Tropical Agriculture Research Vol 16: 128-136 (2004)

Effect of Molybdenum Supplementation on Circulating Mineral Levels, Nematode Infection and Body Weight Gain in Goats as Related to Season

M.M. Mahusoon, A.N.F. Perera[1], E.R.K. Perera[1] and K.A. Perera[1]
Postgraduate Institute of Agriculture
University of Peradeniya
Peradeniya

ABSTRACT. *A study was conducted to determine the effects of molybdenum (Mo) supplementation on circulating mineral levels, nematode infection and body weight gain in goats as related to season. Four treatments consisting of 10 goats each were used as control - free grazing only (T_0); free grazing plus mineral block without Mo (T_1); free grazing plus mineral block with molybdenum of 2 mg Mo kg^{-1} block (T_2) and free grazing plus mineral block with molybdenum of 10 mg Mo kg^{-1} block (T_3). The study continued during rainy and dry seasons for one year. Representative samples of forage, blood and rectal faeces were collected at monthly intervals. These samples were used to determine mineral concentrations of forage, plasma, nematode egg count, haematocrit value and hemoglobin concentration. Body weight of individual animals and weight of mineral block were measured bi-weekly to estimate the mineral block intake and animal live weight gain. Concentrations of minerals in forage were higher during the rainy season ($P<0.05$). Calcium, Mg, K. Fe and Mn contents in all forages were above the recommended levels during both rainy and dry seasons. During the rainy season 23% and 32% forage samples were deficient in Na and P while in the dry season the respective deficiencies were 91% and 100%. Forage Cu and Zn contents were inadequate during both rainy and dry seasons. Mineral concentrations in plasma increased due to mineral supplementation. Plasma Ca, Mg, K, Zn, Fe and Mn contents were above the critical level recommended during both seasons, while 20% and 33% of plasma samples were deficient in P and Cu, respectively. Molybdenum supplementation reduced the nematode egg count and improved haematocrit value, hemoglobin concentration and body weight gain of goats ($P<0.05$) suggesting beneficial effects of molybdenum.*

INTRODUCTION

Gastrointestinal parasites have been a serious problem throughout the world. The most prevalent and economically important parasites found in sheep and goats are *Haemonchus contortus (H. contortus)* and *Trichostrongylus virinus* (*T. virinus*). The larvae of these parasites thrive on warm and wet conditions (Howell *et al.*, 1999). Under experimental conditions, molybdenum (Mo) in the diets of lambs has been found to reduce the total adult worm population and the length of surviving adults of *T.virinus* and *H.contortus* (Suttle *et al.*, 1992a). This could be partly attributable to the direct effect of Mo on the parasite through inhibition of protienase activity. Some indirect evidence suggests that Mo may have enhanced the inflammatory reaction in the intestinal mucosa leading to worm rejection and impaired establishment of worms (Suttle *et al.*, 1992; Underwood and Suttle, 1999). The objective of this study was to examine the effects of Mo supplementation on circulating mineral concentration, nematode infection and body weight gain in goats reared under natural situations.

[1] Department of Animal Science, Faculty of Agriculture,University of Peradeniya, Sri Lanka.

MATERIALS AND METHODS

This experiment was conducted under the Kandyan forest garden system at the National Livestock Development Board Farm, Karandagolle, in the Central Province of Sri Lanka. The ground cover under the forest consisted of natural herbage. However, improved varieties of grasses such as *Brachiaria brizantha, Brachiaria milliformis* and *Panicum maximum* were also present indiscriminately.

The experimental period lasted one complete year beginning from September, 2001 to August, 2002 including both rainy (September to December, 2001 and April to June, 2002) and dry (January to February, 2002 and July to August, 2002) seasons. Forty growing young goats about 6-7 moths old (20 males and 20 females) were used for this experiment. All experimental animals were allowed to graze together on forage under forest from 08.00 hrs to 16.00 hrs. The test diets consisted of mineral blocks (cement 20%, salt 35% and mineral mixture 45%) prepared without molybdenum (T_1) and with molybdenum at two levels i.e., 2 mg kg^{-1} block (T_2) and 10 mg kg^{-1} block (T_3). The ingredient composition of the mineral block is given in the Table 1. Ten goats (5 males and 5 females) each were allocated per treatment. The groups of goats allocated for treatments were balanced by body weight. The test groups were housed separately. The test mineral blocks were offered post-grazing during night for licking *ad libitum* to the different treatment groups housed separately. The weight of the mineral blocks and individual animals were measured bi-weekly to estimate the mineral block intake and the live weight gain.

Forage and blood samples were collected at monthly intervals. The aerial parts of plant were clipped to include leaves, buds and twigs. Blood samples were collected from the jugular vein of animals into vacutainer tubes containing heparin as an anticoagulant. Faecal samples were also collected at monthly intervals from rectum for nematode egg counting. Blood samples were used to determine the haematocrit value and hemoglobin concentration using a haematocrit centrifuge and a hemoglobin meter. Collected forage and plasma samples were prepared for quantification of mineral contents according to the techniques outlined by Fick *et al.* (1979). Calcium, magnesium, copper, zinc, iron and manganese contents of forage and plasma samples were determined using Atomic Absorption Spectrophotometer (Model Shimadzu AAS 6200) according to Duncan (1976). Sodium and potassium contents were determined using Flame Photometry (Model Jenway PFP 7). Phosphorus was analysed by Spectrophotometer method (Model Shimadzu UV 1201) according to Fiske and Subbarow (1925). Data were statistically analysed using SAS (version 6.04) software package. Statistical means were compared using Duncan's Multiple Range Test (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

Forage mineral content

Overall mean mineral content of forage samples during the dry and rainy seasons is presented in Table 2. Seasonal differences in mineral content were found for Ca, P, Mg, Na, K, Cu, Zn, Fe and Mn, with higher concentrations occurring during the rainy season. Mean forage Ca levels during the rainy and dry seasons ranged from 7.4 to 13.4 g kg^{-1} DM and 7.5 to 9.6 g kg^{-1} DM, respectively. Based on the NRC (1981) recommendation (3 g kg^{-1} DM for growing and adult goats) the Ca content in forage was adequate in both seasons. Mean forage P concentrations ranged from 2.4 to 3.9 g kg^{-1} DM

Table 1. Ingredient composition of the mineral blocks.

Ingredient	% of total mixture		
	T_1	T_2	T_3
Cement	20	20	20
Calcium carbonate	2.5	2.5	2.5
Common salt	35	35	35
Di calcium phosphate	40	39.987	39.937
Cobolt choloride	0.02	0.02	0.02
Copper sulphate	0.5	0.5	0.5
Potassium iodate	0.06	0.06	0.06
Sodium selenite	0.02	0.02	0.02
Zinc oxide	1.9	1.9	1.9
Sodium molybdate dehydrate	-	0.013	0.063

T_1 : mineral block without molybdenum ; T_2 and T_3 with molybdenum at 2 and 10 mg kg^{-1} block, respectively.

Table 2. Mineral concentrations of forage as related to season.

Variable	Critical level*	Dry season Mean ± SD	Rainy season Mean ± SD
		g kg^{-1} DM	
Ca	3	7.1 ± 1.5a	10.5± 2.7b
P	2.5	2.2 ± 0.2a	3.0 ± 0.6b
Mg	2	2.3 ± 0.2a	3.0 ± 0.4b
Na	0.6	0.4 ± 0.2a	0.7 ±0.1b
K	8	8.5 ± 2.8a	11.3 ±2.9b
		mg kg^{-1} DM	
Cu	8	6.2 ± 0.9a	8.2 ± 0.5b
Zn	30	26.7 ± 1.2a	29.7 ± 2.3b
Fe	50	205.8 ± 36.3a	325.5 ± 38.2b
Mn	40	112.4 ± 26.9a	126.8 ± 50.2b

Means in the same row bearing different superscripts are significantly different ($P<0.05$)
* NRC (1981), SD – standard deviation.

and 1.9 to 2.6 g kg^{-1} DM, during the rainy and dry seasons respectively. The levels in the dry season were below the NRC (1981) recommendation for goats, suggesting inadequacy during dry season. Forage P was higher during the rainy season. Of all the forage samples analysed, 23% and 91% samples were deficient in P during the rainy and dry seasons, respectively. Mean forage Mg and K levels were adequate during both rainy and dry seasons. Forage Na was higher during the rainy season (0.7 vs. 0.4 g kg^{-1} DM) compared to the dry season. Forage Na deficiencies (< 0.6 g kg^{-1} DM) were much greater during the dry season. Individual evaluation of the forage samples indicated that 32% and 100% of all samples analysed were deficient (<0.6 g kg^{-1} DM) in Na during the rainy and dry seasons, respectively.

Mean forage Cu levels were 8.2 mg kg^{-1} DM and 6.2 mg kg^{-1} DM in the rainy and dry seasons respectively. These forage Cu concentrations were inadequate during dry season compared to the minimum recommended level of 8 mg kg^{-1} DM (NRC, 1981). Forage Fe concentrations were above the requirement of 50 mg kg^{-1} DM (NRC, 1981) averaging 325.5 mg kg^{-1} DM and 205.8 mg kg^{-1} DM in the rainy and dry seasons. Mean forage Mn values of 126.8 mg kg^{-1} DM and 112.4 mg kg^{-1} DM (in rainy and dry seasons) exceeded the recommended level of 40 mg kg^{-1} DM for goats (NRC, 1981). Forage manganese concentrations were extremely variable reflecting substantial species differences (Reid and Horvath, 1980). Of all the samples analysed for Zn, 65% and 100% samples recorded Zn content below the NRC (1981) recommendation of 30 mg kg^{-1} DM during the rainy and dry seasons, respectively. In recent years, Zn deficiency in grazing animals has been reported in a number of tropical countries where the Zn content in the diet was less than 40 mg kg^{-1} DM (McDowell *et al.*, 1983). Ranawana and Rajaratne (1985) also reported similar results for forages from different parts of Sri Lanka.

Plasma mineral content

Mean plasma mineral concentrations (macro and micro) of goats subjected to four treatments in two seasons are presented in Table 3 and 4. The mineral content in plasma of goats was affected by higher level of mineral supplementation (P<0.05). In both seasons, in all treatments, the concentrations of macro minerals (Ca, P, Mg and K) and trace elements (Cu, Zn, Fe and Mn) were above the critical requirements for goats suggested by McDowell *et al.* 1984). In both seasons, significant differences (p<0.05) in Ca content among treatments (8.4, 9.4, 9.9 and 9.9 mg dl^{-1} for treatments T_0, T_1, T_2 and T_3, during rainy season vs. 8.1, 9.3, 9.6 and 9.8 mg dl-[1] for dry season , respectively) were revealed. In the majority of plasma samples, P levels were higher than the suggested critical level of 4.5 mg dl^{-1} while 20% samples obtained during the dry seasons were deficient in P. The parasitic nematode infection (*Trichostrongylus colubriformis* and *Ostertagia circumcincta*) causes remarkable demineralization of the skeleton and induced hypophosphataemia in lambs (Bown *et al.*, 1989). Molybdenum supplementation may overcome this harmful effect by means of increasing plasma P concentration. Mean plasma Mg concentrations in the rainy and dry seasons were 2.4, 2.6, 2.8 and 2.9 mg dl^{-1} and 2.2, 2.5, 2.6 and 2.7 mg dl^{-1} for treatments T_0, T_1, T_2 and T_3, respectively.

Overall mean Cu concentration of collected all samples during the rainy season were normal compared to the suggested critical levels (McDowell *et al.*, 1984) of <0.65 μg ml-[1] for plasma, while 33% of plasma samples obtained during dry season were deficient in Cu. Copper deficiency in animals reported to be caused by a number of known and unknown factors. It is complicated due to the absence of a direct relationship between the incidence of Cu deficiency in animals and concentrations of Cu in forage and soils (Underwood, 1981). Copper deficiency is wide spread among grazing ruminants throughout the world (McDowell, 1985). Simple Cu deficiency which is likely to occur when Cu levels in herbage is less than 5 ppm, is comparatively uncommon in grazing animals (Van Soest, 1982). Plasma Fe showed a marked seasonal effect. Concentrations increased during the rainy season. A decrease was noticed during the dry period. This coincided with the period when natural pastures were mature. According to Grant (1989) this could be of practical significance in communal areas where there is no dosing and poor dipping regimes. Blood suckling parasites and worm burdens tend to lower plasma concentration of Fe. All the plasma samples from the study had greater Fe than the recommended levels. No differences were found among the treatments (T_1, T_2 and T_3) with respect to plasma Cu, Zn, Fe and Mn concentrations (P>0.05).

Table 3. Plasma mineral concentrations of goats as related to season and mineral supplementation.

Variable	Season	CL*	T_0	T_1	T_2	T_3
			(mg dl^{-1})			
Ca	Dry	8	8.1^{a} ±0.2	9.3^{b} ±0.1	9.6^{c} ±0.3	9.8^{c} ± 0.3
	Rainy		8.4^{a} ±0.2	9.4^{b} ±0.3	9.9^{c} ±0.2	9.9^{c} ±0.8
P	Dry	4.5	4.7^{a} ±0.3	5.9^{b} ±0.3	6.4^{c} ±0.2	6.5^{c} ±0.1
	Rainy		5.2^{ca} ±0.4	6.1^{b} ±0.1	6.4^{c} ±0.2	6.6^{c} ±0.2
Mg	Dry	1.8	2.2^{a} ±0.4	2.5^{cb} ±0.1	2.6^{bc} ±0.1	2.7^{c} ±0.1
	Rainy		2.4^{a} ±0.3	2.6^{b} ±0.1	2.8^{b} ±0.1	2.9^{b} ±0.2
Na	Dry	140	141.0^{a} ±5.4	156.2^{b} ±11.1	164^{b} ±9.9	165.2^{b} 11.8
	Rainy		150.3^{a} ±12.1	169.3^{b} ±11.8	172.2^{b} ±6.5	172.5^{b} ± 11
K	Dry	4	4.1^{a} ±0.1	4.6^{b} ±0.1	4.9^{c} ±0.3	4.9^{c} ± 0.3
	Rainy		4.1^{a} ± 0.1	4.7^{b} ±0.1	5.2^{c} ±0.2	5.1^{c} ±0.2

Means in the same row bearing different superscripts are significantly different (p<0.05)
* CL - Critical level (Concentration below which is deficient as suggested by McDowell *et al.*, 1984)
T_0 : free grazing only ; T1 : mineral block without molybdenum ; T_2 and T_3 with molybdenum at 2 and 10 mg kg^{-1} block, respectively.

Indices of nematode infection

In this study, the nematode egg count, haematocrit value (packed cell volume-PCV) and hemoglobin (Hb) concentration were used as indices of nematode infection. Mean values of nematode egg count, haematocrit value and hemoglobin concentration as affected by treatments and season are presented in Table 5. In all treatments nematode egg count was higher (p<0.05) during rainy season.

Control had higher nematode egg count (4544 epg and 4946 epg in dry and rainy seasons) than all mineral supplementation. Inclusion of Mo significantly ($p<0.05$) reduced nematode egg count at both levels in both seasons (164, 249 vs.3558 epg for treatments T_3, T_2 vs. T_1 for dry season and 191, 269 vs. 3955 epg for rainy season, respectively). Mean values of haematocrit during rainy season were lower. Haematocrit value was lower in control groups than mineral supplemented goats (22% and 19.7% in dry and rainy seasons). Molybdenum inclusion significantly ($p<0.05$) improved haematocrit values at both levels (38%, 37.2% vs. 26.6% for treatments T_3, T_2 vs. T_1 during dry season and 35.8%, 33.5% vs. 24.3% during rainy season, respectively). In both seasons, in all treatments the concentration of Hb was lower in control group (6.8 and 6.6 g dl^{-1} in dry and rainy seasons). Supplementation of Mo improved the Hb concentrations in both seasons (12.9, 12.8 vs. 8.6 g dl^{-1} for treatments

Table 4. Plasma micromineral concentrations of goats as related to season and mineral supplementation.

Variable	Season	Critical level*	T_0	T_1	T_2	T_3
			($\mu g\ ml^{-1}$)			
Cu	Dry	0.65	$0.6^b \pm 0.1$	$0.8^a \pm 0.2$	$0.8^a \pm 0.5$	$0.9^a \pm 0.3$
	Rainy		$0.8^b \pm 0.4$	$1.0^a \pm 0.4$	$1.1^a \pm 0.1$	$1.2^a \pm 0.3$
Zn	Dry	0.6	$0.8^b \pm 0.5$	$1.1^a \pm 0.1$	$1.3^a \pm 0.3$	$1.3^a \pm 0.3$
	Rainy		$0.9^b + 0.2$	$1.1^a \pm 0.1$	$1.3^a \pm 0.3$	$1.6^a \pm 0.3$
Fe	Dry	0.89	$1.7^b \pm 0.9$	$2.1^a \pm 0.7$	$2.5^a \pm 1.0$	$2.9^a \pm 0.9$
	Rainy		$2.0^b \pm 0.9$	$2.5^a \pm 0.6$	$2.7^a \pm 0.6$	$2.9^a \pm 0.9$
Mn	Dry	0.3	$0.31^b \pm 0.01$	$0.35^a \pm 0.2$	$0.36^a \pm 0.1$	$0.41^a \pm 0.2$
	Rainy		$0.32^b \pm 0.4$	$0.36^a \pm 0.1$	$0.39^a \pm 0.1$	$0.5^a \pm 0.1$

Means in the same row bearing different superscripts are significantly different ($p<0.05$)

** CL - Critical level (Concentration below which is deficient as suggested by McDowell et al., 1984)*

T_0: free grazing only; T_1: mineral block without molybdenum ; T_2 and T_3 with molybdenum at 2 and 10 mg kg^{-1} block, respectively.

T_3, T_2 vs. T_1 during dry season and 11.9, 11.6 vs. 8.0 g dl^{-1} during rainy season, respectively). These values are in agreement with those reported by Suttle *et. al.* (1992 a and 1992 b) for lambs. Haematocrit value and hemoglobin concentrations were improved due to the suppression of nematode infestation by molybdenum supplementation.

Table 5. Worm count, haematocrit (packed cell volume-PCV) and hemoglobin (Hb) as affected by different treatments and season.

Paramètres	T0	T1	T2	T3
Worm count (epg)				
DS	4544 ^{a}±545	3558 ^{a}±741	249 ^{b}±30	164^{b}±20
RS	4946 ^{a}±541	3955 ^{a}±1097	260 ^{b}±17	191^{b} ±40
PCV (%)				
DS	22^{a} ±3.2	26.6^{b} ±3.3	37.2^{c}± 2.1	38^{c} ±1.4
RS	19.7^{a}±1.5	24.3^{b}±1.7	33.5^{c}±2.8	35.8^{c}±1.5
Hb (g dl^{-1})				
DS	6.8^{a}± 1.1	8.6^{b}±0.5	12.8^{c}±0.8	12.9^{c} ± 0.9
RS	6.6^{a}±0.6	8.0^{b}±0.5	11.6^{c}±1.4	11.9^{c} ± 0.8

Means in the same row bearing different superscripts are significantly different ($p<0.05$)**DS**- dry season **RS**- rainy season

T_0 : free grazing only; T_1 : mineral block without molybdenum ; T_2 and T_3 with molybdenum at 2 and 10 mg kg^{-1} block, respectively.

Table 6. Mean daily mineral consumption and live weight gain of goats in different treatments as related to season.

Variable	T_0	T_1	T_2	T_3
Mineral intake ($g\ h^{-1}\ d^{-1}$)				
Dry season	-	4.5^{a} ± 0.4	6.3^{b} ±0.8	9.1^{c} ± 0.5
Rainy season	-	2.9^{a} ± 0.3	4.3^{b} ±0.4	6.4^{c} ± 1.1
Live weight gain ($g\ kg^{-1}$ BW)				
Dry season	11.2^{a}± 1.1	25.6^{b}± 2.4	35.6^{c}±1.6	36.6^{c}± 1.3
Rainy season	21.8^{a}±1.4	36.1^{b}±1.0	48.1^{c}±1.6	53.4^{d}± 1.8

Means in the same row bearing different superscripts are significantly different ($p<0.05$).

T_o: free grazing only ; T_1 : mineral block without molybdenum ; T_2 and T_3 with molybdenum at 2 and 10 mg kg^{-1} block, respectively.

Mineral supplement consumption and live weight gain

The average daily consumption of mineral supplement and live weight gain of goats are given in Table 6. Mean daily consumption of mineral supplement was greater during dry season (4.5, 6.3 and 9.1 vs. 2.9, 4.3 and 6.4 g per head for the treatments T_1, T_2 and T_3, respectively) than rainy season. This may be due to increase in fibre and lignin content in forage, and decrease in digestibility and mineral availability (McDowell, 1996) during dry season. Inclusion of Mo increased mineral intake. Among the treatments, the mean value of live weight gain was higher (53.4, 48.1 and 36.1 g kg^{-1} BW for the treatments T_3, T_2 and T_1, respectively) during rainy season. Mineral supplementation improved live weight gain significantly ($p<0.05$). Molybdenum inclusion further improved live weight gain in both seasons. Goat experienced higher live weight gain with molybdenum supplementation. This could be attributed to the suppression of nematode infection in animal by molybdenum.

CONCLUSIONS

This study reveals that Ca, Mg, K, Fe and Mn contents of forage were adequate during rainy and dry seasons, while Na and P were deficient during the dry season. Forage Cu and Zn contents were deficient in both seasons. Circulating minerals (Ca, Mg, K, Zn, Fe and Mn) were above the recommended critical level in both seasons, while plasma P and Cu were deficient during dry season. Mineral concentrations of plasma increased by mineral supplementation. Haematocrit value, hemoglobin concentration and live weight gain of animals were improved by Mo supplementation while worm infestation in goats was suppressed. Inclusion of Mp at 10 mg kg^{-1} block was beneficial to goats for improving circulatory mineral levels, blood parameters, suppression of worm infestation and live weight gain. Further studies should be conducted to find out the relationship of other elements especially copper and sulphur with molybdenum.

ACKNOWLEDGEMENTS

We acknowledge the Eastern University, Sri Lanka for funding this study as a part of the first author's Ph.D research project. We extend our sincere thanks to the Deputy Director and Manager of the National Livestock Development Board Farm, Karandagolle for providing facilities to conduct the field experiment and also extend our thanks to the Department of Animal Science for providing facilities to carry out the analytical procedures.

REFERENCES

Bown, M.D., Poppi, D.P., and Sykes, A.R. (1989). The effect of a concurrent infection of *Trichostrongylus colubriformis* and *Ostertagia circumcincta* on calcium, phosphorus and magnesium transactions along the digestive tract of lambs. Journal of Comparative Pathology. 101: 11-30.

Duncan, L. (1976). Clinical analysis by atomic absorption spectroscopy. Varian Techtron Pvt. Ltd. Sydney, Australia.

Fick, K.R., McDowell, L.R., Miles, P.H., Wilkinson, N.S., Funk, J.D. and Conrad, J.H. (1979). Methods of Mineral Analysis for Plant and Animal Tissues. 2nd (Ed). Animal Science Department, University of Florida, Gainesville, FL.

Fiske, I and Subbarow, J. (1925). A Colorimetric method for the analysis of inorganic phosphorus. J. Biological Chem. 66: 375-386.

Grant, C.C. (1989). Development of a system classifying and monitoring the availability of minerals to cattle in the ranching areas of S.W.A./Namibia. PhD thesis. University of Pretoria. South Africa.

Howell, J.M., Luginbuhl, J.M., Grice, M.J., Anderson, K.L., Arasu, and Flowers, J.R. (1999). Control of gastrointestinal parasite larvae of ruminant using nitrogen fertilizer, limestone and sodium hypochloride solution. Small Ruminant Research. 32: 197-204.

McDowell, L.R. (1985). Nutrition of Grazing Ruminants in Warm Climate. Academic Press, NY.

McDowell, L.R. (1996). Feeding minerals to cattle on pasture. Animal Feed Science and Technology 60: 247-271.

McDowell, L.R, Conrad, J.H., Ellis, G.L. and Loosli, J.K. (1983). Minerals for grazing ruminants in tropical region. University of Florida, Gainesville.

McDowell, L.R, Conrad, J.H. and Ellis, G.L. (1984). Mineral deficiencies and imbalances and their diagnosis pp 66-88. *In*: Symposium on Herbivore Nutrition in subtropics and tropics (F.M.C. Bilchrist and R.T. Mackie, Eds.) Pretoria, South Africa.

Nazki, A.R. and Rattan, P.J.S. (1990). Status of blood microelements during different seasons in sheep. Indian Vet. J. 67 : 274-276.

NRC (1981). National Research Council. Nutrient Requirements of Domestic Animals. No.15. Nutritional requirements of goats in temperate and tropical countries. National Academic Science, Washington, DC pp 91.

Ranawane, S.S.E. and Rajaratne, A.A.J. (1985). A study of the mineral status of cattle in small-farmer dairies in Sri Lanka p 774. *In*: Proc. 3rd SAREC Congress, Seoul, S.Korea.

Reid, R.L. and Horvath, D.J. (1980). Soil chemistry and mineral problem in farm livestock. A review. Animal Feed Science and Technology. 5: 95-167.

Snedecor, J.W. and Cochran, W.G. (1980). Statistical Methods. 6th (Ed). Iowa State University, Ames. IA.

.Suttle, N.F., Knox, D.P., Angus, K.W., Jackson, F. and Coop, R.L. (1992 a). Effect of dietary molybdenum on nematode and host during *Haemonchus contortus* infection in lambs. Research in Veterinary Science. 52: 230-235.

Suttle, N.F., Knox, D.P., Jackson, Coop, R.L. and Angus, K.W. (1992 b). Effect of dietary molybdenum on nematode and host during *Trichostrongylus virinus* infection in lambs. Research in Veterinary Science. 52: 224-229.

Underwood, E.J. (1981). The Mineral Nutrition of Livestock, 2nd (Ed). Commonwealth Agricultural Bureau, London.

Underwood, E.J. and Suttle, N. F. (1999). The Mineral Nutrition of Livestock, 3rd (Ed). CAB International, Wallingford, UK.

Van Soest, P. J. (1982). Nutritional Ecology of the Ruminant. Cornell University Press, NY, USA.