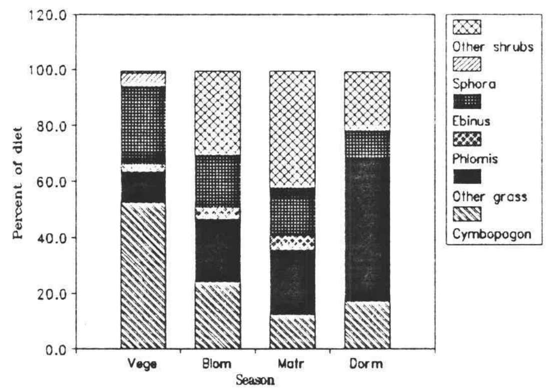

Figure 35. Goat diets during 1989 at Tomagh station.

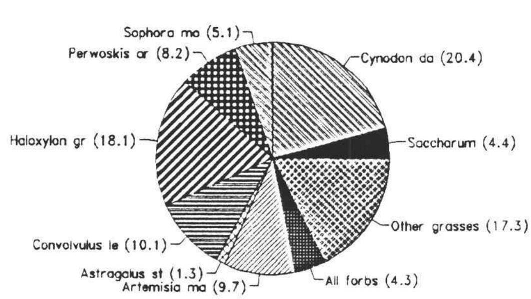

Figure 36. Overall sheep diets during 1988 at Zarchi station.

Table 16. Sheep and goat diets during 1988 at Zarchi station.

		Season				
	Plant species	Vege	Blom	Matr	Dorm	Overall
Sheep	All forbs	7.96	2.99	4.52	1.59	4.26
	Cynodon dactylon	39.90	7.74	8.06	26.08	20.45
	Other grasses	31.18	8.94	20.71	8.27	17.28
	Saccharum spp.	1.53	7.59	2.56	6.09	4.44
	Total grasses	72.62	24.27	31.33	40.44	42.16
	Haloxylon griffithi	3.97	6.18	36.47	25.61	18.06
	Convolvulus leiocalycinus	11.64	12.75	15.44	0.43	10.06
	Artemisia maritima	0.40	10.72	7.58	20.08	9.69
	Perwoskis artiplicifolia	0.00	30.38	1.63	0.36	8.22
	Sophora mollis	0.00	10.25	0.40	9.56	5.05
	Astragalus stocksii	2.09	1.02	2.07	0.00	1.29
	Other shrubs	1.23	1.45	0.42	0.43	0.38
	Total shrubs	19.33	72.74	64.01	56.98	53.26
Goats	All forbs	1.64	4.44	11.43	3.02	5.13
	Other grasses	35.16	8.25	20.10	6.56	17.52
	Saccharum spp.	1.49	20.17	11.75	18.17	12.90
	Cynodon dactylon	17.37	5.23	5.27	5.69	3.39
	Total grasses	54.02	33.66	37.12	30.42	33.81
	Convolvulus leiocalycinus	22.24	15.98	23.19	0.73	15.54
	Astragalus stocksii	16.59	9.70	13.61	6.15	11.52
	Sophora mollis	0.00	2.20	2.13	38.37	10.80
	Artemisia maritima	0.72	10.18	8.28	15.51	8.67
	Perwoskis artiplicifolia	0.00	20.28	2.13	3.79	6.55
	Haloxylon griffithi	1.30	1.16	2.10	0.72	1.45
	Other shrubs	2.59	1.96	0.00	0.78	1.33
	Total shrubs	43.94	61.46	51.45	66.56	55.85

by Ahmed et al. (1981). In their data goat diets were comprised more than 70.0% by browse. Probably this discrepancy in goat diets was because of difference in plant species composition on the ranges.

Both sheep and goats diets across both years indicates that <u>Cymbopogon shoenanthus</u>, the most abundant on Tomagh range, is not a preferred plant species. In the future, special management techniques are required to bring basic changes to plant communities on this range, otherwise sheep and goat productivity will continuously be handicapped by low daily dry matter intakes.

Zarchi-Sheep

Many studies have indicated that sheep are consistent in their use of grasses and normally consume only small amounts of trees and shrubs. Wilson et al. (1975) regarded sheep as grass eaters and in most of their collections the proportion of trees and shrubs species consumed was quite small. Overall sheep diets during 1988 in Zarchi are shown in Figure 36. Sheep demonstrated a strikingly different grazing habit. They consumed a variety of shrubs in large quantity throughout the year. On average, shrubs constituted 53.26% of sheep diets and more than 55.0% in all seasons except April (19.33%), when grasses constituted about two thirds of sheep diets (Table 16). Sheep appeared to shift their diet among shrub species as the season changed. <u>Convolvulus leiocalycinus</u> (Deylunko) appeared to be the most palatable shrub for sheep. Despite the fact that Deylunko did not constitute more than 5.0% of the plant species on Zarchi range, it made up as much as 10% of the sheep diet. During dormancy stage when plants shed their leaves, the percent in the diet decreased. Sheep did not like <u>Artemisia maritima</u> which was the most abundant plant in the area (Figure 38). <u>Haloxylon griffithii</u> was the second most abundant plant species. Its percentage in sheep diets increased gradually (Table 16), probably because sheep needed some time to adapt to its sour taste. In general, <u>Artemisia maritima</u> and <u>Haloxylon griffithii</u> were important as forage source when other species produced minimum dry matter particularly at dormancy (Table 16 and Appendix E). <u>Perwoskis artiplicifolia</u> and <u>Sophora mollis</u> mainly grow within stream channels. Their consumption by sheep was considerable at bloom stage when their new growth was still tender and other plant species had become coarser. Forbs use by sheep was mainly limited to their availability on the range. Grasses contribute very little to the total forage production at Zarchi, even then total grass percentage in sheep diets was unexpectedly as high as 72.62% during spring. <u>Cynodon dactylon</u> and <u>Chrysopogon aucheri</u> comprised 40.0% and 31.0% respectively of the diets. Sheep did not find enough green herbage on the range because of low rainfall in early spring. They grazed mainly on the patches of Cynodon dactylon surrounding water springs. The sheep also searched for Chrysopogon aucheri on the slopes of rolling hills where there was better growing conditions. Grass percentage in the diet declined as season progressed, however, grass patches close to springs were important grazing points for sheep throughout the year. Overall, grasses constituted 42.16% of sheep diets.

Sheep prefer forbs whenever found. About 40.0% of sheep bites were made on ephemeral forbs during the spring of 1989 (Table 17). During late seasons sheep bites on forbs (mainly the perennials Gallonia erientha and Napeta juncea) declined from 14.54% to 7.22%. Overall 17.61% of sheep bites were observed on forbs (Table 17).

During 1989, sheep were not grazed on the rolling hills. Sheep could not find any grass except Poa siniaca in extremely low amounts. On average 80.0% of the sheep diets were comprised of shrubs. Shrubs began to increase in the diets as the dry matter production of short lived annual forbs started declining. Haloxylon griffithii and Convolvulus leiocalycinus were utilized by sheep in similar manner to 1988. Cousinia stocksii appeared to be another good browse source for sheep. On average it received 10.67% bites by sheep. This year (1989) Artemisia maritima was utilized moderately and consistently. It was the most utilized species of 1989. Overall sheep made 40.0% bites on Artemisia plants.

Sheep diets from both years indicated that sheep are strongly affected by forage availability. Sheep do prefer monocots (Squires, 1982). Grasses, forbs and sedges can be major food for sheep (Alexander et al., 1983). However, the browse component of sheep diets could go as high as 90.0% when shrubs dominate the area. This indicates that sheep survive under harsh conditions by making drastic changes in their dietary habits.

Zarchi- Goats

Goats are famous for their ability to utilize browse, however some workers like Migongo-Bake and Hansen (1987) regarded goats as intermediate feeders. Overall goat diets measured in this study during 1988 are shown in Figure 30. Sheep and goats were grazed together. Goats selected approximately equal amounts of grasses as did sheep. On average grasses comprise 39.0% of the sheep diets. Similar to sheep, grasses were utilized consistently by goats (Figure-32). However, overall goats selectivity was greater for <u>Chrysopogon</u> <u>aucheri</u> (17.52%) (other grasses in Table 16) followed by <u>Saccharum</u> <u>spp.</u> (12.90) and <u>Cynodon</u> <u>dactylon</u> (8.39%). <u>Saccharum</u> <u>spp.</u> is a taller species and its increased consumption by goats reflected their browse nature. Forbs were minor diet component because of their limited availability. Overall shrubs made up 56.0% of goat

Table 17. Sheep and goat diets during 1989 at Zarchi station.

	Plant species	Season Vege	Blom	Matr	Dorm	Overall
Sheep	Unknown forb	39.62	3.17	0.00	0.73	10.38
	Gallonia eriantha	0.28	10.36	3.01	0.43	3.52
	Napeta juncea	0.41	1.02	5.38	6.07	3.22
	Other forbs	0.00	0.00	0.00	0.00	0.00
	Total forbs	40.30	14.54	8.39	7.22	17.61
	Poa siniaca	1.85	0.77	0.00	0.37	0.75
	Artemisia maritima	46.38	32.25	40.40	39.60	39.66
	Haloxylon griffithii	3.50	11.86	17.37	22.05	13.69
	Cousinia stocksii	3.35	13.63	11.43	13.79	10.67
	Convolvulus leiocalycinus	0.23	13.25	10.28	13.38	9.29
	Astragalus stocksii	0.27	1.40	8.49	3.40	3.39
	Acantholimon longiflorum	0.64	9.72	2.97	0.21	3.39
	Other shrubs	0.00	1.00	0.00	0.00	0.00
	Total shrubs	54.88	82.11	90.94	92.42	80.08
Goats	Napeta juncea	0.73	8.52	6.50	8.30	6.01
	Gallonia eriantha	1.19	3.00	4.79	0.31	2.32
	Unknown forb	8.29	0.00	0.00	0.59	2.22
	Other forbs	0.00	0.00	0.00	0.29	2.24
	Total forbs	10.21	11.52	11.28	9.48	12.79
	Poa siniaca	1.23	0.84	0.00	0.21	0.57
	Artemisia maritima	30.65	3.53	19.89	24.31	19.59
	Convolvulus leiocalycinus	16.03	18.75	20.62	19.55	18.74
	Astragalus stocksii	12.51	21.27	23.09	10.00	16.72
	Cousinia stocksii	12.95	3.36	9.47	22.24	12.13
	Haloxylon griffithii	6.53	2.48	11.09	13.64	8.43
	Acantholimon longiflorum	6.42	10.23	2.43	0.58	4.92
	Other shrubs	0.00	2.54	0.00	0.00	6.09
	Total shrubs	85.09	62.67	86.60	90.31	86.52

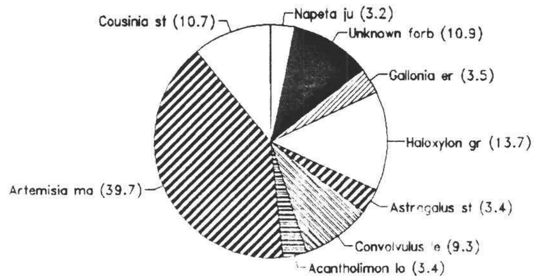

Figure 37. Overall sheep diets during 1989 at Zarchi station.

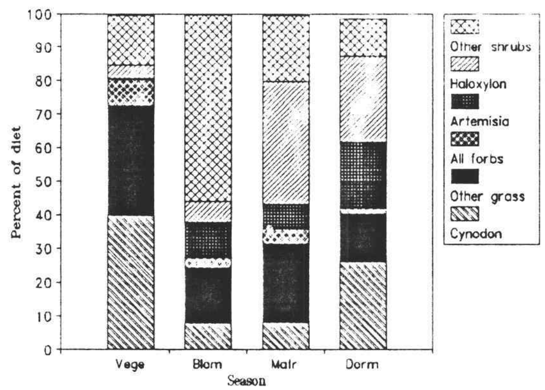

Figure 38. Sheep diets during 1988 at Zarchi station.

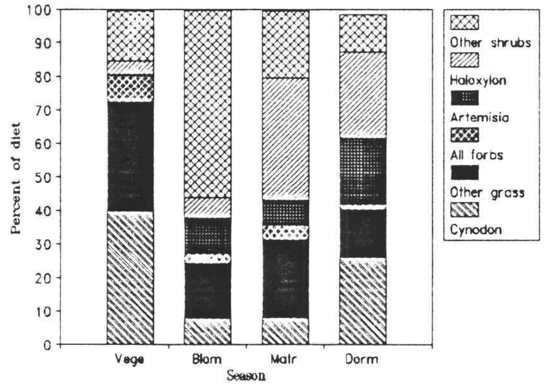

Figure 39. Sheep diets during 1989 at Zarchi station.

diets (Figure 40). Shrubs were utilized consistently. Their percentage in goat diets ranged from 44.0%to 65.0% across the seasons. Wilson et al. (1975) determined the diets of feral goats which consisted 50.0% browse and browse component of the diet ranged from 70.0% to 90.0%. Malechek and Provenza (1981) quoted the results of several studies which indicated important variations, either seasonally or monthly. The patterns of variations differed greatly from study to study because of differences in prevailing forage conditions.

Although the overall shrub component of sheep and goats diets did not differ, they differed in the extent of utilization of various shrub species. Among shrubs, goats primarily selected Convolvulus leiocalycinus and Astragalus stocksii. Most of the time they nibbled the leaves of both bushes. Goats did not like Haloxylon griffithii throughout all the seasons (Table 16). Artemisia maritima and Perwoskis artiplicifolia were utilized similarly to sheep. However, goats consumed considerable amounts of Sophora mollis during fall when other shrubs were entering dormancy. This indicates that goats are capable of utilizing low preference green plant species when palatable green plant material is limited.

In 1989, goats utilized three forage classes in a quite similar order to that exhibited by sheep during the same period. Overall shrubs comprised 81.17% of the total bites by goats followed by forbs 10.62% and grass 0.57% (Figure 41). _Poa siniaca_ was consumed according to its availability. Forbs consumption was consistent and perennial forbs were mainly selected in later seasons. Among shrubs, _Convolvulus leiocalycinus_ and _Astragalus stocksii_ remained most preferred plant species. Although, on average higher percentage of the goat bites were for _Artemisia maritima_ (19.59%) but goats were not consistent in eating it. Preference for _Haloxylon griffithii_ and _Cousinia stocksii_ was improved over the previous year. The use of _Haloxylon griffithii_ by goats increased gradually (Figure 43).

Based on two years sheep and goats diets data, we suggested that management should be directed towards _Convolvulus leiocalycinus_. It is a palatable browse species liked equally by both kinds of livestock. Further studies would be required to gather information about its germination rate, seed production, growth rates and patterns etc. for its successful propagation on Baluchi ranges.

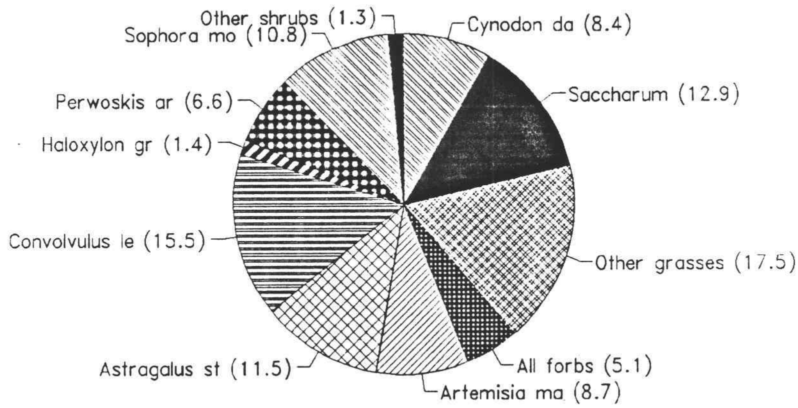

Figure 40. Overall goat diets during 1988 at Zarchi station.

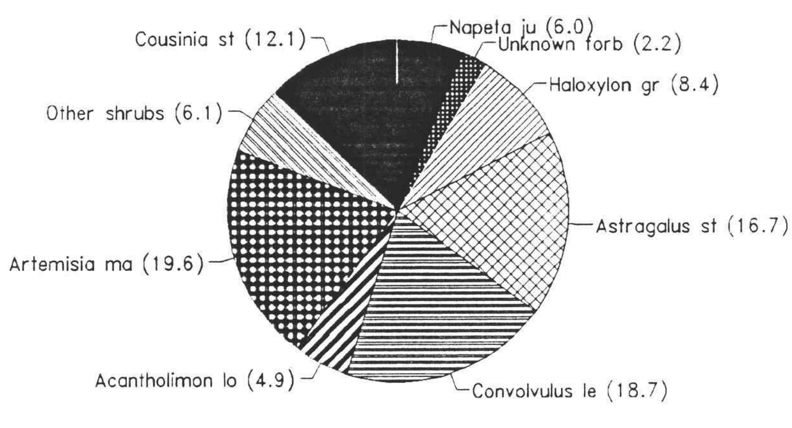

Figure 41. Overall goat diets during 1989 at Zarchi station.

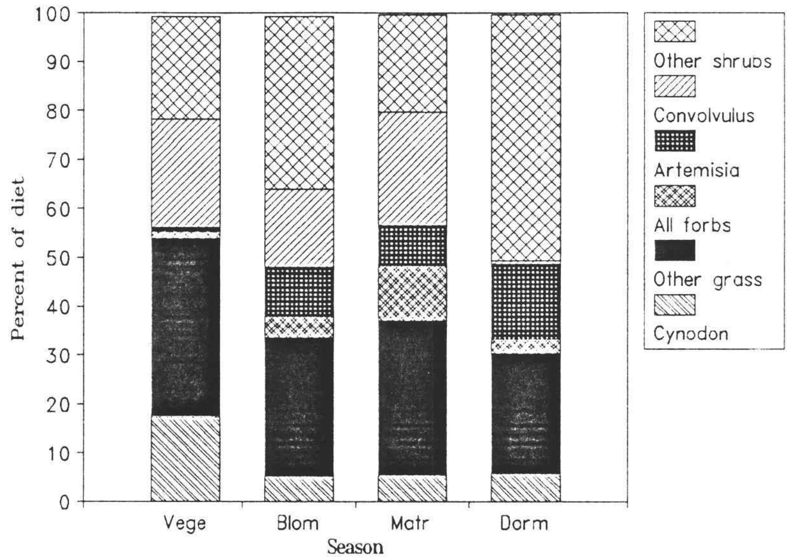

Figure 42. Goat diets during 1988 at Zarchi station.

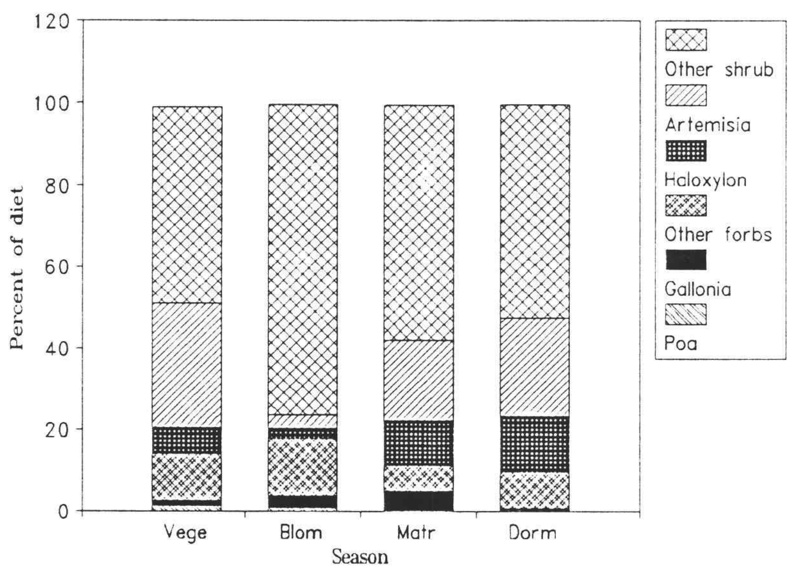

Figure 43. Goat diets during 1989 at Zarchi station.

MANAGEMENT IMPLICATIONS

In Baluchistan, grazing lands are used extensively for livestock production, often with low capital investment on the part of herders. Plant production levels are a primary constraint to management of these ranges. Large, natural variations in the forage available to animals result from weather patterns which demonstrate both year to year and seasonal instability. As a result of these conditions and continuous overstocking, the pastoralists in Baluchistan that rely completely upon range forage suffer from oscillations in animal numbers and productivity (Buzdar and Jameson, 1984). Today, rangelands in Baluchistan are almost completely devastated by overgrazing, however many opportunities for improved range management exist if scientifically based management techniques can be implemented.

Tomagh

It is wise to set stocking rates by calculating the standing crop of those plants eaten by livestock (or projected standing crop for a particular season), animal requirements, and the nutritional content of the forage resources. Table 5 indicates the animal unit months (AUM) available on the Tomagh range based on the per hectare dry matter productivity. In most years, if grazing pressure is moderate (Table 5), forage quantity should not limit animal production. Protein resources then are important if herders are to maintain animal production. Table 17 indicates the available protein on a per hectare basis. When the quality (or quantity) of range forages become limiting to animal production the nutrient needs of animals should be met through external forage sources. For example, if energy is deficient yet protein and phosphorus is adequate then feeding a medium quality straw would be advantageous.

On the Tomagh ranges, especially during the later seasons, when the quality of consumable forage is low and much of the current years production has been consumed, animals would need to be supplemented or moved to shrublands that had been left ungrazed during the spring. Controlled grazing could be used to maintain higher quality in plants for later grazing. If <u>Cymbopogon</u> <u>shoenanthus</u> can be intensively grazed early in the year then protected, it should be possible to elongate the period over which it remains in a vegetative state. This strategy could increase the quality of forage available to animals later in the year since regrowth is typically higher in digestible dry matter and protein.

Creep feeding and early weaning of lambs and kids is another option. This technique can reduce the need for high quality forages in the summer by altering the physiological status of females. Also if the young animals are supplemented, they will grow faster and be better able to adjust to coarser, fibrous forage during later seasons.

Late summer monsoons initiate regrowth of vegetation in this region. Under normal circumstances, animals should be able to maintain minimal levels of nutrient intake from the onset of the monsoons until late fall.

Consideration should always be given to the plants that the flocks depend upon for food. These plants must be allowed to remain in good condition and high vigor. They must maintain enough leaf area to permit assimilation of carbohydrates necessary for successful competition against less desirable plants. Unfortunately, many of the most desirable plants have already been lost over much of this rangeland.

Zarchi

Because Zarchi is dominated by shrubs, this range typically provides animals with high quality forage. Adequate levels of protein are obtained by the flock until early summer if dry matter intake is adequate. At the current stocking densities however, animals have limited intake and therefore energy. Phosphorus deficiencies can also be severe except during the spring.

Stocking rates should be based on dry matter supplies of consumable plants on this rangeland. Digestible energy or dry matter production should be balanced against the amount removed by grazing animals always maintaining enough residual plant material to insure plant health. Stocking rates based upon measured (1987-1988) forage supplies (Table 5) and the requirements and availability of primary nutrients are presented in Tables 8, 9, 12 and 13.

The daily dry matter intake limitations of sheep and goats are important considerations when developing carrying capacities. The estimated average daily dry matter intake for sheep and goats on both sites are presented in Table 18. These estimates are based, unfortunately on the lignin ratio technique which was shown to have a substantial intrinsic error (100+ %). Since samples of the diet of both sheep and goats were collected it is possible to determine the digestibility from <u>in vitro</u> techniques. This analysis will be done upon my return to the Arid Zone Research Institute in Quetta, Pakistan. Additional research is needed on many topics including development of standard procedures for estimating daily dry matter intake by free roaming grazing animals.

Table 18. Estimated daily dry matter intake by sheep and goats using lignin ratio technique.

Site	Animal Species	Year	Vege	%ofB.Wt.	Blom	%ofB.Wt.	Matr	%ofB.Wt.	Dorm	%ofB.Wt.
					Season					
Tomagh	Sheep	1988	0.83	2.97	0.63	2.18	0.58	2.02	0.75	2.23
		1989	0.36	1.33	0.85	2.57	0.92	2.79	0.92	2.44
	Goats	1988	0.28	1.57	0.62	3.09	0.49	2.39	0.57	2.22
		1989	0.07	0.40	0.32	1.59	0.25	1.06	0.86	3.30
Zarchi	Sheep	1988	0.73	2.69	1.49	4.96	0.76	2.74	1.30	4.10
		1989	0.31	1.36	0.71	2.75	0.54	2.21	0.67	2.44
	Goats	1988	0.82	4.93	0.73	3.55	1.02	5.62	0.47	2.14
		1989	0.05	0.30	0.18	0.75	0.31	1.71	0.39	2.02

SUMMARY AND CONCLUSIONS

The main objective of phase II was to assess the nutritional status of sheep and goats grazing rangelands in Baluchistan, Pakistan.

Summary

1. Climatic fluctuations strongly influenced plant productivity on both sites. In Tomagh, standing crop peaked at the second sampling period (bloom season), when 474.0 kg and 510.0 kg of dry matter/ha, respectively, were produced during 1988 and 1989. Dry matter yields varied greatly among years on Zarchi site. Per hectare yields of 1989 for bloom and maturity seasons were two times greater than yields of 1988.

2. Grasses were dominant in Tomagh both years (greater than 80.0% of all forage). Among grasses *Cymbopogon shoenanthus* was the most abundant grass. Zarchi was a shrub dominated range area. On average, shrub biomass was 91.0% and 94.0% of all vegetation respectively for 1988 and 1989. *Artemisia maritima* constituted highest percentage while *Haloxylon griffithii* was second during both years. Grasses have a negligible contribution to production on this range.

3. In general, ash, phosphorus and crude protein contents of herbage declined with advance of season. However, neutral detergent fiber and acid detergent fiber of plant

cell walls had strong positive linear relationship with phenological stage.

4. In 1988, percent contribution of forage classes to the diets of Tomagh sheep averaged across all seasons was highest for grass (91.0%) followed by forbs (6.0%) and shrubs (3.0%). Overall sheep diets during 1989 comprised of 90.0% grass, 9.0% shrubs and a forb component of 1.0%. In 1988, Tomagh goat diets were approximately similar to sheep diets. Among grasses *Saccharum spp.* was heavily and consistently selected. Goats preferred grasses (53.0% of diet) followed by shrubs (42.0%) and forbs (3.0%) during 1989.

5. At Zarchi, on average shrub constituted 53.0% of sheep diets during 1988 and sheep appeared to shift their diets among shrubs as the season changed. In 1989, 80.0% of sheep diets were composed of shrubs. Shrubs increased in sheep diets as short lived annual forbs started declining. Zarchi goats selected approximately equal amounts of grasses as did sheep during 1988. On average grasses comprised 39.0% of goat diets. Overall shrubs contributed 56.0% to goat diets. However, in 1989, shrubs comprised 81.0% of goat diets followed by forbs 11.0%.

Conclusions

1. Natural variations in weather limit forage production stability on rangelands of Baluchistan, Pakistan. In most

years if grazing pressure is moderate, forage quantity should not limit sheep and goats production. Stocking rates suggested in this study can serve as guide lines for future grazing strategies.

2. Retrogression of climax plant communities to disclimax types is wide spread in Tomagh area. Palatable perennial grasses (like Chrysopogon aucheri) have been almost completely replaced by perennial grass of low palatability (Cymbopogon shoenanthus). A rapid establishment of Cymbopogon shoenanthus on large scale has brought a considerable decline in plant species diversity. It is critical to direct future research towards the establishment of new desirable plant communities.

3. Sheep and goats grazing two types of rangelands in Baluchistan would experience severe phosphorus deficiencies for most parts of the year.

4. In areas like Zarchi, crude protein deficiencies would limit animal productivity after the late spring. Protein supplementation in combination with phosphorus would be necessary to sustain animals during most of the year.

5. Energy deficiency may not be a constraint to better animal production on grass dominated Baluchi ranges like Tomagh; however, on areas like Zarchi, severe energy deficiency may threaten sheep and goat survival.

6. On Tomagh, sheep and goats are forced to graze on unpalatable perennial grass which limits their dry matter

intakes. Riparian zones (dried stream beds) are good source of green and palatable forage material for animals throughout much of the year, but these areas are limited in extent.

7. At Zarchi, management should be directed towards expanding Convolvulus leiocalycinus, a palatable browse species which is equally liked by both sheep and goats. Further studies are required to gather information about its germination rate, seed production, growth patterns etc. for successful propagation.

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APPENDICES

Appendix A. Monthly temperatures in centigrades at Tomagh station.

	1988			1989		
Months	Maximum	Minimum	Mean	Maximum	Minimum	Mean
January	11.9	3.5	7.7	9.9	1.0	4.0
February	13.9	4.6	9.2	x	x	x
March	16.4	7.4	11.9	14.8	5.0	10.0
April	24.9	14.8	19.8	20.8	9.0	15.0
May	31.1	19.3	25.2	x	x	x
June	32.5	20.5	26.5	30.4	18.0	24.0
July	30.7	18.8	24.7	19.9	3.0	8.0
August	29.4	19.3	24.3	x	x	x
September	29.4	18.6	24.0	x	x	x
October	x	x	x	24.3	12.0	18.0
November	18.9	7.0	13.0	x	x	x
December	14.0	3.0	8.0	x	x	x

x = data not available

Appendix B. Monthly temperatures in centigrade at Zarchi station.

Months	1988 Maximum	1988 Minimum	1988 Mean	1989 Maximum	1989 Minimum	1989 Mean
January	x	x	x	x	x	x
February	x	x	x	x	x	x
March	x	x	x	x	x	x
April	24.9	10.5	17.7	x	x	x
May	31.3	15.9	23.6	x	x	x
June	32.8	17.7	25.2	x	x	x
July	33.9	21.8	27.8	30.3	18.3	22.8
August	31.1	17.5	24.3	32.8	15.8	24.5
September	x	x	x	29.3	9.46	20.1
October	24.3	4.71	14.2	x	x	x
November	19.9	-0.3	9.55	18.1	0.78	9.57
December	x	x	x	x	x	x

x = data not available

Appendix C. Monthly rainfall in millimeters at Tomagh and Zarchi stations.

Months	Tomagh 1987	Tomagh 1988	Tomagh 1989	Zarchi 1987	Zarchi 1988	Zarchi 1989
January	x	7.0	18.3	x	11.3	20.5
February	50.6	13.0	0.0	x	8.0	9.3
March	146.3	104.6	204.7	42.0	29.0	3.0
April	59.0	0.0	10.4	0.0	2.0	44.1
May	87.7	0.0	0.0	0.0	0.0	0.0
June	41.6	18.3	70.4	0.0	0.0	0.0
July	2.1	38.5	10.7	0.0	13.0	38.7
August	27.2	30.5	0.0	0.0	0.0	0.3
September	0.0	0.0	0.0	0.0	0.0	0.0
October	0.0	0.0	0.0	0.0	x	0.0
November	0.0	0.0	0.0	0.0	1.2	2.8
December	7.9	0.0	0.0	0.0	x	0.0

x = data not available

Appendix D. Productivity and relative species composition at Tomagh station.

	Plant species												
	Cysh	Chau	Phst	Shamen*	Vese	Rhpe	Prpa	Saca	Olfe	Ebst	Epin	Ptol	Total
April, 1988													
Composition(%)	62.07	4.69	0.00	0.00	0.00	0.00	2.89	3.10	13.04	14.10	0.11	0.00	100.00
DM/Ha(Kg)	162.69	12.29	0.00	0.00	0.00	0.00	7.58	8.13	34.19	36.95	0.29	0.00	262.12
Ash/Ha(Kg)	12.37	1.07	0.00	0.00	0.00	0.00	0.53	1.18	1.44	1.83	0.03	0.00	18.44
CP/Ha(Kg)	15.70	1.61	0.00	0.00	0.00	0.00	1.22	1.05	2.94	4.25	0.02	0.00	26.80
P/Ha(Kg)	0.21	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.06	0.00	0.00	0.35
NDF/Ha(Kg)	101.94	7.91	0.00	0.00	0.00	0.00	2.79	2.66	13.18	18.84	0.11	0.00	147.43
ADF/Ha(Kg)	54.38	4.22	0.00	0.00	0.00	0.00	1.90	2.00	8.49	11.82	0.09	0.00	82.90
May, 1988													
Composition(%)	81.01	3.42	0.43	0.00	0.00	1.92	1.52	5.78	0.81	2.38	2.72	0.00	100.00
DM/Ha(Kg)	397.45	11.38	2.34	0.00	0.00	9.53	6.97	22.08	3.11	7.91	12.89	0.00	473.67
Ash/Ha(Kg)	23.02	1.09	0.18	0.00	0.00	0.57	0.34	3.08	0.24	0.65	1.03	0.00	30.21
CP/Ha(Kg)	25.67	1.39	0.22	0.00	0.00	0.79	0.32	1.39	0.26	1.01	0.87	0.00	31.92
P/Ha(Kg)	0.58	0.03	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.02	0.01	0.00	0.68
NDF/Ha(Kg)	258.66	11.04	1.04	0.00	0.00	3.71	3.92	11.70	1.51	6.32	5.70	0.00	303.59
ADF/Ha(Kg)	144.62	6.48	0.67	0.00	0.00	2.17	2.68	8.05	1.05	4.88	4.32	0.00	174.92
July, 1988													
Composition(%)	73.13	7.03	1.87	0.00	0.00	3.39	0.58	2.55	6.06	0.00	3.18	2.20	100.00
DM/Ha(Kg)	348.78	33.52	8.93	0.00	0.00	16.18	2.76	12.15	28.91	0.00	15.19	10.48	476.91
Ash/Ha(Kg)	24.20	2.56	1.59	0.00	0.00	0.60	0.13	1.41	1.27	0.00	1.02	0.56	33.32
CP/Ha(Kg)	13.29	1.22	0.41	0.00	0.00	0.70	0.11	0.59	1.55	0.00	0.88	0.81	19.55
P/Ha(Kg)	0.23	0.02	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.29
NDF/Ha(Kg)	224.76	21.63	3.79	0.00	0.00	9.94	1.46	4.44	9.51	0.00	5.36	4.36	285.25
ADF/Ha(Kg)	136.20	12.60	3.04	0.00	0.00	7.71	1.09	3.72	7.00	0.00	4.62	2.83	178.83
September, 1988													
Composition(%)	77.94	8.72	3.16	0.00	0.00	0.00	0.00	4.56	1.05	1.66	2.90	0.00	100.00
DM/Ha(Kg)	195.77	21.90	7.95	0.00	0.00	0.00	0.00	11.46	2.65	4.16	7.29	0.00	251.18
Ash/Ha(Kg)	12.86	1.39	1.26	0.00	0.00	0.00	0.00	0.82	0.14	0.21	0.43	0.00	17.11
CP/Ha(Kg)	1.96	0.33	0.23	0.00	0.00	0.00	0.00	0.49	0.19	0.15	0.22	0.00	3.58
P/Ha(Kg)	0.08	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.12
NDF/Ha(Kg)	114.57	12.57	3.69	0.00	0.00	0.00	0.00	3.07	0.74	2.26	2.27	0.00	139.18
ADF/Ha(Kg)	69.29	7.89	2.86	0.00	0.00	0.00	0.00	2.50	0.59	2.02	2.14	0.00	87.27

Appendix D. (continued)

* = local name

	Cysh	Chau	Phst	Shamen*	Vese	Rhpe	Prpa	Saca	Olfe	Ebst	Epin	Ptol	Total
	Plant species												
April, 1989													
Composition(%)	67.48	4.23	0.25	0.14	0.16	0.00	0.00	2.07	4.12	0.36	21.18 '		100.00
DM/Ha(Kg)	68.24	4.23	0.23	0.05	0.06	0.00	0.00	1.52	4.78	0.32	30.24	0.00	109.66
Ash/Ha(Kg)	5.68	0.41	0.03	0.02	0.02	0.00	0.00	0.33	0.19	0.02	2.09	0.00	8.78
CP/Ha(Kg)	7.21	0.61	0.03	0.02	0.02	0.00	0.00	0.30	0.39	0.05	1.84	0.00	10.46
P/Ha(Kg)	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.13
NDF/Ha(Kg)	46.79	3.01	0.13	0.07	0.09	0.00	0.00	0.75	1.76	0.20	8.91	0.00	61.70
ADF/Ha(Kg)	24.96	1.61	0.09	0.06	0.07	0.00	0.00	0.56	1.13	0.13	7.34	0.00	35.94
May, 1989				Legspp	Tespp		Zos						
Composition(%)	80.54	4.83	1.81	0.57	0.17	0.68	0.23	2.80	0.00	2.32	6.04	0.00	100.00
DM/Ha(Kg)	412.72	25.39	7.51	3.99	1.20	4.03	1.39	13.07	0.00	11.23	29.17	0.00	509.69
Ash/Ha(Kg)	24.63	1.66	0.83	0.23	0.06	0.22	0.09	1.61	0.00	0.68	2.46	0.00	32.47
CP/Ha(Kg)	27.46	2.16	0.98	0.27	0.06	0.30	0.11	0.73	0.00	1.06	2.07	0.00	35.20
P/Ha(Kg)	0.62	0.04	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.03	0.00	0.76
NDF/Ha(Kg)	276.73	16.76	4.73	1.50	0.61	1.41	0.61	7.99	0.00	6.62	13.61	0.00	330.57
ADF/Ha(Kg)	154.73	9.84	3.05	1.06	0.34	0.82	0.43	6.17	0.00	5.12	10.31	0.00	191.86
July, 1989													
Composition(%)	71.48	11.27	0.40	0.19	0.00	0.00	0.00	3.89	4.40	4.38	3.99	0.00	100.00
DM/Ha(Kg)	294.90	52.14	3.85	0.77	0.00	0.00	0.00	15.76	22.96	18.74	13.87	0.00	422.99
Ash/Ha(Kg)	22.68	3.93	0.32	0.11	0.00	0.00	0.00	2.06	0.88	0.74	1.22	0.00	31.95
CP/Ha(Kg)	12.46	1.87	0.08	0.04	0.00	0.00	0.00	0.86	1.08	0.86	1.06	0.00	18.30
P/Ha(Kg)	0.21	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.27
NDF/Ha(Kg)	210.66	33.26	0.77	0.42	0.00	0.00	0.00	6.51	6.62	12.31	6.44	0.00	276.97
ADF/Ha(Kg)	127.66	19.38	0.62	0.34	0.00	0.00	0.00	5.45	4.87	9.55	5.54	0.00	173.41
September, 1989												Cosp	
Composition(%)	83.20	11.33	0.09	0.00	0.05	0.00	0.00	0.69	0.35	1.78	2.02	0.50	100.00
DM/Ha(Kg)	425.28	63.09	0.65	0.00	0.32	0.00	0.00	2.70	1.57	8.79	9.38	3.27	515.04
Ash/Ha(Kg)	34.02	4.89	0.12	0.00	0.02	0.00	0.00	0.24	0.10	0.53	0.68	0.15	40.74
CP/Ha(Kg)	5.19	1.17	0.02	0.00	0.01	0.00	0.00	0.14	0.14	0.39	0.34	0.14	7.54
P/Ha(Kg)	0.21	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.29
NDF/Ha(Kg)	303.10	44.09	0.37	0.00	0.23	0.00	0.00	0.88	0.54	5.80	3.55	2.26	360.82
ADF/Ha(Kg)	183.29	27.67	0.28	0.00	0.14	0.00	0.00	0.72	0.43	5.18	3.35	1.77	222.84

Appendix E. Productivity and relative species composition at Zarchi station.

	Plant species																
	Chau	Neju	Tumo	Scpu	Lal*	Gaer	Shosh*	Leg. spp.	Mato	Cole	Arma	Hagr	Aclo	Asst	Cost	Hein	Total
April, 1988																	
Composition(%)	2.28	0.00	0.25	0.15	0.10	0.67	0.00	0.00	0.00	0.00	55.79	13.37	8.25	16.13	0.00	0.00	96.99
DM/Ha(Kg)	1.67	0.00	0.19	0.11	0.07	0.49	0.00	0.00	0.00	0.00	40.78	9.77	6.03	11.79	0.00	0.00	73.10
Ash/Ha(Kg)	0.14	0.00	0.02	0.01	0.01	0.03	0.00	0.00	0.00	0.00	4.39	1.29	0.30	1.24	0.00	0.00	7.44
CP/Ha(Kg)	0.22	0.00	0.02	0.01	0.01	0.06	0.00	0.00	0.00	0.00	6.79	2.30	0.29	2.14	0.00	0.00	11.84
P/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.02	0.00	0.02	0.00	0.00	0.13
NDF/Ha(Kg)	1.06	0.00	0.08	0.04	0.03	0.22	0.00	0.00	0.00	0.00	12.49	2.62	3.62	2.23	0.00	0.00	22.39
ADF/Ha(Kg)	0.57	0.00	0.07	0.04	0.03	0.18	0.00	0.00	0.00	0.00	9.94	1.48	2.76	2.05	0.00	0.00	17.10
May, 1988																	
Composition(%)	0.00	10.82	0.00	0.00	0.00	0.10	0.00	0.00	0.00	5.40	51.14	24.27	3.22	0.00	5.05	0.00	100.00
DM/Ha(Kg)	0.00	10.46	0.00	0.00	0.00	0.07	0.00	0.00	0.00	5.68	56.41	27.26	4.26	0.00	4.90	0.00	109.04
Ash/Ha(Kg)	0.00	1.53	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.22	5.02	3.31	0.29	0.00	0.51	0.00	10.89
CP/Ha(Kg)	0.00	1.23	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.48	9.02	6.58	0.25	0.00	0.49	0.00	18.06
P/Ha(Kg)	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.16	0.03	0.00	0.00	0.01	0.00	0.23
NDF/Ha(Kg)	0.00	5.09	0.00	0.00	0.00	0.05	0.00	0.00	0.00	3.82	25.37	8.59	1.65	0.00	3.10	0.00	47.68
ADF/Ha(Kg)	0.00	4.01	0.00	0.00	0.00	0.04	0.00	0.00	0.00	2.66	19.33	4.55	1.36	0.00	2.35	0.00	34.30
May, 1988																	
Composition(%)	0.00	15.15	0.00	0.00	0.00	1.93	0.00	0.00	0.00	5.86	56.05	10.26	0.00	0.00	8.93	1.81	100.00
DM/Ha(Kg)	0.00	15.58	0.00	0.00	0.00	1.98	0.00	0.00	0.00	6.02	57.61	10.55	0.00	0.00	9.18	1.86	102.78
Ash/Ha(Kg)	0.00	1.17	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.20	2.52	1.61	0.00	0.00	0.53	0.18	6.32
CP/Ha(Kg)	0.00	0.58	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.28	1.71	1.04	0.00	0.00	0.34	0.08	4.08
P/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02
NDF/Ha(Kg)	0.00	9.27	0.00	0.00	0.00	1.22	0.00	0.00	0.00	3.71	34.37	3.69	0.00	0.00	5.19	0.49	57.93
ADF/Ha(Kg)	0.00	7.77	0.00	0.00	0.00	0.95	0.00	0.00	0.00	2.72	27.15	2.10	0.00	0.00	4.17	0.47	45.32
September, 1988																	
Composition(%)	0.00	0.00	0.00	0.00	0.00	2.83	0.00	0.00	0.00	0.00	54.18	30.70	5.69	0.00	6.60	0.00	100.00
DM/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	1.58	0.00	0.00	0.00	0.00	30.18	17.10	3.17	0.00	3.68	0.00	55.70
Ash/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	2.07	2.53	0.23	0.00	0.24	0.00	5.17
CP/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	1.20	2.52	0.12	0.00	0.08	0.00	3.95
P/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.05
NDF/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	1.16	0.00	0.00	0.00	0.00	18.23	7.40	2.39	0.00	2.64	0.00	31.81
ADF/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	16.14	4.15	2.05	0.00	2.21	0.00	25.50

Appendix E. (continued)

* = local name

	Chau	Neju	Tumo	Scpu	Lal*	Gaer	Shosh*	Leg. spp.	Mato	Cole	Arma	Hagr	Aclo	Asst	Cost	Hein	Total
	Plant species																
April, 1989	Posi				Alde									Acmu			
Composition(%)	2.67	0.33	1.69	1.25	4.96	2.80	0.43	1.11	2.30	2.31	61.31	14.25	0.41	0.66	3.49	0.00	100.00
DM/Ha(Kg)	3.33	0.35	1.96	1.73	4.22	3.25	0.29	0.93	2.35	2.97	63.97	17.70	0.27	0.80	3.59	0.00	107.71
Ash/Ha(Kg)	0.29	0.05	0.20	0.15	0.58	0.20	0.05	0.13	0.27	0.19	7.26	2.07	0.02	0.07	0.38	0.00	11.91
CP/Ha(Kg)	0.29	0.06	0.24	0.17	0.69	0.35	0.06	0.15	0.32	0.54	11.76	3.69	0.02	0.13	0.73	0.00	19.21
P/Ha(Kg)	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.14	0.03	0.00	0.00	0.01	0.00	0.22
NDF/Ha(Kg)	1.54	0.11	0.78	0.57	2.28	1.36	0.20	0.51	1.06	0.84	20.66	4.20	0.27	0.24	1.07	0.00	35.68
ADF/Ha(Kg)	0.84	0.10	0.66	0.49	1.94	1.12	0.17	0.43	0.90	0.73	16.44	2.37	0.21	0.20	1.06	0.00	27.63
May, 1989			Homu				Murobey*										
Composition(%)	0.31	0.00	0.08	0.13	0.55	1.54	0.07	0.00	0.40	2.80	54.56	19.42	7.50	1.10	11.54	0.00	100.00
DM/Ha(Kg)	1.49	0.00	0.25	0.64	1.18	3.65	0.15	0.00	1.91	6.57	129.68	41.12	20.09	3.69	31.45	0.00	241.86
Ash/Ha(Kg)	0.10	0.00	0.03	0.04	0.15	0.45	0.02	0.00	0.11	0.25	11.88	5.87	1.50	0.24	2.58	0.00	23.20
CP/Ha(Kg)	0.06	0.00	0.02	0.03	0.13	0.35	0.02	0.00	0.09	0.55	21.34	11.68	1.27	0.19	2.50	0.00	38.23
P/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.38	0.06	0.01	0.00	0.03	0.00	0.50
NDF/Ha(Kg)	0.42	0.00	0.10	0.15	0.60	1.61	0.10	0.00	0.44	4.39	60.05	15.25	8.53	1.67	15.74	0.00	109.04
ADF/Ha(Kg)	0.25	0.00	0.06	0.13	0.53	1.45	0.08	0.00	0.39	3.06	45.75	8.08	7.01	1.26	11.93	0.00	79.97
July, 1989																	
Composition(%)	0.23	0.00	0.00	0.00	0.62	0.94	0.01	0.00	0.24	0.52	60.68	29.40	0.94	0.59	5.81	0.00	100.00
DM/Ha(Kg)	0.50	0.00	0.00	0.00	1.58	2.29	0.03	0.00	0.71	1.29	169.16	72.81	3.75	2.32	16.90	0.00	271.34
Ash/Ha(Kg)	0.11	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.05	0.05	7.41	12.57	0.13	0.13	0.95	0.00	21.66
CP/Ha(Kg)	0.03	0.00	0.00	0.00	0.07	0.08	0.00	0.00	0.03	0.07	5.04	8.13	0.09	0.03	0.60	0.00	14.17
P/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.06
NDF/Ha(Kg)	0.36	0.00	0.00	0.00	0.95	1.61	0.02	0.00	0.37	0.90	101.19	28.72	1.76	1.07	9.17	0.00	146.12
ADF/Ha(Kg)	0.25	0.00	0.00	0.00	0.77	1.26	0.01	0.00	0.30	0.66	79.94	16.32	1.19	0.85	7.37	0.00	108.93
September, 1989																	
Composition(%)	0.22	0.00	0.00	0.00	0.13	0.45	0.21	0.00	0.30	2.21	62.44	20.81	3.80	3.66	5.76	0.00	100.00
DM/Ha(Kg)	0.61	0.00	0.00	0.00	0.24	0.43	0.37	0.00	0.78	5.11	128.98	39.41	7.77	7.46	15.83	0.00	207.00
Ash/Ha(Kg)	0.09	0.00	0.00	0.00	0.01	0.03	0.03	0.00	0.05	0.14	8.06	5.32	0.50	0.65	0.95	0.00	15.83
CP/Ha(Kg)	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.02	0.32	4.68	5.30	0.26	0.18	0.33	0.00	11.15
P/Ha(Kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.03	0.01	0.01	0.01	0.00	0.18
NDF/Ha(Kg)	0.40	0.00	0.00	0.00	0.15	0.29	0.19	0.00	0.48	3.07	71.08	15.56	5.34	5.07	10.37	0.00	111.99
ADF/Ha(Kg)	0.31	0.00	0.00	0.00	0.13	0.24	0.16	0.00	0.41	2.38	62.97	8.73	4.58	4.26	8.69	0.00	92.85

Appendix F. Nutritive value of range plant species across growing seasons at Tomagh station.

Local Name	Botanical Name	Sampling Dates	DM%*	Ash%*	CP%*	CP%**	P%*	P%**	NDF%*	ADF%*
Saba	Chrysopogon aucheri	April, 1st week	31.82	8.75	13.18	16.98	0.16	0.170	64.94	34.61
Saba	Chrysopogon aucheri	May, last week	40.01	6.75	8.57	14.61	0.16	0.120	68.06	39.94
Saba	Chrysopogon aucheri	July, 1st week	69.23	8.25	3.93	11.20	0.05	0.070	69.77	40.65
Saba	Chrysopogon aucheri	October, 1st week	94.20	7.75	1.85	6.60	0.08	0.020	69.89	43.86
Sarganrae	Cymbopogon shoenanthus	April, 1st week	32.73	7.67	9.74	14.80	0.13	0.150	63.23	33.73
Sarganrae	Cymbopogon shoenanthus	May, last week	41.98	6.00	6.69	12.80	0.15	0.090	67.41	37.69
Sarganrae	Cymbopogon shoenanthus	July, 1st week	77.79	7.50	4.12	9.40	0.07	0.040	69.67	42.22
Sarganrae	Cymbopogon shoenanthus	October, 1st week	93.74	8.00	1.22	5.20	0.05	0.025	71.27	43.10
Sarghusae	Saccharum spp.	April, 1st week	25.94	10.75	10.51	15.90	0.17	0.220	66.94	36.59
Sarghusae	Saccharum spp.	May, last week	40.46	8.50	6.73	14.00	0.09	0.140	74.07	39.86
Sarghusae	Saccharum spp.	July, 1st week	45.94	8.00	2.52	11.50	0.09	0.070	75.69	44.72
Sarghusae	Saccharum spp.	October, 1st week	51.82	6.25	5.02	4.70	0.09	0.020	72.55	47.41
Arandok	Phlomis stewartii	April, 1st week	40.14	12.00	11.22	12.20	0.13	0.060	46.13	31.89
Arandok	Phlomis stewartii	May, last week	63.98	9.00	10.66	8.73	0.12	0.047	51.45	33.16
Arandok	Phlomis stewartii	July, 1st week	99.16	19.25	4.97	5.25	0.09	0.034	45.84	36.82
Arandok	Phlomis stewartii	October, 1st week	93.11	35.50	3.51	11.28	0.11	0.087	56.62	43.76
Sandrash	Veronica seniola	April, 1st week	25.98	9.50	13.36	17.30	0.19	0.140	45.76	35.59
Sandrash	Veronica seniola	May, last week	41.97	10.00	9.85	15.05	0.15	0.100	48.83	36.41
Sandrash	Veronica seniola	July, 1st week	47.02	8.50	3.95	12.78	0.13	0.060	46.65	35.80
Sandrash	Veronica seniola	October, 1st week	69.10	6.00	3.65	6.50	0.09	0.030	62.66	48.04
Aghzai	Centaurea spp.	April, 1st week	38.64	8.50	12.74	19.06	0.15	0.240	51.53	42.99
Aghzai	Centaurea spp.	May, last week	52.27	4.50	7.32	15.58	0.13	0.140	54.01	39.48
Aghzai	Centaurea spp.	July, 1st week	84.97	14.25	4.64	12.40	0.05	0.080	61.30	52.00
Aghzai	Centaurea spp.	October, 1st week	92.18	14.50	5.16	7.00	0.09	0.034	59.68	50.47
Shamshobae	Perwoskis artiplicifolia	April, 1st week	21.66	9.75	17.28	15.60	0.24	0.200	34.27	29.46
Shamshobae	Perwoskis artiplicifolia	May, last week	28.29	13.00	12.89	13.90	0.20	0.110	35.76	34.34
Shamshobae	Perwoskis artiplicifolia	July, 1st week	36.03	8.50	4.41	10.40	0.13	0.060	37.06	29.07
Shamshobae	Perwoskis artiplicifolia	October, 1st week	41.38	11.00	8.70	5.16	0.23	0.040	29.19	26.31
Sanble	Ebenus stellatus	April, 1st week	35.37	5.00	11.62	15.32	0.17	0.250	51.45	32.29
Sanble	Ebenus stellatus	May, last week	38.71	5.75	8.98	14.00	0.21	0.150	55.92	43.22
Sanble	Ebenus stellatus	July, 1st week	60.94	4.00	4.65	12.30	0.04	0.070	66.43	51.53
Sanble	Ebenus stellatus	October, 1st week	78.03	6.00	4.49	6.60	0.08	0.017	66.06	59.00

Appendix F. (continued)

Local Name	Botanical Name	Sampling Dates	DM%*	Ash%*	CP%*	CP%**	P%*	P%**	NDF%*	ADF%*
Sperghoai	Salvia cabulica	April, 1st week	29.58	14.67	13.00	16.10	0.13	0.140	32.99	24.77
Sperghoai	Salvia cabulica	May, last week	46.22	11.25	5.08	13.90	0.06	0.100	42.75	29.43
Sperghoai	Salvia cabulica	July, 1st week	53.91	12.50	5.22	11.20	0.06	0.060	39.53	33.13
Sperghoai	Salvia cabulica	October, 1st week	63.96	8.75	5.24	5.95	0.08	0.034	32.64	26.51
Jangli Badam	Prunus padus	April, 1st week	32.39	7.00	16.30	15.67	0.08	0.150	37.21	25.25
Jangli Badam	Prunus padus	May, last week	53.62	4.75	4.51	14.00	0.16	0.090	54.49	37.27
Jangli Badam	Prunus padus	July, 1st week	66.90	5.00	4.17	10.30	0.05	0.070	57.05	42.63
Jangli Badam	Prunus padus	October, 1st week	59.27	12.50	2.58	5.40	0.08	0.020	29.20	26.14
Sarvand	Olea ferruginea	April, 1st week	41.37	4.25	8.68	17.68	0.12	0.250	38.89	25.07
Sarvand	Olea ferruginea	May, last week	44.48	6.25	6.84	15.80	0.06	0.140	39.16	27.27
Sarvand	Olea ferruginea	July, 1st week	53.60	4.75	5.79	12.60	0.05	0.080	35.56	26.19
Sarvand	Olea ferruginea	October, 1st week	56.06	6.25	8.75	6.49	0.13	0.040	34.18	27.11
Uman	Ephedra intermedia	April, 1st week	50.47	9.00	7.92	19.90	0.07	0.170	38.34	31.60
Uman	Ephedra intermedia	May, last week	55.24	8.00	6.71	17.10	0.10	0.120	44.19	33.48
Uman	Ephedra intermedia	July, 1st week	61.26	7.25	6.26	13.20	0.04	0.070	38.17	32.86
Uman	Ephedra intermedia	October, 1st week	57.14	7.25	3.62	7.18	0.08	0.025	37.88	35.72
Sussae	Convolvulus spinosus	April, 1st week	47.71	4.25	6.92	16.28	0.22	0.140	64.36	48.09
Sussae	Convolvulus spinosus	May, last week	64.29	3.00	5.67	13.90	0.09	0.110	70.04	52.98
Sussae	Convolvulus spinosus	July, 1st week	75.91	4.00	3.90	11.20	0.06	0.070	71.05	52.73
Sussae	Convolvulus spinosus	October, 1st week	80.97	4.50	4.29	5.16	0.09	0.025	68.91	54.13
Sarwanjgae	Rhamnus persica	April, 1st week	57.25	6.75	10.27	16.60	0.05	0.170	35.00	16.67
Sarwanjgae	Rhamnus persica	May, last week	57.80	6.25	8.64	14.79	0.06	0.120	40.69	23.78
Sarwanjgae	Rhamnus persica	July, 1st week	55.09	7.00	9.39	11.20	0.06	0.080	30.20	18.44
Sarwanjgae	Rhamnus persica	October, 1st week	57.77	7.50	9.67	5.07	0.09	0.050	29.31	17.31
Maranzgae	Pterophyrum olivieri	April, 1st week	58.62	4.75	7.55	16.30	0.10	0.150	50.92	29.30
Maranzgae	Pterophyrum olivieri	May, last week	58.68	5.50	7.90	13.80	0.05	0.090	52.16	34.51
Maranzgae	Pterophyrum olivieri	July, 1st week	59.18	5.75	8.35	11.90	0.05	0.060	44.95	29.20
Maranzgae	Pterophyrum olivieri	October, 1st week	58.53	5.75	10.86	5.40	0.10	0.010	43.68	32.22

* = data for the year 1988

** = data for the year 1989

Appendix G. Nutritive value of range plant species across growing seasons at Zarchi station.

Local Name	Botanical Name	Sampling Dates	DM%*	Ash%*	CP%*	CP%**	P%*	P%**	NDF%*	ADF%*
Gandumka-S	Hordeum murinum	April, 1st week	36.71	10.00	10.01	9.81	0.16	0.250	53.38	29.10
Gandumka-S	Hordeum murinum	May, last week	46.44	13.75	8.55	14.97	0.12	0.120	56.04	33.86
Gandumka-S	Hordeum murinum	July, 1st week	96.65	18.25	4.12	8.14	0.05	0.080	57.04	39.69
Gandumka-S	Hordeum murinum	October, 1st week	92.85	14.67	4.34	6.20	0.08	0.031	65.02	50.34
Simsook	Nepeta juncea	April, 1st week	23.21	14.75	17.81	10.56	0.23	0.205	29.72	26.65
Simsook	Nepeta juncea	May, last week	44.26	13.00	10.43	9.10	0.16	0.140	43.12	33.95
Simsook	Nepeta juncea	July, 1st week	84.90	7.75	3.81	7.97	0.03	0.070	61.28	51.37
Simsook	Nepeta juncea	October, 1st week	96.50	5.00	2.55	7.20	0.06	0.050	65.62	58.04
Tusso	Gallonia eriantha	April, 1st week	26.30	6.67	11.52	12.25	0.17	0.200	45.10	37.16
Tusso	Gallonia eriantha	May, last week	34.10	12.00	9.33	13.74	0.10	0.100	38.91	43.15
Tusso	Gallonia eriantha	July, 1st week	78.48	5.00	3.28	13.29	0.02	0.050	63.24	49.20
Tusso	Gallonia eriantha	October, 1st week	87.83	6.00	1.75	7.79	0.11	0.010	67.14	54.42
Murobey	Unidentified forb	April, 1st week	29.70	11.25	9.58	13.80	0.10	0.140	53.13	44.87
Marobey	Unidentified forb	May, last week	33.27	8.50	8.86	10.42	0.11	0.100	54.03	43.32
Marobey	Unidentified forb	July, 1st week	26.27	10.75	5.72	7.09	0.12	0.040	44.02	36.55
Marobey	Unidentified forb	October, 1st week	58.95	7.25	3.42	5.93	0.09	0.010	50.75	44.10
Bundi	Haloxylon griffithii	April, 1st week	30.28	13.50	24.06	19.03	0.22	0.200	27.33	15.44
Bundi	Haloxylon griffithii	May, last week	51.44	12.50	24.88	16.44	0.12	0.140	32.48	17.21
Bundi	Haloxylon griffithii	July, 1st week	56.75	15.75	10.19	13.40	0.04	0.080	36.00	20.46
Bundi	Haloxylon griffithii	October, 1st week	62.52	13.50	13.45	5.25	0.08	0.030	39.48	22.15
Shenlao	Astragalus stocksii	April, 1st week	39.94	10.75	18.55	15.80	0.15	0.135	19.33	17.79
Shenlao	Astragalus stocksii	May, last week	57.04	6.50	8.33	15.41	0.07	0.080	52.45	40.72
Shenlao	Astragalus stocksii	July, 1st week	61.41	5.00	6.37	7.35	0.04	0.050	60.90	51.65
Shenlao	Astragalus stocksii	October, 1st week	64.96	4.00	8.45	5.09	0.11	0.010	62.85	51.31
Deylunkoo	Convolvulus leiocalycinus	April, 1st week	23.21	7.75	21.83	16.50	0.33	0.150	33.86	29.26
Deylunkoo	Convolvulus leiocalycinus	May, last week	48.18	3.75	8.12	14.63	0.11	0.120	64.78	45.14
Deylunkoo	Convolvulus leiocalycinus	July, 1st week	56.76	3.50	4.74	6.83	0.02	0.070	63.45	46.49
Deylunkoo	Convolvulus leiocalycinus	October, 1st week	63.90	2.75	6.34	4.20	0.09	0.020	60.01	46.63
Khalighapit	Acantholimon longiflorum	April, 1st week	57.38	5.00	4.96	16.30	0.04	0.255	61.24	46.66
Khalighapit	Acantholimon longiflorum	May, last week	60.52	8.25	7.01	8.23	0.07	0.080	47.05	38.64
Khalighapit	Acantholimon longiflorum	July, 1st week	91.73	5.25	3.51	3.88	0.02	0.050	69.24	56.15
Khalighapit	Acantholimon longiflorum	October, 1st week	88.36	6.50	3.35	3.30	0.07	0.010	68.72	59.00

Appendix G. (continued)

Local Name	Botanical Name	Sampling Dates	DM%*	Ash%*	CP%*	CP%**	P%*	P%**	NDF%*	ADF%*
Jirr	Artemisia maritima	April, 1st week	27.56	11.00	17.80	12.69	0.22	0.240	31.28	24.89
Jirr	Artemisia maritima	May, last week	44.27	9.00	16.17	11.91	0.29	0.160	45.50	34.67
Jirr	Artemisia maritima	July, 1st week	93.87	4.50	3.06	9.19	0.01	0.080	61.45	48.55
Jirr	Artemisia maritima	October, 1st week	83.67	6.25	3.63	8.60	0.09	0.010	55.11	48.82
Nerianband	Cousinia stocksii	April, 1st week	29.52	10.00	19.42	8.56	0.22	0.220	28.49	28.05
Nerianband	Cousinia stocksii	May, last week	44.42	9.25	8.97	11.91	0.11	0.160	56.40	42.74
Nerianband	Cousinia stocksii	July, 1st week	95.88	6.00	3.79	2.10	0.03	0.050	58.18	46.74
Nerianband	Cousinia stocksii	October, 1st week	91.07	6.00	2.09	1.60	0.06	0.030	65.49	54.89
Mungli	Hertia intermedia	April, 1st week	14.55	11.33	20.82	11.31	0.23	0.230	21.65	22.91
Mungli	Hertia intermedia	May, last week	75.36	10.00	8.94	12.69	0.13	0.135	39.99	19.42
Mungli	Hertia intermedia	July, 1st week	90.62	10.00	4.27	8.49	0.03	0.070	27.23	26.04
Mungli	Hertia intermedia	October, 1st week	38.16	8.75	4.56	5.60	0.09	0.030	18.27	18.03
Shampeshtair	Sophora mollis	April, 1st week	30.95	5.25	17.90	11.75	0.15	0.210	44.38	35.60
Shampeshtair	Sophora mollis	May, last week	25.57	7.00	12.32	12.43	0.16	0.160	56.86	36.11
Shampeshtair	Sophora mollis	July, 1st week	56.20	5.50	5.31	12.78	0.06	0.060	39.46	31.27
Shampeshtair	Sophora mollis	October, 1st week	58.21	7.75	11.31	9.10	0.10	0.050	35.39	28.72
Karpitch	Acantholimon munroanum	April, 1st week				16.50		0.155		
Karpitch	Acantholimon munroanum	May, last week	54.60	9.00	6.96	5.31	0.05	0.120	62.66	47.02
Karpitch	Acantholimon munroanum	July, 1st week	89.60	7.75	2.14	5.16	0.01	0.070	66.38	52.77
Karpitch	Acantholimon munroanum	October, 1st week	92.42	8.75	2.35	4.03	0.08	0.020	67.97	57.09

* = data for the year 1988

** = data for the year 1989