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# Mineral status of Livestock (Goats and Sheep) Based on Soil, Dietary Components and Animal Tissue Fluids in Relation to Seasonal Changes and Sampling Periods in Specific Region of Pakistan

[1]Zafar Iqbal Khan, [1]Muhammad Ashraf, [2]Muhammad Yasin Ashraf, [3]Zia-ur-Rahman and [1]Altaf Hussain
[1]Department of Botany, University of Agriculture, Faisalabad, Pakistan
[2] Nuclear Institute for Agriculture and Biology (NIAB) Faisalabad, Pakistan
[3]Department of physiology and Pharmacology, University of Agriculture Faisalabad, Pakistan

**Abstract:** The study was conducted at the Livestock Experimental Station Rakh Khairewala, District Layyah, southern Punjab, Pakistan, to determine the translocation of mineral nutrients from soil to plants and from plants to goats and sheep. Soil and forage samples were collected fortnightly from two sites of the same farm, during winter and summer of 2001. Feed and water samples were also collected along with soil and forage to study the effect of mineral supplement contained in feed. Samples of blood, milk, urine and faeces were obtained from 60 animals consisting of 30 sheep and 30 goats during the two seasons of the year, grouped into 3 classes with 20 animals per class of each animal type as follows: Class 1 contained 10 lactating sheep or goats, class 2 comprised of 10 non-lactating sheep or goats and, class 3 consisted of 10 male sheep or goats. All the soil, forage, feed, water and animal samples were analysed for 10 minerals like $Ca^{2+}$, $Mg^{2+}$, $K^{+}$, $Na^{+}$, $Fe^{2+}$, $Cu^{2+}$, $Zn^{2+}$, $Mn^{2+}$, $Co^{2+}$ and $Se^{2+}$. In the site having sheep population all the soil minerals except $Co^{2+}$ and $Se^{2+}$ were found to be above the critical levels and considered adequate for normal plant growth during both seasons, while $Co^{2+}$ and $Se^{2+}$ in the soil were deficient during both seasons. Forage $Na^{+}$ and $Zn^{2+}$ in summer were at marginal deficient levels and in winter only $Na^{+}$ was slightly deficient. Feed $Ca^{2+}$ levels were marginally deficient during both seasons for normal requirements of sheep. Soil samples taken from the pasture grazed by goats had marginal deficient levels of soil $K^{+}$ in the summer season, moderate soil $Na^{+}$ during winter and marginal deficient during summer and sever deficient levels of $Co^{2+}$ and $Se^{2+}$ during both seasons of the year. While forage contained severe deficient level of $K^{+}$, moderate deficient level of $Na^{+}$ and marginal deficient level of $Co^{2+}$ during winter and marginal deficient $Ca^{2+}$, $Mg^{2+}$, $Cu^{2+}$ and $Se^{2+}$, moderate deficient level of $Fe^{2+}$ and severe deficient levels of $K^{+}$, $Na^{+}$, $Zn^{2+}$, $Mn^{2+}$ and $Co^{2+}$ during summer season. Feed $Ca^{2+}$ concentrations were moderately deficient during both seasons. The effects of feed supplement at both ranches in raising the plasma mineral level was different in different groups of animals in different seasons. The moderate deficient level of plasma minerals like $Ca^{2+}$ and $Na^{+}$, marginal deficient levels of $K^{+}$ and $Mg^{2+}$ during winter and summer and to that of $Cu^{2+}$ during summer in lactating goats, while in non-lactating goats in plasma, moderate levels of $Ca^{2+}$ and $Na^{+}$ and marginal deficient levels of plasma $K^{+}$ and Mg during both seasons were found. Plasma of male goats contained marginal deficient levels of $Ca^{2+}$ during winter, $K^{+}$ during both seasons and $Mg^{2+}$ during summer, while moderate deficient levels of $Ca^{2+}$ were found in summer and $Na^{+}$ during both seasons of the year. In lactating sheep plasma had marginal deficient levels of $Ca^{2+}$ in summer $K^{+}$ and $Na^{+}$ in winter, $Mg^{2+}$ in both seasons and moderate deficient levels of $Ca^{2+}$ in winter and $K^{+}$ and $Na^{+}$ in summer season, while in non-lactating sheep plasma $Ca^{2+}$ was in moderate deficient level in winter and $Na^{+}$ in summer. In addition, marginal levels of $Ca^{2+}$ during summer and those of $Na^{+}$ during winter and of $K^{+}$ and $Mg^{2+}$ during both seasons were observed. In male sheep plasma $K^{+}$ and $Mg^{2+}$ in both seasons. $Ca^{2+}$ in summer and $Na^{+}$ in winter were marginal deficient minerals while $Ca^{2+}$ in winter and $Na^{+}$ in summer were in moderate deficient levels. However, the supplementation of feed containing minerals seemed to be contributed much to the well being of the animals particularly with no micro mineral in plasma overwhelmingly deficient. No toxic accumulation of any mineral was found in forage or feed during this study. Based on mineral status of the animals, $Ca^{2+}$, $K^{+}$, $Na^{+}$, $Mg^{2+}$ and $Cu^{2+}$ were deficient in plasma which may be a factor for limiting livestock production in this specified region of Pakistan. Supplementation with fortified mixtures containing these elements in appropriate proportion with high bioavailability would seem adequate in these regions during both seasons of the year to increase the productivity of goats and sheep at that farm. Studies should be carried out to determine the need and economic benefits of mineral supplementation.

Key words: Mineral, livestock, soil, components, fluids and sampling

## Introduction

Livestock in Pakistan is the backbone of agriculture and plays a very important role in the economy of the country. Its contribution is more than 8% to annual GDP of the country. Livestock provides essential animal protein to human population in the form of milk, meat, eggs and other dry by products. In addition, it provides motive power, hide, skin and considerable share in foreign exchange. Pakistan is facing a serious shortage of meat and milk. From the meat and milk viewpoint sheep and goats cannot be neglected. Meat of sheep and goats is eaten more than beef. Milk of sheep and goats is also used in many areas of Pakistan (Gillani, 1993).

The levels of nutrition and mineral utilization are known to affect the reproducing ability of both male and female sheep and goats. Minerals are the essential nutrients bearing a significant role in the animal nutrition, because their excess or deficiency produces detrimental effects on the performance of livestock. Trace elements Cu, Co, Zn, Fe, Se, I, Mo, Mn and certain macro-elements like K, Ca, Na, Cl, P have been found to be very essential for normal livestock growth (Underwood, 1981). Mineral imbalances in soil and forage have long been held responsible for impaired performance among the ruminants. Infertility, non-infectious abortions, anemia and bone abnormalities are some of the clinical signs suggested for mineral deficiencies in livestock (McDowll *et al.*, 1983 and Bicknell, 1995).

Pakistan is a land of different soils having different agro-climatic regions. The quality and quantity of nutrients of forage mainly depend on irrigation. Mineral availability, particularly trace elements, vary to a very great extent from soil to plants and animals. Micronutrients are depleted more from light textured and calcareous soils, particularly when high yielding crop varieties are grown under intensive cropping system (McDowell and Valle, 2000). Limited research work conducted in the country has indicated areas of mineral imbalance and deficiencies in the soil, water and feed stuffs. With the increase in human population, the demand of milk and meat production is increasing day by day and to meet these demands, there is an immense need to improve the health status and production capability of dairy animals. This can only be achieved if we are abreast with the physiological norms, the disturbance of which lowers productivity. There are numerous problems of health, reproduction and meat production in sheep and goats in different regions of the world. Wasting diseases, loss of hair, depigmented hair, skin disorders, non-infectious abortion, diarrhoea, anaemia, loss of appetite, bone abnormalities, tetany, low fertility, retained placenta, still birth, .mastitis sudden death, pica and immune suppression are clinical signs often suggestive of mineral deficiencies through out the world (McDowell and Valle, 2000; Langlands *et al.*, 1994).

Despite these problems, very little information is available on blood chemistry of goats and sheep belonging to different agro-climatic regions. There are various factors, which play important role in their rate of reproduction and minerals are one of them. Mineral elements are dietary essentials for all animals and influence the efficiency of livestock production. Infact approximately 5% of the body weight of an animal consists of minerals (McDowell, 1997). Minerals are required for the proper functioning of animal body and to prevent the diseases in the animals caused by their deficiency (Langlands *et al.*, 1994 and Swecker *et al.*, 1995). Minerals in addition to vitamins are involved in tissue defense mechanisms against free radical damage to biological systems, several metalloenzymes which includes glutathione peroxidase (Se), catalase (Fe) and superoxide dismutase (Cu, Zn and Mn) are also critical in protecting the internal constituents from oxidative damage (McDowell, 2002).

A major problem in formulating precise nutritional requirements for minerals in the small holder growing areas is the lack of appropriate in farmers knowledge. Farmers in most of the developing countries have a high quest for information on how they can improve the productivity of their animals for cash benefits and provision of draft power. Our ability to monitor trace minerals in livestock has greatly increased with the development of very sensitive analytical procedures (Bicknell, 1995). Trace mineral imbalances exert a significant effect on the health and productivity throughout the tropical countries. This is particularly true in the small holder grazing areas where there is no supplementation. For example, after P, the deficiency of Cu is the more limiting mineral to grazing livestock in tropics (McDowell *et al.*, 1993) and low Cu level due to Mo toxicity has been recorded as a suspected deficient element in some areas.

Deficiencies are difficult to detect in early stages or in milder forms. Phosphorus and S deficiencies are potentially diseases of economic significance and are only occasionally seen, presumably because of frequent applications of fertilizers and the use of grain and hay supplements. In the pastoral areas, P deficiency is a major problem affecting cattle (McCosker and Winks, 1994): it is generally assumed that sheep at pasture are not susceptible to P deficiency (Underwood 1981). Livestock in different regions of the world are also at risk of S and Na deficiencies (Winter and McLean, 1988). Sodium deficiency is suspected in animals in areas, especially on pastures receiving K fertilizers (Harris *et al.* 1986).

It has been reported that livestock at pasture were unlikely to be at risk of Ca deficiency because when herbage was low in Ca it was likely to be low in other nutrients whose nutritional effects would overshadow any inadequacy in Ca (Underwood, 1981). However, acute hypocalcaemia is a common problem in dairy cows in early lactation (Harris, 1981) and in pregnant ewes lambing in winter and spring (Grant *et al.*, 1988). It is suspected that an imbalance of the major cations and anions of the diet predisposes lactating cows and pregnant ewes to hypocalcaemia. Chronic calcium deficiency causing reduced growth rate has also been reported in sheep fed grain and little roughage during drought (Peet *et al.*, 1985). Magnesium deficiency (grass tetany) usually occurs in lactating cows grazing grass-dominant pastures in late autumn and in winter (Harris *et al.*, 1983; Lewis and Sparrow, 1991). The disorder is uncommon in sheep and is not found in cattle grazing tropical pastures.

Trace element deficiencies found or suspected of limiting livestock productivity include Cu deficiency over extensive areas of world (Murphy *et al.*, 1981; Wesley-Smith and Schlink, 1990). Animals most susceptible to trace element deficiencies are young rapidly growing animals and animals during their first pregnancy and lactation. Sheep appear to be more susceptible to Se and Co deficiency and less susceptible to Cu deficiency than cattle (Judson and McFarlane, 1998).

Zn affects reproductive efficiency in both bulls and cows. In bulls, this is mainly a result of degeneration of testicular cells. Zn deficiency in cows leads to non-infectious abortions, low birth weight of the calves and reduced viability (Bicknell, 1995). Molybdenum has been classed as essential trace element, but in animal nutrition it gained importance because of condition known as "Molybdenosis" where its toxic role is more prominent (Suttle and Field, 1983). Manganese is an activator of many enzymes like bone phosphatase, peptidase, choline esterases etc. Its deficiency causes poor growth, leg disorder, poor fertility and frequent abortion in animals (Ivan and Grieve, 1975). Excessive Fe can cause Cu deficiency (McDowell *et al.*, 1993). Animals receive adequate amounts of Cu in the rainy and Se in the dry season (Mpofu *et al.*, 1999). Forage containing excess amounts of mineral elements, when consumed by livestock result in toxicity. In nature, trace mineral toxicities occur in all living organisms. In some instances, the toxicities are a direct consequence of the organism's position in the food chain and their environment, while in others they are based upon genetic abnormalities resulting in physiological impairment (Gupta, 1998). The most toxic effects in livestock appear to be dependent upon different factors. Composition of feed high in Mo can cause molybdenosis (toxicity of Mo result in Cu deficiency) in livestock (Maskall and Thornton, 1989).

The more commonly observed toxicities in the grazing animal include fluorosis in sheep and cattle in northern Australia and Cu toxicity in sheep in different parts of the world. It has been reported that two forms of Cu toxicity affecting sheep occur in different parts of the world (Hosking *et al.*, 1986). The main form of Cu toxicities occurs in sheep ingesting heliotrope. The resulting pyrrolizidine alkaloid damage to the liver from the heliotrope is associated with excessive accumulation of Cu in the liver (Allen *et al.*, 1979). The other form of chronic Cu toxicity occurs in sheep on pasture of high subterranean clover content (Hosking *et al.*, 1986). Acute selenosis resulting in rapid death has been observed in sheep grazing a highly seleniferous areas supported vegetation with high Se concentrations. Manganese toxicity has been suspected in sheep grazing lupins but not on pasture with Mn concentrations in excess. It is possible that high Fe concentrations in these pastures may have reduced the toxic effects of excess Mn because of the mutual antagonism between the two elements during absorption (Judson and McFarlane, 1998).

Generally, livestock serves first to meet dietary and farm work requirements and second as a source of income. The limited feed resources indicate that increased production cannot be achieved merely through increasing the number of the animals, but reinforcing the need to improve the productivity of feed quality.

Goat and sheep production is the center piece of Pakistan's meat industry and forage is used as the primary source of nutrients. However forage and soil mineral imbalances are common in this region, typified by acid, sandy, infertile soils. Majority of forages are frequently deficient in essential minerals in relation to ruminants requirements (Tiffany *et al.*, 2001 and Arizmendi-Maldonado *et al.*, 2002). Many naturally occurring deficiencies in grazing livestock can be related to soil characteristics (McDowell, 1992 and 1997).

Mineral nutrition disorders range from acute mineral deficiency or toxicity diseases, characterized by well marked clinical signs and pathological changes, too difficult to diagnose mild and transient conditions expressed as vague unthriftiness or unsatisfactory growth and production. The latter assume great importance because they occur over large areas and affect a large number of animals. Mineral deficiency signs can be confusing, as observed conditions can involve more than one mineral and can be combined with the effects of protein deficiencies various types of parasitism, toxic plants and infectious diseases (Vargas and McDowell, 1997).

Poor animal growth and reproduction problems are common even when forage supply is adequate and can be directly related to mineral deficiencies caused by the low mineral concentration in soils and associated forages (McDowell, 1997). In fact, forage alone rarely can meet all the mineral requirements of grazing animals (McDowell, 1992). Therefore mineral supplementation is strongly recommended.

Assessment of mineral status of grazing animals involves sampling of forage consumed by animals and soil upon which the forage grow. A sample of greatest value from soil, forage and animal tissues depends upon the minerals in question (McDowell, 1985). The soil- plant-animal system is a complex system which has not been investigated adequately especially in developing countries. Information is required on interrelationships of minerals among soil, plant and animals (Mtimuni *et al.*, 1990).

Pastoral industry in different countries has to thrive on native pasture, which is believed to be low in nutritive value. This nutritive levels result in slow growth rate, maturity and reproductive problems, low meat and milk production and general weakness with a predisposition for the occurrence of bacteriological, viral and parasitic diseases and mortality from bacterial infection (Chew, 2000). Fluctuations of nutrient contents of the pasture results in the familiar pattern of growth rate of animals on native grasses, i.e rapid growth in the rainy seasons, then followed by a loss of body weight in the dry seasons.

Mineral supplementation to grazing ruminants have been investigated since the pioneer work of Theiler *et al.* (1928). However results are not always favourable. If mineral supplementation to grazing ruminants can economically improve animal productivity, the impact will be great considering the large amount of land involved.

Diet is a useful diagnostic tool in predicting adequacy of different minerals. Selective grazing adventitious ingestion of soil and variability in mineral reserves of animals, however, limit the usefulness of pasture nutritive value in detecting nutrient status of grazing animals. Selectivity of grazer may vary with animal species, availability of plant, stage of maturity, intensity of grazing and weather conditions (Langlands and Holmes, 1978; McDowell, 1987)

Soil ingestion by the grazing animals should also be considered in total nutrient uptake. Thornton (1974) estimated that 1.1 to 10.7% of dry matter intake was ingested soil and he indicated that the animals may ingest 10 times the amount of Cu-P-Arsenic in the form of soil than by herbage. The amount of soil ingested depends on the season. Ingested soil could be a source of Co, Mn, Se, Zn and I.

A multitude of factors influence the productivity of goat and sheep herd; however, the overwhelming factor is undoubtedly inadequate nutrition, especially during the dry season (McDowell, 1997). Areas which seem to have the most potential for increased goat and sheep production are subject to extensive dry periods. Animals in these areas depend mostly entirely on pasture production. Inadequate nutritional levels which interfere with animal production occur in many parts of the world. In Pakistan livestock production in general is limited by nutrient deficiencies including inadequate mineral levels and toxicities. Grazing animals depend almost entirely on forage for their mineral supply.

To overcome the present situation, more research is required on the subject to locate the areas and extent of these mineral imbalances. The conclusive results will predict the direct or indirect effects of these imbalances on productive and reproductive performance of livestock in these areas. This will further be helpful in specifying the areas visualizing the etiological factors of impaired production of livestock in the particular region. The foremost findings will be the provision of guidelines in formulating the premixes for farm animals. This will also be helpful in increasing the productivity and further economic benefits of the livestock.

It was aimed at stimulating interest in mineral nutrition of small holder livestock in general and trace mineral nutrition in particular. It will assist to know how it is possible to improve the productivity by improving mineral nutrition of our animals for cash benefits and for the provision of the draft power. This will help improve the feeding of animals by livestock producers to expand prophylactic measures to control abnormalities caused by mineral deficiency/toxicity. By evaluating the mineral status of the soil, forage and animals, it will be possible to improve nutritional constraints limiting animal productivity and health conditions.

**Animals and Research Sites:** The study was conducted at the Livestock Experimental Station Rakh Khairewala, District Layyah, southern Punjab, Pakistan to determine the translocation of mineral nutrients from soil to plants and from plants to animals (goats and sheep) with respect to seasons. Requirement and availability of minerals to ruminants on the basis of soil, forage, feed and water was assessed. Deficiency or toxicity of elements on the basis of plasma mineral status of the animals and pastures along with feed supplements during two different seasons of the year was also assessed.

Sixty animals, 30 goats and 30 sheep, from two ranches during two consecutive seasons of the year were used in this study. Soil, forage, feed and water samples were collected from the two sites of the same

farm. Blood plasma, milk, faeces and urine samples were collected from each of the following classes of animals: Class 1 contained ten lactating sheep or goats, class 2 comprised of ten non-lactating sheep or goats, class 3 consisted of ten male sheep or goats.
Calcium, potassium, magnesium, sodium, copper, iron, zinc, manganese, cobalt and selenium concentrations were determined in all samples from pasture soil, forage, feed, water and animals.
The detection of mineral element deficiencies or excesses involves clinical, pathological and analytical criteria as well as response from specific element supplementation. Clinical signs of mineral deficiencies along with soil, water, plant and animal tissue analyses have all been used with varying degrees of success to establish mineral deficiencies and toxicities. The most reliable method to confirm mineral deficiencies is response derived from specific mineral supplementation. However, supplementation studies are costly in time and resources, if conducted with adequate control and assessment.

**Clinical and Pathological Evaluation:** Changes in animal appearance or level of production can often be an early indication of diet inadequacy, where the nutritional abnormalities are acute, or severe, well-marked clinical and pathological stigmata appear making detection and correction relatively easy. For examples, severe or acute deficiencies of iodine (I), magnesium (Mg) and copper (Cu) and toxicities of selenium (Se) and fluorine (F) are often characterized by specific clinical signs, but nutritional disorders are often mild or marginal and expressed only as a vague un-thriftiness or sub-optimal growth, fertility, or productivity. Unfortunately, these changes are often nonspecific and indistinguishable from those resulting from inadequate energy-protein or vitamins, or from parasitism or toxic plants. Therefore, it often becomes necessary to resort to chemical analyses in order to adequately determine mineral insufficiencies.
Since early diagnosis is the key to preventive treatment and preventive treatment is clearly superior to curative treatment given after productivity losses or mortality have occurred, it is important to develop detection techniques capable of giving an early and secure diagnosis (Underwood, 1979)

**Analysis of Soils and Dietary Components:** Mineral deficiencies and excesses have been established by soil, water and plant analyses. Although highly variable, all mineral elements essential as dietary nutrients occur to some extent in water. Nevertheless, grazing livestock obtain the majority of their mineral requirements from forages that, under some conditions are contaminated with soil.
Plants withdraw essential elements from the soil solution in quantities to satisfy their own requirements as well as satisfying many of the requirements of grazing livestock. Besides essential plant elements, plants also withdraw $Se^{2+}$, $Co^{2+}$ and $I^-$, which are essential for the grazing ruminants. The soil-plant relationship is direct in that the plant must obtain all mineral nutrients from the specific soil with which it has contact.
The concentration of the mineral in a soil is an uncertain guide to its concentration in the forage. Soil analysis, though useful for pasture fertilization, has been eliminated in some investigations because of lack of direct relationship to mineral content of herbage growing on the soil. For instance, plants growing on Co-deficient soil may not necessarily be deficient in Co nor would a soil rich in $Co^{2+}$ necessarily yield plants with high levels of $Co^{2+}$ (Latteur, 1962). However, in the Netherlands, soil analysis is preferred to that of forage analysis to establish a $Co^{2+}$ deficiency [Netherlands Committee on Mineral Nutrition (NCMN), 1973].
Mineral analysis of the forage consumed by the grazing animals is basic to mineral status diagnosis. If mineral concentrations are below minimum requirements or above the minimum tolerance level, there is an immediate suggestion of a nutritional problem. However, relying on a forage mineral analysis to establish mineral status assumes that the sample is representative of what animals consume.
Additional disadvantages of forage element analyses to assess mineral adequacy is the difficulty of estimating forage intake and digestibility. The majority of mineral requirements is given in percentage or ppm (mg/kg), which assumes the expected consumption as estimated by dietary standards [i.e., National Research Council (NRC) or Agricultural Research Council (ARC). Unfortunately, commonly used dietary standards are based on temperate forage consumption data and, therefore, would over-estimate the intake of minerals. It is generally accepted that tropical forages are less digestible than are temperate species and, therefore, daily consumption by grazing ruminants is lower. For more accuracy, total grams of specific minerals consumed per day and not forage concentrations, determine the true adequacy of a mineral. Likewise, relative adequacy based on forage mineral concentrations is dependent on interactions with other nutrient fractions, such as proteins, lipids, or other elements, that can greatly affect the availability of the respective elements for digestion, absorption and retention (Eagan, 1975; Haenlein, 1987)
Forage analysis for certain trace minerals will be erroneously high due to the inherent problem of sampling forages free from contaminating soil. Mineral

elements such as $Ca^{2+}$, $K^{+}$, P and Mo would not be greatly affected by soil contamination, since soil levels would be approximately equal to or less than plant material concentrations. In contrast, soil mineral levels of $Co^{2+}$, $Fe^{2+}$, $I^{-}$, $Na^{+}$, $Mn^{2+}$ and $Se^{2+}$ and to a lesser extent, $Zn^{2+}$ and $Cu^{2+}$, would be higher than forages, and even slight contamination caused by splashing rain could give an erroneously high impression of concentration of these elements (Healy, 1973 and Grace *et al.*, 1996).

**Analysis of Animal Fluids:** Undoubtedly, forage analysis is a much better indicators of mineral status for ruminants than soil analysis. Likewise, animal tissue/fluid mineral concentrations are better indicators, of the availability of most minerals than are forage mineral analyses. Grazing livestock obtain part of their mineral supply from the consumption of water, soil, leaves, tree bark, etc. rather than entirely from forages. Livestock tissue mineral concentrations, therefore, more accurately portray the contribution of the total environment in meeting requirements of grazing animals.

Animal fluid levels of minerals, in addition to concentrations of particular enzymes, metabolites, or organic compounds with which the mineral in question is associated functionally, are also important indicators of mineral status (McDowell, 1987; Puls, 1994; Judson and McFarlane, 1998).

As the minerals form a crucial part in the nutrition of ruminants and are often the limiting factors in their diets, particularly in tropical regions (McDowell *et al.*, 1976 and McDowell, 1985). Mineral concentrations of plasma provide an indication of the complete mineral uptake of grazing animals, also reflecting water, soil and other non-forage sources, with the exception of reserves mobilized from bone. Furthermore, this analysis of mineral concentrations can provide an indication of the sub clinical presence of deficiencies (Underwood, 1981) impacting optimum production.

The mineral concentrations in the plasma or of their functional forms, such as thyroxin for iodine and vitamin $B_{12}$ for cobalt must be maintained within narrow limits, if growth, health and productivity of animals are to be sustained. Deviation from these normal limits, which are now well defined for most elements, therefore, constitute useful diagnosis indicators. A further valuable aspect of such fluid composition changes is that they frequently arise prior to the appearance of adverse clinical signs (Underwood, 1979 and McDowell, 1987)

Certain plasma minerals are greatly reduced in animals fed a severely deficient diet (Miller and Stake, 1974; Sutherland, 1980; McDowell, 1985 and Minson, 1990). Assessment of mineral status on the basis of plasma of grazing animals has been considered an important strategy to increase animal productivity, especially in those countries or areas, where mineral deficiencies or imbalances are commonly found.

Ideally, animal scientists would like to determine the mineral status of an animal by measuring the mineral content of one tissue that is readily available from a live animal. Although unfortunately, no mineral cconcentrations of anyone tissue or fluid will portray the status of all minerals, the blood plasma is considered very useful tissue fluid as it indicate the animal status of most of the minerals with low concentrations indicative of dietary deficiency or excess. Plasma minerals after absorption immediately reflect the dietary intake, absorption and availability through gastrointestinal tract. The organ, tissue, or fluid chosen for analyses varies with the element, but estimation of blood plasma or serum minerals and enzyme concentration have wide applicability and do not, of course, require sacrifice of animals. The levels of certain trace elements in hair or wool, urine and even in milk are also of value in the detection of deficiency or toxicity status. Although individual variability can be very high, external contamination provides problems for trace elements status evaluation. Whole blood or blood plasma is widely used for studies in mineral nutrition. Values significantly and consistently above or below "normal" concentrations or ranges provide suggestive but no conclusive evidence of dietary excess or deficiency of particular minerals.

This study was designed to evaluate the concentrations of critical macro-and micro-minerals in the plasma of goats and sheep in addition to determine the status of these nutrients in soil, forage, feed and water in different seasons of the year to have the knowledge of correct time for supplementation.

**General Discussion on the Basis of Results with Respect to different Factors Involved in the Bio-availability of Mineral Elements in Relation to Seasonal Change:** Effects of deficiency and excesses of minerals, their critical or average values in different samples, requirements and tolerance for minerals in dietary components and their concentrations in different samples taken from the animals have been presented in Table, 1to 7.

The results indicated that in lactating goats plasma minerals except $Zn^{2+}$ and $Mn^{2+}$ were higher during winter showing the higher availability of the elements as compared to that in summer. Excretion of $Ca^{2+}$, $Mg^{2+}$, $Cu^{2+}$, $Zn^{2+}$, $Mn^{2+}$ and $Co^{2+}$ through faeces was maximum during winter and minimum during summer. This was attributed to less absorption of these minerals through gastrointestinal tract. The contents of these minerals were high in winter which showed less absorption as is evident from their corresponding

Table 1: Minerals included in study for sheep and goats, with their functions and effects of deficiency or toxicity

| Element | Function | Deficiency | Toxicity |
|---|---|---|---|
| Calcium | bone, heart function enzyme activation, neuromuscular action | milk fever,lethargy, weak bones | depressed intake and gain |
| Cobalt | constituent of vitarnin B12 | listless, anaemic, inappetence, rough hair impaired conception | low growth, muscular incoordination, rough hair, increased blood haemoglobin and PCV |
| Copper | Many enzyme systems, haemoglobin formation, cartilage/bone formation | poor or faded hair, reduced growth, lameness | anorexia, jaundice, abdominal pain haemolytic crisis |
| Iron | Haemoglobin, various enzymes | seldom except in milk-fed calves, anaemia | decreased intake and gain anaemia, anorexia, blindness, abortion, diarrhoea, abdominal pain |
| Magnesium | energy, fat and protein metabolism | loss of appetite, reduced gain, hyperexcitability, "grass tetany" incoordination, convulsions | reduced intake, diarrhoea |
| Manganese | growth, skeleton reproduction | impaired reproduction, skeletal abnormalities, abortion, reduced growth | disruption of rumen flora, reduced appetite, reduced growth, anaemia |
| Potassium | electrolyte, nerve impulse transmission | rapid decline in feed and water intake, loss of vigour, pica | unlikety to occur, Cardiac problems, oedema |
| Selenium | antioxidant, enzyme constituent | retained placenta, cystic ovaries, weak calves, poor reproduction, reduced immune function, white muscle disease | abortion, "blind staggers", hair loss lameness, inappetence, lassitude, death |
| Sodium | electrolyte, nerve impulse transmission | common in grazing cattle, depressed appetite | diarrhoea, anorexiathirst, salivation abdominal pain, convulsions, muscular spasms |
| Zinc | epidermal tissues, skeletal formation wound healing | poor reproduction, rough skin, poor immune function, reduced intake and growth | uncommon: anaemia, reduced bone formation reduced weight gain |

Sources: National Research Council, 1980, Mineral Tolerance of Domestic Animals, Washington, D.C: National Academy of Sciences

Table 2: Average value of minerals in soil, milk, plasma, faeces and urine samples

| Mineral mg $kg^{-1}$ | Soil[a] mg $kg^{-1}$ | Milk[b] mg $L^{-1}$ | Plasma[c] mg $L^{-1}$ | Faeces[d] mg $kg^{-1}$ | Urine[e] mg $L^{-1}$ |
|---|---|---|---|---|---|
| $Ca^{2+}$ | >71 | >1200 | >80 | >5800 | >60 |
| $K^{+}$ | >62 | >1500 | >200 | >8000 | >3000 |
| $Mg^{2+}$ | >30 | >100 | >20 | >1900 | >100 |
| $Na^{+}$ | >62 | >500 | >3000 | >2000 | >500 |
| $Cu^{2+}$ | >0.3 | >0.2 | >0.65 | >11 | >0.25 |
| $Fe^{2+}$ | >2.5 | >0.4 | >1.0-2 | >200 | -- |
| $Zn^{2+}$ | >1 | >4 | >0.6 | >13 | >2 |
| $Mn^{2+}$ | >5 | >0.1 | >0.015- 0.5 | >50 | -- |
| $Co^{2+}$ | >0.1 | - | >0.2ng $ml^{-1}$ | --- | -- |
| $Se^{2+}$ | >0.5 | >0.02 | >0.03 | >0.041 | -- |

Mineral concentration in Soil, Milk, Plasma, Faeces and Urine are higher than the above given values. a Viet and lindsay, 1973: Breland, 1976, Rhue and Kidder, 1978;McDowell *et al.*, 1990; b. Underwood, 1981. c, d, e. Pamela *et al.*, 2001

concentrations in faeces during this season. Plasma $Ca^{2+}$, $K^{+}$, $Mg^{2+}$, $Na^{+}$ and $Cu^{2+}$ were found to be deficient despite the high contents of these minerals in all feed sources during both seasons. Moderate levels of plasma $Ca^{2+}$ and $Na^{+}$, marginal deficient levels of $K^{+}$ and $Mg^{2+}$ during both seasons and marginal deficient levels of $Cu^{2+}$ only during winter were found. All the other minerals were above the required range based on mineral status of plasma. Low levels of $Ca^{2+}$, $K^{+}$, $Mg^{2+}$, $Na^{+}$ and $Cu^{2+}$ in blood plasma of lactating goats were due to low availability and high loss through urine after absorption in winter and high loss through milk in summer. During winter, loss of these minerals through urine was higher than that in summer and that of $Ca^{2+}$, $K^{+}$ and $Mg^{2+}$ was more through urine than to milk. However, translocation of $Na^{+}$ and $Cu^{2+}$

Table 3: Mineral requirments and tolerances for ruminants (goats and sheep) in forage, feed and water (sources)

| Mineral mg $Kg^{-1}$ | Minimum Concentrations | Maximum Tolerable Concentrations |
|---|---|---|
| $Ca^{2+}$ | 1500-2600 | 20000 |
| $K^{+}$ | 5000 | 30000 |
| $Mg^{2+}$ | 1200 | 5000 |
| $Na^{+}$ | 700-900 | 35000 |
| $Cu^{2+}$ | 5 | 25 |
| $Fe^{2+}$ | 40 | 500 |
| $Zn^{2+}$ | 20-30 | 300 |
| $Mn^{2+}$ | 15-25 | 1000 |
| $Co^{2+}$ | 0.11 | 10 |
| $Se^{2+}$ | 0.05 | 2 |

where range is given, the lower value is for maintenance and the higher value is for growing and lactating animals. (NRC, 1980; SCOA, 1990; Reuter and Robinson, 1997)

Table 4: Mineral concentrations of soil, forage, feed and water samples from goats pasture during different seasons of year

| Sample Type | Season | Mineral $Ca^{2+}$ | $K^{+}$ | $Mg^{2+}$ | $Na^{+}$ | $Cu^{2+}$ | $Fe^{2+}$ | $Zn^{2+}$ | $Mn^{2+}$ | $Co^{2+}$ | $Se^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil | Winter | 798.85 | 85.05 | 455.10 | 49.90 | 3.08 | 57.55 | 4.55 | 58.65 | 0.026 | 0.077 |
| mg $kg^{-1}$ | Summer | 804.40 | 58.50 | 409.40 | 53.00 | 3.09 | 49.95 | 4.23 | 63.50 | 0.024 | 0.055 |
| Forage | Winter | 13995.00 | 2890.0 | 3015.00 | 550.00 | 23.63 | 140.25 | 57.53 | 69.29 | 0.102 | 0.098 |
| mg $kg^{-1}$ | Summer | 2540.00 | 2054.00 | 1155.00 | 425.00 | 5.81 | 33025 | 13.65 | 12.00 | 0.048 | 0.051 |
| Feed | Winter | 2290.20 | 7644.75 | 5566.60 | 12145.75 | 17.75 | 707.75 | 77.55 | 128.20 | 3.23 | 0.57 |
| mg $kg^{-1}$ | Summer | 2383.05 | 7687.85 | 5495.60 | 11737.50 | 22.20 | 638.90 | 95.15 | 143.20 | 2.80 | 0.56 |
| Water | Winter | 34.05 | 3.36 | 63.05 | 27.25 | 0.057 | 0.34 | 0.613 | 0.017 | 0.029 | -- |
| mg $L^{-1}$ | Summer | 32.20 | 3.17 | 60.25 | 20.45 | 0.052 | 0.030 | 0.607 | 0.020 | 0.026 | -- |

Means are based on following number of samples: soil (60), forage (60), feed (20), water (20) in each season

Table 5: Mineral concentration of different sample types as related to season and animal class (goats)

| Sample Type (Lactating animal) | Season | Mineral $Ca^{2+}$ | $K^{+}$ | $Mg^{2+}$ | $Na^{+}$ | $Cu^{2+}$ | $Fe^{2+}$ | $Zn^{2+}$ | $Mn^{2+}$ | $Co^{2+}$ | $Se^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plasma | Winter | 60.44 | 174.86 | 19.32 | 2218.13 | 0.81 | 5.19 | 2.08 | 0.85 | 0.62 | 0.08 |
| mg $L^{-1}$ | Summer | 59.22 | 171.43 | 18.90 | 2067.50 | 0.68 | 4.90 | 2.31 | 1.00 | 0.54 | 0.08 |
| Milk | Winter | 701.25 | 417.50 | 83.03 | 453075 | 0.30 | 0.379 | 3.46 | 0.11 | 0.12 | 0.014 |
| mg $L^{-1}$ | Summer | 960.75 | 542.50 | 90.03 | 309.25 | 0.30 | 0.319 | 2.46 | 0.09 | 0.12 | 0.013 |
| Faeces | Winter | 14396.75 | 8211.90 | 10116.13 | 1811.50 | 11.59 | 232.58 | 74.83 | 62.85 | 2.50 | 0.031 |
| mg $kg^{-1}$ | Summer | 13917.75 | 842.88 | 9718.45 | 2127.25 | 10.40 | 243.16 | 66.13 | 57.30 | 2.13 | 0.036 |
| Urine | Winter | 115.80 | 3031.88 | 553.93 | 1041.70 | 0.04 | -- | 0.019 | -- | -- | -- |
| mg $L^{-1}$ | Summer | 90.03 | 2841.00 | 513.70 | 952.55 | 0.04 | -- | 0.017 | -- | -- | -- |
| Non-Lactating | | | | | | | | | | | |
| Plasma | Winter | 66.73 | 200.78 | 20.98 | 2204.93 | 1.26 | 5.65 | 0.94 | 1.73 | 0.68 | 0.09 |
| mg $L^{-1}$ | Summer | 65.77 | 195.03 | 20.02 | 2132.65 | 0.76 | 5.32 | 2.19 | 1.27 | 0.57 | 0.08 |
| Faeces | Winter | 13784.50 | 8245.65 | 8949.38 | 2057.46 | 13.46 | 253.60 | 67.75 | 63.45 | 2.00 | 0.04 |
| mg $kg^{-1}$ | Summer | 13862.80 | 8270.95 | 8655.80 | 2075.65 | 12.18 | 262.80 | 69.23 | 66.13 | 1.98 | 0.04 |
| Urine | Winter | 99.10 | 3221.58 | 624.90 | 971.88 | 0.33 | -- | 2.04 | -- | -- | -- |
| mg $L^{-1}$ | Summer | 90.33 | 2985.55 | 598.73 | 1026.63 | 0.29 | -- | 2.47 | -- | -- | -- |
| Male-animals | | | | | | | | | | | |
| Plasma | Winter | 69.64 | 192.91 | 23.31 | 2221.73 | 0.79 | 5.16 | 2.31 | 0.63 | 0.74 | 0.09 |
| mg $L^{-1}$ | Summer | 67.33 | 180.56 | 22.18 | 2204.75 | 0.82 | 5.17 | 1.99 | 0.56 | 0.70 | 0.08 |
| Faeces | Winter | 13233.18 | 7709.55 | 10325.70 | 1898.18 | 11.95 | 213.58 | 64.30 | 54.13 | 1.94 | 0.03 |
| mg $kg^{-1}$ | Summer | 11010.38 | 7558.00 | 9739.90 | 1942.95 | 10.97 | 221.75 | 59.43 | 59.03 | 2.20 | 0.04 |

Means are based on the following number of samples: Plasma (60), Faeces (60), Milk (40) and Urine (40) from lactating, Plasma, Faeces and Urine from non-lactating and plasma and faeces from male animals during each season

Table 6: Mineral concentration of soil, forage, feed and water samples from sheep pasture during different seasons of year

| Sample Type | Season | Mineral $Ca^{2+}$ | $K^{+}$ | $Mg^{2+}$ | $Na^{+}$ | $Cu^{2+}$ | $Fe^{2+}$ | $Zn^{2+}$ | $Mn^{2+}$ | $Co^{2+}$ | $Se^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil | Winter | 806.82 | 126.32 | 476.38 | 137.80 | 1.76 | 96.32 | 5.48 | 42.30 | 0.029 | 0.079 |
| mg kg$^{-1}$ | Summer | 793.62 | 114.78 | 463.27 | 148.07 | 2.15 | 76.67 | 5.19 | 49.77 | 0.025 | 0.066 |
| Forage | Winter | 8240.00 | 18988.33 | 4723.33 | 628.33 | 12.27 | 162.40 | 49.32 | 70.51 | 0.167 | 0.141 |
| mg kg$^{-1}$ | Summer | 3991.67 | 22275.00 | 1748.33 | 840.00 | 12.53 | 119.52 | 25.01 | 65.78 | 0.168 | 0.97 |
| Feed | Winter | 1767.70 | 10644.80 | 17446.3 | 9143.50 | 23.85 | 630.80 | 72.60 | 34.75 | 1.95 | 0.45 |
| mg kg$^{-1}$ | Summer | 1699.00 | 10746.70 | 17356.00 | 8951.05 | 29.10 | 685.90 | 128.25 | 50.45 | 1.25 | 0.41 |
| Water | Winter | 78.35 | 5.52 | 70.05 | 51.45 | 0.07 | 0.04 | 0.72 | 0.02 | 0.03 | -- |
| mg L$^{-1}$ | Summer | 75.35 | 4.59 | 65.10 | 47.30 | 0.06 | 0.03 | 0.59 | 0.02 | 0.02 | -- |

Means are based on the following number of samples: Soil (60), Forage (60), Feed (20) and Water (20) in each season

Table 7: Mineral concentration of different sample types as related to season and animal class (sheep)

| Sample Type (Lactating animal) | Season | Mineral $Ca^{2+}$ | $K^{+}$ | $Mg^{2+}$ | $Na^{+}$ | $Cu^{2+}$ | $Fe^{2+}$ | $Zn^{2+}$ | $Mn^{2+}$ | $Co^{2+}$ | $Se^{2+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plasma | Winter | 60.47 | 177.18 | 19.43 | 2589.25 | 1.17 | 4.092 | 1.74 | 0.51 | 0.57 | 0.069 |
| mg L$^{-1}$ | Summer | 76.73 | 158.27 | 21.36 | 2382.70 | 0.85 | 2.633 | 0.95 | 0.65 | 0.62 | 0.091 |
| Milk | Winter | 550.75 | 1165.50 | 111.80 | 421.75 | 0.30 | 0.36 | 1.29 | 0.088 | 0.113 | 0.014 |
| mg L$^{-1}$ | Summer | 900.00 | 1079.25 | 104.10 | 358.25 | 0.24 | 0.48 | 0.56 | 0.088 | 0.137 | 0.014 |
| Faeces | Winter | 10778.6 | 7619.20 | 2238.00 | 1572.00 | 30.20 | 1509.58 | 56.42 | 53.08 | 2.17 | 0.035 |
| mg kg$^{-1}$ | Summer | 10705.4 | 7380.63 | 2276.00 | 1605.00 | 30.43 | 1300.15 | 63.38 | 55.33 | 2.30 | 0.034 |
| Urine | Winter | 116.93 | 2904.00 | 421.00 | 893.67 | 0.039 | --- | 0.038 | -- | -- | -- |
| mg L$^{-1}$ | Summer | 132.25 | 2880.40 | 340.98 | 1105.30 | 0.034 | --- | 0.036 | -- | -- | -- |
| Non-Lactating | | | | | | | | | | | |
| Plasma | Winter | 63.63 | 170.70 | 19.15 | 2758.05 | 1.32 | 3.48 | 0.77 | 0.56 | 0.58 | 0.073 |
| mg L$^{-1}$ | Summer | 91.78 | 195.16 | 21.55 | 2277.30 | 0.94 | 2.99 | 1.61 | 0.63 | 0.62 | 0.094 |
| Faeces | Winter | 10245.6 | 7553.90 | 2442.15 | 1503.32 | 13.79 | 1078.80 | 55.05 | 54.00 | 2.06 | 0.027 |
| mg kg$^{-1}$ | Summer | 10056.00 | 7391.80 | 2350.93 | 1571.80 | 12.66 | 1151.78 | 61.59 | 57.38 | 2.12 | 0.033 |
| Urine | Winter | 87.60 | 2803.25 | 375.03 | 871.55 | 0.037 | -- | 0.048 | -- | -- | -- |
| mg L$^{-1}$ | Summer | 92.85 | 2642.25 | 321.65 | 929.63 | 0.038 | -- | 0.040 | -- | -- | -- |
| Male-animals | | | | | | | | | | | |
| Plasma | Winter | 64.45 | 180.17 | 19.14 | 2802.75 | 1.340 | 4.34 | 1.58 | 0.85 | 0.57 | 0.078 |
| mg L$^{-1}$ | Summer | 89.86 | 184.16 | 20.10 | 2245.00 | 1.093 | 4.22 | 1.11 | 0.66 | 0.79 | 0.118 |
| Faeces | Winter | 8299.47 | 7101.25 | 2351.83 | 1323.72 | 17.25 | 920.93 | 55.40 | 48.60 | 2.24 | 0.029 |
| mg kg$^{-1}$ | Summer | 8218.00 | 6973.33 | 2345.80 | 1357.75 | 15.94 | 1216.25 | 57.00 | 57.53 | 2.18 | 0.33 |

Means are based on the following number of samples: Plasma (60), Faeces (60), Milk (40) and Urine (40) from lactating, Plasma, Faeces and Urine from non-lactating and plasma and faeces from male animals during each season

was more towards to milk than to urine during winter. $Cu^{2+}$ loss through urine was equal during both seasons, but the retention of this element was minimum in plasma during summer. $Fe^{2+}$, $Zn^{2+}$, $Mn^{2+}$, $Co^{2+}$ and $Se^{2+}$ were above the critical levels in plasma and except $Zn^{2+}$ and $Mn^{2+}$ these were higher during winter than that during summer. Loss of $Fe^{2+}$ and $Se^{2+}$ through faeces was low in winter while that of $Zn^{2+}$, $Mn^{2+}$ and $Co^{2+}$ was high, but these elements were translocated more to milk during winter as compared to that in summer.

In non-lactating goats blood plasma minerals except $Zn^{2+}$ were higher during winter than those during summer. As the source contents of these minerals were higher during this season, these contributed considerably to raise the level of plasma minerals in winter, while the source contents of $Zn^{2+}$ were ineffective in raising the plasma $Zn^{2+}$ level. The higher plasma levels of all minerals except $Mg^{2+}$ and $Cu^{2+}$ can be related to low fecal loss of these minerals during winter. Similarly low plasma mineral levels may be attributed to high fecal loss during summer. Loss of $Ca^{2+}$, $K^{+}$, $Mg^{2+}$, $Cu^{2+}$ and $Zn^{2+}$ through urine was high in winter showing the high availability, but their normal levels were not retained in plasma.

Moderate deficient levels of $Ca^{2+}$ and $Na^{+}$ and marginal deficient levels of $K^{+}$ and $Mg^{2+}$ were found in plasma despite the high levels of these minerals in all external feed sources. It seems that absorption and bioavailability is not dependent on mineral contents of the diet, but depends on other dietary factors which may involve the requirements and absorption of these minerals through gastrointestinal tract (Hegsted, 1973 and McDowell, 1997). High losses of these nutrients through faeces and urine after absorption may also have been dependent on certain interaction and antagonistic role of certain minerals, in addition to controlling mechanisms under the action of hormones (NRC, 1980; McDowell, 1992 and Rojas *et al.*, 1993). In the plasma of male goats all minerals except $Cu^{2+}$ and $Fe^{2+}$ were higher in winter than those during summer, showing the dietary intake of these minerals as the mineral contents of the sources consumed by animals were considerably high during winter. Plasma $Cu^{2+}$ showed less absorption through intestinal tract perhaps due to interaction with Mo and S complex formed between Mo, S and $Cu^{2+}$ in the gastrointestinal tract (Suttle and McLauchlan, 1976; Nelson, 1988; Judson and McFarlane, 1998; Underwood and Suttle, 1999). All the other minerals such as $Ca^{2+}$, $K^{+}$, $Mg^{2+}$, $Cu^{2+}$ and $Zn^{2+}$ showed high absorption as well as excretion, which can be related to higher source contents of these minerals in the feed and water sources. Excretion of $Na^{+}$, $Fe^{2+}$, $Co^{2+}$, $Mn^{2+}$ and $Se^{2+}$ was low during winter showing the maximum absorption by the animals through the digestive canal. Plasma of male goats contained marginal deficient levels of $Ca^{2+}$ during winter. The moderate deficient levels of $Ca^{2+}$ during summer and $Na^{+}$ during both seasons were observed in blood plasma which can be related to more loss through urine after absorption, or to less absorption or more loss through fecal excretion.

In this study, it was found that at goat ranch all the soil minerals except $K^{+}$, $Na^{+}$, $Co^{2+}$ and $Se^{2+}$ were found to be above the critical level and likely to be adequate for the normal growth of plants growing therein. Soil $K^{+}$ and $Na^{+}$ were in marginal deficient levels during summer and moderate deficient level of soil $Na^{+}$ during winter. Levels of both soils $Co^{2+}$ and $Se^{2+}$ during winter and summer were severely deficient for the normal growth of plants. The levels of $K^{+}$, $Mg^{2+}$, $Fe^{2+}$, $Zn^{2+}$, $Co^{2+}$ and $Se^{2+}$ in soil were supra-optimum.

Forages at this ranch contained severe deficient level of $K^{+}$, moderate deficient level of $Na^{+}$ and marginal deficient level of $Co^{2+}$ during the winter season, whereas marginal deficient levels of $Ca^{2+}$, $Mg^{2+}$, $Cu^{2+}$ and $Se^{2+}$, moderate deficient level of $Fe^{2+}$ and severe deficient levels of $K^{+}$, $Na^{+}$, $Zn^{2+}$, $Mn^{2+}$ and $Co^{2+}$ were found during summer. Forage $Ca^{2+}$, $Mg^{2+}$, $Cu^{2+}$, $Fe^{2+}$, $Zn^{2+}$, $Mn^{2+}$ and $Se^{2+}$ during winter were adequate for the requirements of ruminants. Feed Ca contents during both seasons were deficient marginally and considered inadequate for livestock, while the other minerals were above the requirements of animals during both the seasons. Feed $K^{+}$, $Mg^{2+}$, $Fe^{2+}$, $Mn^{2+}$, $Co^{2+}$ and $Se^{2+}$ were in higher amounts and $Ca^{2+}$, $Zn^{2+}$ and $Cu^{2+}$ in lower amounts in winter than those in summer. Water minerals except Mn were slightly higher during winter than those in summer to complement the forage and feed mineral contents to fulfill the need of animals. However, the pooled data on the mineral contents of forage, feed and water showed that the levels of these minerals were higher during winter than those during summer at goat ranch.

In lactating sheep $Ca^{2+}$, $Mg^{2+}$, $Mn^{2+}$, $Co^{2+}$ and $Se^{2+}$ levels were lower in plasma but those of $K^{+}$, $Na^{+}$, $Cu^{2+}$, $Fe^{2+}$ and $Zn^{2+}$ higher during winter than those during summer. All the minerals except $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ were in normal range and cannot be considered deficient on the basis of mineral status in plasma. Moderate levels of $Ca^{2+}$ during winter and of $K^{+}$ and Na during summer were found. In contrast, levels of $Ca^{2+}$ in summer, those of $Na^{+}$ and $K^{+}$ in winter and of $Mg^{2+}$ during both seasons were marginally deficient. Although $Ca^{2+}$, $Mg^{2+}$, $Co^{2+}$ and $Se^{2+}$ contents of the sources were high in winter, they were not effective to elevate the plasma $Ca^{2+}$ and $Mg^{2+}$ levels. The low levels of source $K^{+}$, $Na^{+}$, $Cu^{2+}$, $Fe^{2+}$ and $Zn^{2+}$ were effective in raising the plasma levels of the animals during winter. Only the plasma $Mn^{2+}$ levels, responded with the source $Mn^{2+}$ concentration. Low plasma levels of $Ca^{2+}$ and Mg may be related to high excretion through milk and that of $Mn^{2+}$, $Co^{2+}$ and $Se^{2+}$ through faeces during winter. This suggests higher absorption and availability of $Ca^{2+}$ and $Mg^{2+}$ and less absorption of $Mn^{2+}$, $Co^{2+}$ and $Se^{2+}$ through gastrointestinal passage. Deficient plasma levels of $Ca^{2+}$, $K^{+}$, $Mg^{2+}$ and $Na^{+}$ may have been due to an impairment of metabolism and interaction of these elements with other minerals in forage or feed in the digestive canal of the animals. Low levels of $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $Cu^{2+}$ and $Zn^{2+}$ were found in faeces showing the high absorption of these elements by the animals, while low urine concentrations of $Ca^{2+}$, $Na^{+}$ and $Zn^{2+}$ can be related to high excretion through milk in lactating sheep after absorption during winter. High levels of $K^{+}$ and $Mg^{2+}$ of urine may also have been responsible for deficient levels of these minerals in blood plasma.

Plasma $Ca^{2+}$, $Mg^{2+}$, $Co^{2+}$ and $Se^{2+}$ of non-lactating sheep showed a decreasing trend in winter showing no dietary intake of these minerals as the levels of these minerals were maximum during winter. Similarly $Na^{+}$, $Cu^{2+}$ and $Fe^{2+}$ showed an increasing tendency despite the low levels of dietary intake during winter. Plasma $K^{+}$, $Zn^{2+}$ and $Mn^{2+}$ showed a positive relation with dietary intake during both seasons. All the minerals except $Ca^{2+}$, $K^{+}$, $Mg^{2+}$ and $Na^{2+}$ were in the normal range based on plasma mineral status. In contrast, moderate deficient levels of $Ca^{2+}$ in winter, $Na^{+}$ in summer and marginal deficient levels of $K^{+}$ and $Mg^{2+}$ during both seasons were found on the basis of critical levels in plasma. The low levels of plasma $Ca^{2+}$, $K^{+}$ and $Mg^{2+}$ during winter can be related to higher excretion of these minerals through faeces during this season. Low levels of plasma $Ca^{2+}$ and $Na^+$ also indicate that these minerals were absorbed at the slow rate as is evident from the low amount excreted through urine. High excretion of $K^+$, $Mg^{2+}$ and $Zn^{2+}$ also indicate the low retention of these minerals under the action of certain ligands and hormones controlling the homoeostatic conditions (Miller *et al.*, 1972; McDowell, 1985).

In male sheep, all the minerals except $K^+$ were not affected by the mineral contents of the source. However, they were affected to some extent by the seasons as is evident that source contents of $Ca^{2+}$, $Mg^{2+}$, $Co^{2+}$ and $Se^{2+}$ were higher and the remaining minerals were lower during winter than those during summer, but these source contents were found to be ineffective in affecting plasma minerals during both seasons. Only plasma $K^+$ levels showed dietary reflection in male sheep. $Ca^{2+}$, $K^+$, $Mg^{2+}$ and $Na^+$ found to be deficient. Depending upon the criteria, $Ca^{2+}$ during winter and $Na^+$ during summer were moderately deficient, while $K^+$ and $Mg^{2+}$ during both seasons were marginally deficient. Low levels of $Ca^{2+}$, $K^+$, $Mg^{2+}$, $Cu^{2+}$ and $Co^{2+}$ during winter may have been due to high excretion through faeces, showing less absorption and availability of these minerals through gastrointestinal tract. However, $Se^{2+}$ showed no such trends in relation to absorption and fecal excretion. The high levels of $Na^+$, $Fe^{2+}$, $Zn^{2+}$ and $Mn^{2+}$ during winter in plasma and low in fecal excretion showed higher absorption and availability.

At the sheep ranch all the soil minerals except $Co^{2+}$ and Se were sufficiently high to meet the requirements of plants for normal growth during both seasons. In contrast, soil $Co^{2+}$ and $Se^{2+}$ levels were severely deficient during both seasons and considered inadequate for plant growth. Soil $Ca^{2+}$, $K^+$, $Mg^{2+}$, $Fe^{2+}$, $Zn^{2+}$, $Co^{2+}$ and $Se^{2+}$ were higher and $Na^+$, $Cu^{2+}$ and $Mn^{2+}$ lower during winter than those during summer. Date for different elements of forages indicated that forage $Na^+$ and $Zn^{2+}$ concentrations during summer were at the marginal deficient levels and only $Na^+$ was moderately deficient during winter. In contrast, all the other minerals were within the required range of animals during both seasons.

Forage concentrations of $Ca^{2+}$, $Mg^{2+}$, $Cu^{2+}$, $Fe^{2+}$, $Zn^{2+}$, $Mn^{2+}$ and $Se^{2+}$ were found to be higher and $K^+$, $Na^+$ and $Co^{2+}$ lower during winter than those during summer. Feed Ca concentrations were at moderate deficient level during winter and summer and were below the requirements of animals. However, the levels of other minerals were above the required range and within the tolerable levels during both seasons. The levels of $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $Co^{2+}$ and $Se^{2+}$ were in the maximum range and $K^+$, $Cu^{2+}$, $Fe^{2+}$, $Zn^{2+}$ and $Mn^{2+}$ in the minimum range during winter as compared to that during summer contained in the feed. Water mineral contents such as $Ca^{2+}$, $K^+$, $Mg^{2+}$, $Na^+$, $Fe^{2+}$ and $Zn^{2+}$ were higher in winter than those during summer.

The pooled mineral data of forage, feed and water showed high levels of $Ca^{2+}$, $Mg^{2+}$, $Co^{2+}$ and $Se^{2+}$ and low levels of $K^+$, $Na^+$, $Cu^{2+}$, $Fe^{2+}$, $Zn^{2+}$ and $Mn^{2+}$ during winter than those during summer.

Similar low soil mineral levels as found on goat and sheep ranches in this study have already been reported, e.g. for $K^+$ (Tiffany *et al.*, 1999) in North Florida, $Na^+$ (Morillo *et al.*, 1989) in Venezuela, Co (McDowell, 1989) in Florida and for $Se^{2+}$ (Merkel *et al.*, 1990; Cuesta *et al.*, 1993) in Florida. Thus the low forage minerals observed during different seasons at both ranches can be related to the reports mentioned earlier e.g., for $K^+$ (Vargas and McDowell, 1997) in Central America and the Caribean $Mg^{2+}$ (Tiffany *et al.*, 2001) in Florida, $Na^+$ (Prabowo *et al.*, 1990) in Indonesia, $Cu^{2+}$ (Ogebe and McDowell, 1998; Tiffany *et al.*, 2000) in Florida, $Fe^{2+}$ (Espinoza *et al.*, 1991) in Florida, $Zn^{2+}$ and $Mn^{2+}$ (Velasquez-Pereira *et al.*, 1997) in Nicaragua, $Co^{2+}$ (Rojas *et al.*, 1993) in Venezuela and for forage $Se^{2+}$ (Espinoza *et al.*, 1991) in Florida.

Mineral concentrations in plasma of different domestic animals below the critical levels as found in this study have already been reported (McDowell *et al.*, 1984) in Central American and Caribean regions e.g., for $Cu^{2+}$ in Guatemala (Tejada *et al.*, 1987) and Venezuela (McDowell *et al.*, 1989 and Pastrana *et al.*, 1991), for $Na^+$ and $K^+$ in India (Limpoka *et al.*, 1987; Oba *et al.*, 1988; Kulkarni and Talveker, 1984), Pakistan (Gillani, 1984) and for $Ca^{2+}$ and $Mg^{2+}$ in Colombia (Pastrana *et al.*, 1991 and McDowell *et al.*, 1984).

Levels of different minerals in plasma showed a negative association with mineral contents of the sources consumed by the animals during different seasons. This suggests that during different seasons an impairment of metabolism of different mineral occurred, probably due to interaction with other nutrients, under the control of certain hormones and other conditions which would seem not adequate for maximum absorption and availability of these minerals. There are many dietary factors affecting the availability, absorption and requirements of various minerals to animals (Judson and McFarlane, 1998). The involvement of these factors may possibly be related to low levels of $Ca^{2+}$, $K^+$, $Mg^{2+}$, $Na^+$ and $Cu^{2+}$ in goats and sheep.

The implications of these findings are discussed in terms of possible antagonistic and other dietary interactions rendering the minerals deficient in plasma in different classes of goats and sheep during winter and summer (McDowell, 1997; Judson and McFarlane, 1998).

Supplies of minerals are influenced by climate and soil on which feed plants grew as well as by stage of maturity of the plants and their parts (Fiedler and Heinze, 1985; Szentmihalyi *et al.*,1985 and Kalac, 1986). $Cu^{2+}$ contents in red clover have been reported to decrease from 13 to 8 mg $kg^{-1}$ DM, in fescue grass from 11 to 6, in forage rye from 9 to 3, when sampled in different months of the year (Anke and Szentmihalyi, 1986). There are also many mineral interactions in the feed ration influencing net absorption (Haenlein, 1987). Mineral ions compete for anionic ligands to form insoluble precipitates. They also compete for transport proteins and block enzyme reactions. Vitamins also affect mineral absorption. Fiber in the ration depresses mineral absorption. Chelation between amino acids influences mineral absorption. Mineral absorption availability varies with the physical and chemical configuration of the mineral source, forage to grain rations, water contents in the feed, acid-base balance and feed additives all influence mineral gross and net absorption, i.e., digestibility minus excretion into the urine, faeces and perspiration.

The form of the mineral and the presence of other minerals or organic constituents in the diet can markedly affect requirements of dietary minerals (Ammerman *et al.*, 1995). These interactions are difficult to quantify in the field and may involve two or more dietary constituents.

It is known that the absorption of $Ca^{2+}$ in the gastrointestinal tract in the animal body is associated with P. The factors which keep the $Ca^{2+}$ and P in solution help in the absorption of these elements. The vitamin D and parathyroid hormone are involved in absorption from intestine by influencing the production of 1, 25 – dihydroxycholecalciferol, a derivative of vitamin D, which is concerned with the formation of Ca – binding protein. Excessive P and Mg decrease absorption of Ca:P ratio. The ratio should not be below 1:1 (McDowell, 1997; Underwood, 1981). Livestock will tolerate dietary Ca:P ratios of more than 10:1 without ill effects provided if the P intakes are adequate (Ternouth, 1990). The cation-anion balance of the diet can affect the ability of the dairy animals to utilize dietary Ca and the tissue Ca reserve in meeting the demand of lactation.

It has been reported that certain hormones and vitamin D prevent wide changes in blood $Ca^{2+}$ levels (McDowell, 1992). Plasma $Ca^{2+}$ below normal limits indicated that goats and sheep have severe $Ca^{2+}$ deficiency during both seasons. It has been suggested that in animals a mechanism exists for controlling the blood $Ca^{2+}$ concentration within a narrow limits by adjusting the dietary $Ca^{2+}$ absorbed and when dietary $Ca^{2+}$ is inadequate, by reabsorbing $Ca^{2+}$ from body reserves (Rowlands, 1980). Plasma $Ca^{2+}$ concentrations may be related with dietary intake (Black *et al.*, 1973) and is more affected by the amounts of P and $Mg^{2+}$ in the diet than by $Ca^{2+}$ itself (Steveens *et al.*, 1971). Plasma $Ca^{2+}$ concentrations in influenced only by severe deficiency and $Ca^{2+}$ level in the forage and feed may be a most suitable criterion in assessing the status of $Ca^{2+}$ (NCMN, 1973).

It has been suggested that excess of dietary $K^+$ is normally excreted from the body chiefly in the urine under the control of certain hormones. High intake of this element may interfere with the absorption and metabolism of $Mg^{2+}$ in animals and its excretion is mainly through urine. Excessive levels of $K^+$ induce $Mg^{2+}$ deficiency and Mg deficiency also reduces $K^+$ retention leading to $K^+$ deficiency (McDowell, 1987). High dietary levels of $K^+$ and N will inhibit Mg absorption from the rumen. Diets of low $Na^+$ content increase dietary Mg requirements indirectly by raising the $K^+$ concentrations in the rumen. Dietary $K^+$ markedly affects the availability of Mg to livestock (Dua and Care, 1995).

The present information indicated that $Mg^{2+}$ present in the diet is poorly absorbed from the alimentary canal; only small amount of Mg present in the herbage can be utilized by the ruminants (McDowell, 1985). Since adult animals have only very small readily available reserves of body Mg that are dependent upon a regular dietary supply. However, excessive Mg upsets $Ca^{2+}$ and P metabolism (McDowell, 1997). Age of animal can affect requirement of minerals through changes in efficiency of absorption (Standing Committee on Agriculture, 1990). Endocrine regulation of Mg metabolism appears to be involved in maintaining the homeostatic conditions (Rojas *et al.*, 1993). Urinary loss of $Mg^{2+}$ is considered a better criterion for assessing the plasma $Mg^{2+}$ concentration (Judson and McFarlane, 1998).

$Na^+$ is absorbed principally through upper parts of small intestine and also in the rumen. It is also stored in most fluids, tissues and bone and is excreted through urine and faeces. Few hormones like aldosterone and antidiuretic are known to control the homeostatic conditions by adjusting the $Na^+$ to $K^+$ ratio in extracellular fluids (NRC, 1980). The Na:K ratio, ammonia in the stomach of animals and binding of $Mg^{2+}$ by fatty acids or bacterial protein hinder $Mg^{2+}$ absorption through the gut. The $Mg^{2+}$ requirements of animals are also increased as a result of low $Na^+$ intake in the forage and feed (Judson and McFarlane, 1998).

The inhibitory effects of Mo and S on $Cu^{2+}$ availability have received considerable attention, thiomolybdate, formed from Mo and S in the rumen, complex with $Cu^{2+}$ making it unavailable to animal. The assessment of the inhibitory effects of Mo and S on $Cu^{2+}$ availability was reported (Suttle and Mclauchlan, 1976) using sheep given semi-purified diets. Dietary $Fe^{2+}$ concentrations of 500-600 mg/kg DM have been shown to reduce $Cu^{2+}$ utilization in sheep and cattle (Towers and Grace, 1983; Grace and Lee, 1990).

Specific mineral requirements are difficult to pinpoint since exact needs depend on chemical form and numerous mineral interrelationships. The relative biological availability of the desire element in a compound or supplement is one of the major considerations in the selection of a suitable source of the element (Ammerman and Millar, 1975). Numerous dietary factors, including protein source and level, interrelationships among the mineral ions and certain chelating agents, influence the utilization of mineral ions. With some elements, the chemical form has a major impact on the availability of the element. For instance, $Fe^{2+}$ is far more available as ferrous sulfate than as ferric oxide (Miller, 1979; Towers and Grace, 1983; Grace and Lee, 1990).

Other constituents of the diet often have a major impact on the amount of minerals needed and tolerated. For instance, $Cu^{2+}$ requirements and tolerance are very closely related to dietary Mo. As the Mo increases, the need and tolerance for $Cu^{2+}$ also increase. Even the form of the Mo seems to have an influence, with that in natural forages having more than added inorganic Mo (Miller, 1979 and McDowell, 1985).

In many respects, the dietary requirements for minerals are more difficult to accurately define than those for the organic nutrients because many factors determine the utilization of minerals. For example, interrelationships among minerals or relationships between minerals and organic fractions may result in enhanced or decreased mineral utilization (Reddy *et al.*, 1987; NRC, 1989; Beck *et al.*, 1994). Numerous mineral interrelationships that affect requirements and mineral status of the animal include Ca-P, Ca-Zn, Cu-Mo-S, Cu-Fe, Se-As, Se-S, Fe-P, Na-K and Mg-K (Judson and McFarlane, 1998). The organic constituents of the diet can have a major impact on the amounts of different mineral elements needed and tolerated. A good illustration is the relationship between vitamin E and $Se^{2+}$ and between vitamin $B_{12}$ and $Co^{2+}$; also, the effect of vitamin D on $Ca^{2+}$ and P metabolism is well known (McDowell, 1997). Goitrogenic substances and chelates such as oxalic acid and phytic acid each influence specific mineral requirements (McDowell, 1976; McDowell and Valle, 2000).

Seasons and stage of maturity may also be responsible to affect the mineral contents of the animals. Lush spring pasture is low in $Mg^{2+}$ and can result in cases of grass tetany in animals. Forage that are very mature are more lignified than young immature plants. Nutrients that are bound in lignin are no longer available for digestion. Thus, source contents, that are high in minerals but low in mineral availability, are not good mineral sources. Homeostatic conditions or regulations tend to buffer marginally deficient or excessive intakes by changing the efficiency of absorption and excretion. Factors which greatly reduce forage intake, such as low protein $> 7.0\%$ and increased degree of lignification, likewise reduce total minerals consumed. It is therefore uneconomical to provide mineral supplements to grazing livestock if the main nutrients that are lacking energy and / or protein. There are notable exceptions to the seasons of the year when mineral supplementation is most critical.

Mineral availability, however, is very difficult and expensive to measure. Research should be continued in this area. The old saying "a little bit is good, a lot is better" is definitely not the truth in the case of minerals. Awareness of mineral interactions is important when large quantities of specific minerals are added to the soil or feed in order to prevent subsequent losses in animal production.

The bottom line is one feed or ration, will not meet the requirements of every class of livestock. Rations should be formulated based on chemical analysis of home-grown feeds and rechecked any time; a feed livestock class or feeding regime is changed; otherwise production may suffer.

## Conclusion

In this study it was found that at pasture site I having goats and sites II having sheep, the soil was deficient of $K^{+}$ in summer and of $Co^{2+}$, $Na^{+}$ and $Se^{2+}$ during both seasons. Similarly, forage was deficient in $Ca^{2+}$, $Mg^{2+}$, $Cu^{2+}$, $Fe^{2+}$, $Zn^{2+}$, $Mn^{2+}$ and $Se^{2+}$ during summer season while for $K^{+}$, $Na^{+}$ and $Co^{2+}$ during both seasons. Thus it is recommended that:

i. Soil amendment with appropriate fertilizer treatment of soil be done.
ii. Mineral intake by animals depends more on the type of plants and level of consumption than on the parent rock from which the soil was derived and on which plants are grown. Thus improved varieties of forage species be grown which accumulate maximum amounts of these minerals to fulfill the requirements of livestock. As the herbs and legumes are the richer sources than grasses, they be preferably be grown in this area.
iii. Stage of forage maturity may also be taken into account while harvesting the forage for consumption or grazing purpose as the content of different minerals are affected by advancing maturity.
iv. Pasture management involving liming and fertilization can usually be extremely beneficial to

increase forage macro mineral concentration. Mineral status of goats and sheep based on plasma minerals showed deficiency of $Ca^{2+}$, $K^{+}$, $Mg^{2+}$ and $Na^{+}$ in lactating, non lactating and male animals during both seasons and $Cu^{2+}$ during summer in lactating goats only. In sheep, $Ca^{2+}$, $K^{+}$, $Mg^{2+}$ and $Na^{+}$ in all classes of animals were found to be deficient. Therefore, it is recommended that deficiency of $Ca^{2+}$ be overcome by direct treatment of animals through supplementation of these minerals in the diet. Many of the materials used as P supplement, supply significant amounts of $Ca^{2+}$ such as di-calcium phosphate and monocalcium phosphate in mineral mixtures.

v. Several safe and practical means of raising the $Mg^{2+}$ intakes of animals sufficient to maintain normal plasma value and to prevent losses from lactation tetany have been devised.

vi Foliar dusting of pasture, with calcined magenesite (MgO) before or during tetany prone periods is one such means.

vii. An oral supplement is of value only during seasonal occurrences of grass tetany. The provision of special high Mg-mineral blocks or mineral salt mixtures on pasture is more effective in raising the blood Mg levels quickly during both seasons.

viii. It is known that subcutaneous injection of single dose of 400-ml of a 25% solution of magnesium sulfate or intravenous injection of similar dose of magnesium lactate restores plasma $Mg^{2+}$ of an affected animal within about 10 minutes.

ix. Depending upon $K^{+}$ levels in forages and feed already supplied to animals, it may be necessary to add supplemental $K^{+}$. Several chemical forms of $K^{+}$, including the chloride, carbonate, bicarbonate and orthophosphate sources, are approximately equal in value and $K^{+}$ from forages also appears to be effectively utilized.

x. As the forages were found to have inadequate quantities of $Na^{+}$ to meet the requirement of grazing livestock throughout the year, it is suggested that this inadequacy should be overcome by the practice of providing common salt *ad Libitum*. The salt needs of grazing animals can easily be met with mineral mixtures containing 20 to 35% salt and consumed at a rate of 45-g per head daily. Farmers are advised to meet mineral requirements of their flocks through use of free-choice dietary minerals.

xi. For the prevention of $Cu^{2+}$ deficiency in lactating goats in summer season, it is advised to provide additional $Cu^{2+}$ to animal diet for the correction of $Cu^{2+}$ deficiency. It is known that supplemental Cu is best supplied by incorporation of the element into a concentrate mixture. However, this method is usually economically prohibitive under grazing conditions. Cu can be added in drinking water at the rate of 2 to 3 mg $L^{-1}$ to prevent deficiencies.

xii. Supplying $Cu^{2+}$ in the water probably has more problems and may be less satisfactory than other methods of supplementation. Under grazing condition $Cu^{2+}$ deficiency can be prevented by provision of Cu-containing supplements, by dosing or drenching animals an intervals with Cu-compounds, or by injection of organic complexes of $Cu^{2+}$.

xiii. Sub-cutaneous or intramuscular injection of some safe and slowly absorbed form of $Cu^{2+}$ (glycinate) constitute satisfactory means of treating animals in $Cu^{2+}$ deficiency.

In this study it was found that although sufficient amounts of minerals were present in the feed supplement being offered to the animals at farms for complementing the forage mineral for the requirement of livestock, most of the minerals found deficient in different classes of animals. It showed that all the minerals in the feed were not effective in elevating the plasma mineral levels in some animals during different seasons. It is therefore suggested that supplementation studies be conducted to determine the need and economic benefits of mineral supplementation in the following aspects in order to evaluate mineral supplement for ruminants, (i) requirements of target animals for the essential nutrients; this includes the age and breed of the animals involved and stage of current production or reproduction cycle and intended purpose for which the animals are being fed, (ii) relative biological availability of the mineral sources from which they will be provided. Only the presence of an element in the supplement does not indicate its 100% availability (iii) palatability of mineral mixture (iv) availability of energy-protein supplement (v) approximate daily intake per head of the mineral mixture and total DM by the target animals (vi) concentration of all the essential nutrients in the mineral mixture and forages so that ratio and interrelationships among minerals may be ascertained, like Ca:P, Cu:Mo:S, Ca:Al, P:Cu:Se, vitamin D:Ca, Co:Vitamin $B_{12}$. Thus other studies are needed to be carried out to clarify phenomenon like interactions digestibility and bioavailability of minerals, because when animals receive a mineral supplement, effect of individual minerals was confounded with others, so further investigation to eliminate un-necessary minerals in the supplement is also needed (vii) to develop methods to evaluate the mineral status of grazing livestock and biological assay techniques for minerals in both forages and mineral supplements (viii) to improved methods of providing supplemental minerals for livestock are needed, particularly for grazing animals, with cost-benefit relationships established (ix) to formulate free-choice mineral supplements for various soil types and ecological regions, information on mineral supplement consumption is required. Nutritional relationships to diseases and parasites, environment and stresses and non-nutrient factors affecting requirement need to be investigated, when normal mineral levels are found, they have been adequately supplied to the animals through forage and supplemented mineral mixture to avoid shotgun approach and the antagonistic behaviour of minerals.

Based on findings of deficient or borderline levels of minerals in forage, feed and plasma, supplemental mineral mixture should be provided to animals at pasture. It is recommended that supplement feed should be fed to entire herd at pasture, all over the year in order to supply animal's need.

Association or correlation among minerals in soil, plant and animal tissues are low or non-existent. This is because there are many factors affecting mineral availability from the soil, forage and even within the animal. All the factors in soil which affect mineral uptake by the roots of plants and the factors which affect mineral availability in different parts of the aerial parts of a plant, in the digestive tract of animals and even in the tissues of the animals need to be investigated to enable prediction of mineral status of animals to be made from mineral content of soil and plants. It is concluded therefore that accurate prediction of animal performance from mineral content of soil or even from forage that the animal consumes is indeed quite a challenging task.

The observations on the seasonal availability of minerals to grazing animals through forage from soil lead to conclusions that supplementation with mineral mixture of high bioavailability rather than high mineral contents is more effective during both seasons of the year. Calcium, magnesium, potassium, sodium and copper in some instances were considered to be limiting factors in the production of goats and sheep in this specified region of Pakistan.

Detailed studies are needed to determine if mineral deficiencies or excesses are limiting grazing livestock production. Mineral supplementation studies are needed to evaluate cost-benefit relationships of providing supplement minerals.

When there is no information available on mineral status for specific regions, then complete (shotgun) mineral mixtures are warranted. However, with additional information on likely limiting minerals, more economical mixes can be formulated. The specifically tailored mineral supplements may produce equal production against complete commercial supplements along with a high cost saving.

This dissertation will be a stimulus and a guide to research in mineral deficiencies and toxicities for grazing ruminants for cash-benefit and provision of draft power. This will help in improving the feeding of animals by livestock producers to expand prophylactic measures to control abnormalities caused by mineral deficiencies or toxicities.

Specific minerals should not be seen as a cure-all or scapegoat for any particular problem without thorough investigation first. Minerals are interactive ingredients in feeding program as they are dependent on plant, animal and management factors. Taking minerals lightly without considering all these factors can prevent us from achieving our animal's potential for maximum production.

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