ISSN 0189-0514

National Animal Production Research Institute
Ahmadu Bello University
P.M.B 1096, Shika-Zaria,
Kaduna State, Nigeria.
Email: japr@napri.gov.ng Url: journals.napri.gov.ng

J. Anim. Prod. Res. (2018) 30(2):156-165

EFFECT OF MINERAL SUPPLEMENTATION ON PLASMA MINERAL CONCENTRATIONS OF GRAZING BUNAJI CATTLE

[1]Madziga, I. I. and **[2]Alawa, C. B. I.**

*[*1]National Animal Production Research Institute, Ahmadu Bello University, Shika-Zaria, Nigeria*

[2]Faculty of Veterinary Medecine, University of Abuja, Abuja, Nigeria

[*]Corresponding Author's Email & Phone Number: iimadziga2k@gmail.com +234 7037063934

ABSTRACT

A 15-week experiment was conducted to determine the effect of mineral supplementation on plasma mineral concentration and performance of grazing Bunaji heifers. Twenty heifers were allotted to five treatments as follows: 1. Common salt, 2. Potash (Kanwa), 3. Phosphorus, 4. common slat + potash + phosphorus, 5. Control. Blood was collected twice during the period of the study for mineral analysis. Live weight changes were taken fortnightly and the potash used was analyzed for mineral composition. Differences were not observed in plasma mineral concentration among the treatments. There were also no observed differences in average daily gains between the treatments. However, when the period under study was divided into phases, it was found that differences ($p<0.05$) existed in average daily gains. The conclusion from this study indicates that daily weight gains vary over the wet season with best gains occurring during the earlier parts of the wet season, therefore supplementation should be maximized at this period. For effective mineral supplementation of grazing animals, the mineral composition of pastures, the effect of soil ingestion and gastro- intestinal parasitism should be taken in to consideration.

Key words: Plasma mineral concentration, Supplementation, Pasture, Grazing, Bunaji heifers,

INTRODUCTION

With advancements in disciplines, such as animal health, pasture management, and reproductive performance, livestock agriculture, including beef production, has become more of a performance-based system. In order for these animals to produce to their greatest genetic potential, it is of major importance to make sure their greater nutritional demands are met (Burnett, 2017).

Greater performing and productive cattle result in greater nutritional demands for energy, protein, vitamins, and minerals. According to Greene (2000), beef cattle can derive a large part of their nutritional demands from forages. However, forage alone does not provide a complete feed for beef cattle nutritional requirements (Greene, 1997). For any animal to maintain long term production, mineral supplementation is necessary (Greene, 2000). Ammerman and Goodrich (1983) stated that the importance of mineral elements on the health and well-being of animals and humans has been recognized for centuries, although individual elements involved were unknown.

Mineral supplementation is a necessity in order to maintain optimal production in beef cattle. It has been shown that trace minerals, such as Zn, Mn, and Cu are necessary in beef cattle for optimal reproductive efficiency, maximal growth rate and rate of gain do, and adequate health and well-being. However, the sources of trace minerals in the diet impact their bioavailability to the animal (Burnett, 2017). Kegley and Spears (1994) found that an organic Cu source was equal to or more bioavailable than the inorganic Cu source, CuSO4. Ahola *et al*. (2004) found that supplementing beef cows with organic proteinate sources of Cu, Zn, and Mn tended to increase pregnancy rates.

Mineral requirements of beef cattle include both macro minerals and micro minerals. Macro minerals are normally required in larger amounts by beef cattle, thus receiving the name macro- or major. Beef cattle requirements for macro minerals are determined based on the stage of life and level of production (NASEM, 2016). Micro minerals are normally required and supplied in much smaller quantities. Trace mineral requirements tend to remain very similar for all stages of life or production, with one exception, Mn (NASEM, 2016).

Therefore, the purpose of the current study was to investigate the effect of supplemental trace minerals as sulphates (Zn sulphate, Mn sulphate, and Cu sulphate) compared to hydroxychloride trace mineral sources (Zn hydroxychloride, Mn hydroxychloride, and basic Cu chloride; Micronutrients USA, Indianapolis, IN) on beef heifer development.

MATERIALS AND METHODS

Study Location

The study was carried out at the National Animal Production Research Institute, Shika – Zaria. Shika is situated in the Northern Guinea Savanna Zone of Nigeria between latitudes 11^{o}N and 12^{o}N and longitudes of 7^{o}E and 8^{o}E at the elevation of 640 meters above sea level. The zone is characterized by a rainy season that starts in April/May which stabilizes in June and ends in October. The mean annual rainfall is 1100mm; maximum temperature varies between 27^{o}C and 35^{o}C depending on the season while the relative humidity is about 72%. The dry season begins with a period of dry cool weather called harmattan that last from October to January. The harmattan is followed by a dry hot weather from February to April. The relative humidity at this period is 37%. The study was carried out from July to September.

Source of Experimental Material

The experimental animals sourced from the Beef Research Programme Farm of the National Animal Production Research Institute, Shika – Zaria comprising 20 Bunaji heifers (1½ -2 years old), weighing averagely 248.5 kg were used. All the minerals used were obtained from the Institute's laboratory except the potash which was obtained from an open market in Samaru, Zaria. The experiment lasted for 15 weeks (July-October). The experimental animals were allotted randomly to 5 treatments of 4 heifers per treatment as follows:

Treatment 1 -60g common salt alone (S)

Treatment 2 -60g Kanwa alone (K)

Treatment 3 -130g single superphosphate fertilizer (SSP) to provide 10g of phosphorus (P)

Treatment 4 -60g common salt. 60g Kanwa and 130g SSP (phosphorus) (S+K+P)

5Treatment 5 -Control, no mineral supplement.

The heifers were fed the above quantity of supplements in one hundred grammes cottonseed cake used as carrier for the supplements. The control group also received one hundred grammes of cotton seed cake. Each animal was individually pen-fed the supplement in the morning after which the animals went out as a group to graze from 8:00am to 5:00pm daily.

About 10mls of whole blood was collected from each heifer via jugular venepuncture in heparinised trace mineral-free vacutainer tubes (Becton Dickson Co., Lakes, NJ) just before commencement and at the end of mineral supplementation. Samples were placed in ice for 5 before being centrifuged at 2,000 x g for 15 minutes. Plasma was then transferred to acid-washed storage vials and stored in the refrigerator. The mineral concentrations were measured after samples were thawed at room temperature for 3 to 4 h. For the analysis, 1 ml of 10% (wt/vol) trichloroacetic acid solution was added to one ml of plasma or standard and then vortexed vigorously for 20 s. To aid in precipitation, the sample was placed in a -20^{o}C freezer for 30 min, and then centrifuged at 1,200 xg for 10

min at room temperature. The supernatant was removed and diluted in deionized water to concentrations that fit within a linear range of a standard curve generated by linear regression of known concentrations. The concentration of the minerals was read at 324.7 mm using flame atomic absorption spectrophotometer (model 1275, Varian, Walnut Creek, CA) according to the methods of Whiteside (1976) at the Ahmadu Bello University Teaching Hospital, Shika. Live weight changes were taken bi-weekly. The major pasture species composition of the grazing area was identified as well as the pasture species preferred by the grazing animals.

Data analysis

Data generated on concentration of mineral and plasma were assessed using a restricted maximum likelihood-based, mixed effects model, repeat measures analysis (PROC MIXED; SAS Inst. Carry, NC). Differences among means were determined using single-degree of freedom contrast. Comparisons made were by Control Vs Supplemented

RESULTS AND DISCUSSION

The effect of mineral supplementation on plasma mineral level is presented in Table 1. Mineral supplementation did not significantly influence the plasma level of the animals investigated. The plasma level of most of the minerals measured was observed to be lower at the end of the trials. However, the level of phosphorus was higher at the end of the trial for all treatment groups. The plasma levels of sodium were higher at the end of the trial for treatment groups on common salt. Kanwa and the control but lower for the groups on phosphorus, and a mixture of common salt, Kanwa and phosphorus.

For most of the minerals, it was observed that their plasma levels were lower at end than they were at the beginning of the experiment. This may be due to the fact that the animals were gaining weight during the trial period and therefore were utilizing the minerals at the tissue level hence their removal from the blood. The observed higher plasma sodium concentration at the end of the trial for the animals on salt and Kanwa supplementation was probably due to supply of sodium from the supplements. Plasma phosphorus level were observed to be higher at the end of the trial for all treatment groups. This may be attributable to either the effect of the supplements or the fact that phosphorus levels are higher in forages during the wet season. The higher sodium level recorded at the end of the trial for the control animals may be due to its incorrect level in the plasma is not a good sample for assessing body sodium. That mineral supplementation did not influence plasma mineral level could be attribution to several factors which include:-

1. That plasma which was the sample used for analysis is not a good indicator for levels of all minerals especially phosphorus and sodium (Little, 1982).
2. The animals were grazing and could have ingested appreciable amounts of soil thus providing additional source of minerals (Healy, 1973; Grace and Healy, 1974). This would ultimately reduce the animals' response to mineral supplementation which would only be realized when other nutritional requirements (energy and protein) have been optimally met and
3. The animals used were not high producing animals whose physiological status will easily respond to mineral supplementation. Little (1981) has reported that response to mineral supplementation is more marked in high producing animals.

Table 1: Effect of mineral supplementation on plasma mineral level of heifers gazing natural pastures

	S	K	P	S+K+P	Ctrl
Ca(mg/l)					
Before	130.00±27.16	162.50±37.99	203.75±72.67	248.75±45.52	172.50±58.04
After	121.25±8.26	87.50±6.61	127.50±12.66	233.75±77.90	133.75±19.51
Mg(mg/1)					
Before	15.00±3.54	18.75±3.15	18.75±2.39	20.00±2.04	21.25±4.73
After	15.57±0.25	15.50±0.29	15.50±9.29	16.75±1.11	15.75±0.25
Zn(ug/m1)					
Before	2.25±0.77	1.86±0.72	1.62±0.37	1.87±0.89	2.00±0.67
After	0.30±0.14	0.23±0.06	0.18±0.03	0.40±0.14	0.50±0.23
Mn(ug/ml)					
Before	1.00±0.20	1.50±.045	1.75±0.52	1.12±0.37	1.50±0.35
After	0.11±0.02	0.78±0.02	0.07±0.01	0.12±0.01	0.11±0.04
Co(ug/ml)					
Before	0.30±0.10	0.45±0.13	0.40±0.14	0.25±0.05	0.40±0.11
After	0.07±0.01	0.07±0.010.05±0.00	0.11±0.05	0.10±0.05	0.10±.03
P(mg/1)					
Before	89.19±21.32	93.46±9.53	78.30±11.71	98.25±14.69	98.25±6.05
After	158.00±13.36	154.28±27.70	123.52±10.24	124.07±13.73	128.12±16.20
Na(mg/1)					
Before	1987.50±496.81	1762.50±99.22	2981.25±401.99	3375.00±982.66	2512.50±385.47
After	2662.50±370.60	2268.75±163.10	2681.25±416.88	2550.00±342.32	2943..75±517.24
K(mg/1)					
Before	89.86±10.33	89.38±4.72	83.12±14.64	97.12±10.21	114.37±7.45
After	86.30±12.80	88.30±0.36	123.37±4.69	98.25±34.63	116.25±23.59

S: Common salt, K: Kanwa, P: Phosphorus, S+K+P: Common salt +Kanwa + Phosphorus.

Table 2 presents the effect of supplementation on performance, while table 3 presents the effect of season on study. The average daily weight gains of 0.388±0.02 kg for common salt supplementation, 0.446±0.04 kg for Kanwa, 0.384±0.03 kg for phosphorus, 0.376±0.03 kg for mixture of common salt, Kanwa and phosphorus and 0.432±0.06 kg/day without supplementation. Common salt, Kanwa or phosphorus did not significantly influence the average daily gains of the animals. However, when the period under study gains of the animals. However, when the period under study was divided into phases, it is found that phases had significant effect on the average daily weight gain (table 3). The average daily gains for phase 1 (early July – early August) was significantly higher

($p<0.05$) than that for phase 2 (early August – 1st week of September) which was higher ($p<0.05$) that the gain for phase 3 (early September early October).

Table 2: Performance of the Bunaji heifers grazing natural pasture and supplemented with common salt, Kanwa and phosphorus

Treatment	S	K	F	S+K+P	Ctrl
AIW (kg)	148.25±10.20	148.75±10.92	148.25±10.96	149.25±.12.25	148.75±10.49
AFW. (kg)	172.25±11.06	176.33±11.18	173.00±12.72	172.50±13.87	175.25±12.99
AWG (kg)	24.00±2.75	27.58±3.49	24.75±3.50	23.25±2.80	26.50±3.80
ADG (kg/day)	0.388±0.02	0.446±0.04	0.384±0.03	0.376±0.031	0.432±0.06

AIW: Average Initial Weight, AFW: Average Final Weight, ADG: Average Daily Gain

Table 3: Effect of season on mineral supplementation of Bunaji heifers grazing natural pasture and supplemented with common salt, Kanwa and phosphorus

Parameter	1	2	3
AIW (kg)	148.65±36	148.65±8.36	148.65±8.36
AFW (kg).	163.05 ± 3.92^{a}	174.60 ± 9.24^{b}	183.95 ± 9.57^{c}
AWG (kg)	14.40 ± 1.23^{a}	25.95 ± 1.56^{b}	35.30 ± 1.94^{c}
ADG (kg/day)	0.450 ± 004^{a}	0.405 ± 0.02^{b}	0.360 ± 0.02^{c}

Means with different superscript within the same row are significantly different ($p<0.05$)
Phase 1: Early July – Early August, Phase 2: Early August 1st week of September
Phase 3: Early September – Early October. AIW: Average Initial Weight, AFW: Average Final Weight, AWG: Average Weight Gain. ADG: Average Daily Gain.

The average daily gain (ADG) of between 0.376 kg and 0.446 kg observed in the study were in conformity with the results of earlier studies on Bunaji (1978), Call *et al*. (1978) Agishi (1979), Okeagu (1981) and Adamu *et al*, (1991). Higher ADG for cattle of other breeds grazing improved pastures has been reported by Devendra (1986) and de Leeuw (1992)

The animals used in study were grazed from 9:00am to 5:00pm for the purpose of parasite control (grazing at this time is aimed at avoiding the period when there is dew on the pasture and consequently the likelihood of heavier load of helminth larvae on the

pasture). This grazing period is shorter that when animals are permanently on pasture. Grazing time is a factor determining feed intake and ultimately animal performance. Thus the short grazing time may have affected the animals' ability to make higher gains. This may be particularly true in the wet season when fodder quality is comparatively good and grazing time is shortest (Bayer and Ochere, 1982).

The non-significant differences of mineral supplementation on live-weight gains supports the observation of Adamu *et al.* (1993) but contrasts with the earlier works by Adamu *et al*. (1991) and Little (1980). However, it should be noted that energy and protein may still be limiting in the wet season. Bishop (1965) reported that tropical forages have peak concentrations of minerals like phosphorus, sodium, magnesium, potassium and chlorine following active growth in the wet season. Similar observations were made by Davies *et al* (1938), Robinson and Sageman (1967), Shaw (1978) and de Sousa (1978). Call *et al.,* (1978) observed no difference in average weight gains (0.45kg/day), feed efficiency or appetite between Hereford heifers fed for two years on a diet containing 0.14% phosphorus (66% of NRC recommendation) and comparable heifers receiving the same diet supplementation with monosodium phosphate to provide a total of 0.3% phosphorus. There also exist variations in the bioavailability of minerals depending on their sources and constituents (McDowell) *et al.,* 1993).

Phase (and period during the wet season) significantly ($p<0.0001$) influenced the ADG. The ADG for phase 1 was higher (0.450 kg/day) than that for phase 2 (0.405/day) and phase 3 (0.360kg/day). This trend agrees with the work of Adamu *et. Al.,* (1993) where there was progressive decline in ADG over the rainy season. This observation is further supported by the work of Haggar (1970) and Haggar and Ahmed (1971) where the nutritive value of forages was seen to decline with the change in season.

Table 4 presents the mineral composition of Kanwa Calcium, Potassium, and Copper concentrations observed were similar to that obtained by Otchere (1984), while iron, manganese, zinc and magnesium values were within the range recorded by Ikwuegbu *et al* (1985). The pasture grazed in this experiment was dominated by perennial grasses, mainly Andropogonspecies, Bracharia and Sporobolus species. Other species include *Cenchrus ciliaris, Urelytrum muricatum. Panicum* phrimitodiesa and Elionurus pubigunii. The native legumes occurring in the area were Tephrosia praeteolata, Cassia rotindofolia, Desmodium velitinum and Alyscarpus species. The dominant trees found in the area are Acacia albida. Butyrospermum paradonum, and Khaya senegalensis. The preference species by the grazing animals in order of preference were Tephrosia praetolata, Alyscarpus species, Desmodium velitinum, Bracharia species, panicum species, and Andropogon species.

Table 4 Mineral composition of Kanwa

Mineral	Unit	Quantity
Calcium	%	24.5
Potassium	%	2.0
Potassium	%	5.0%
Sodium	%	.0
Magnesium	ppm	1006.3
Zinc	ppm	1006.3
Copper	ppm	27.9
Manganese	ppm	242.6
Iron	ppm	97.5

ppm: parts per million; %: percent

Table 5 Composition of Single Superphosphate fertilizer (SSP)

Element	Unit	Quantity
Phosphorus	%	18
Sulphur	%	13

CONCLUSION

It is concluded from this study that Bunaji heifers can gain up to 446g/day grazing natural pasture during the wet season. Mineral supplementation had no significant effect on weight gains for cattle grazing natural pasture. Daily weight gains vary over the wet season. Weight gains are best during the early wet season followed by the min-wet season. Mineral supplementation did not significantly increase the ADG and plasma mineral level of cattle grazing natural pasture during the season. The mineral composition of pastures should be evaluated while planning mineral supplementation schemes for grazing animals, also influence of soil ingestion and gastro-intestinal parasitism for grazing animals is of potential importance.

REFERENCES

Adamu, A.M. (1990) Wet season Phosphorus and nitrogen supplements for steers and heifers grazing native pasture. NAPRI Seminar series.

Adamu, A.M. Eduvie, L.O. Ehoche, O.W. Lufadeju, E.A Olorunju, S.A.S, Okaiyeto, P.O., Hena, S.W., Tanko R.J., Adewuyi, A.A. Magaji, S.O. (1991). Effects of nitrogen, energy and mineral supplementation on growth and reproduction performance of Bunaji heifers grazing native pastures and crop residues. Proceeding of a workshop on Forage Production and Utilization in Nigeria. Adamu, A.M., Mani, R.I., Osinowo,

O.A., Adeoye, K.B.and Ajeleye, E.O. (Eds), NLPD, Kaduna, Nigeria.

Adamu A.M.., Eduvie, L.O. Olorunju, S.A.S., Ehoche, O.W., Lufadeju, E.A. Tanko, R.A. and Mohammed, A.K. (1993). Effect of mineral and protein supplementation on the performance of heifers grazing crop residues and range paper presented at a Workshop on Livestock Systems Research, 11-16th July, Zaria, Nigeria.

Agishi, E.C. (1979). The performance of young heifers grazing buffel – grass-verano stylo pastures. Annual Report, NAPRI Shika. Pp. 90-91.

Ahola, J.K., Baker, D.S., Burns, P.D., Mortimer, R.R., Enns, R.M., Whittier, J.C., Garry, T.W. and Engle T.E. (2004). Effect of zinc and manganese supplementation and sources on reproduction, mineral status and performance of grazing beef cattle over two-year period. *Journal of Animal Science: 82:2375-2383*

Ammerman. C.B. and Goodrich, R.D. (1983). Advances in mineral nutrition in ruminants. *Journal of Animal Science, 57:519-533*

Bayer, W. and Otchere, E.O. (1982). Grazing time of White Fulani cattle kept by settled pastoralists on Kaduna plains: In: Beef Production in Nigeria (Osinowo, O.A.,

Ikhatua, U. J., and Ehoche., O.W. (Eds). *Proceedings of National Conference on Beef Production, Kaduna, Nigeria. Pp. 611 – 612*.

Bishop I.H.K. (1965). Feeding phosphates to cattle. South African Dept. of Agric. Technical

Services. Bulletin No. 365.

Burnett, R.H. (2017). Supplemental Trace Minerals (Zn Cu and Mn) as Sulfates or Hydroxyl

Trace Mineral Sources for Beef Heifers. Master Thesis, University of Arkansas Butterworth M.H. (1985) Beef cattle nutrition and tropical pasture Longman, London.

Call, J.W., Butcher, J.E. Blake, J.T., Smart, R.A. and Shupe, J.C. (1978). Phosphorus influence on growth and reproduction of beef cattle. *Journal of Animal Science,* 47:216-225.

Davies, J.G. Scott, A.E and Kennedy, J.F. (1938). The yield and composition of a Mitchell grass pasture for a period of twelve months. *Journal of the Council for Science and Industrial Research Australia, 11:127-139.*

de Leeuw P.N. (1992). Growth performance of immature cattle grazing in West African range lands A review. Paper presented at a Training Course on Ruminant Nutrition and Feeding systems, 16-23 April. ILCA Addis Ababa, Ethiopia.

de Leeuw, P.N. and Agishi, E.C (1978). A partial economic analysis of grazing systems in the savannah zone. 8th Livestock Conference Samaru, Sept. 1978.

de Leeuw, P.N. and Brinckman, W.L. (1974). Pasture and rangeland improvement in the Northern Guinea and Suda zones of Nigeria. In: J.K. Losli, V.A. Oyenuga and

B.M. Babatunde (Eds.) Animal Production in the Tropics, Heinemann, Ibadan. Pp.124-136

de Sousa, J.C. (1978). Interrelationships among mineral levels in soil, forage and animal tissues on ranches in northern Matto Grasso Brazil. PhD Thesis. University of Florida.

Devendra. C. (1986). Leucaena forage supplementation of ruminant diets in the Asean region. In Rice straw and related feeds in ruminant ration. Ibrahim, M.N.M. and Schiere,

J.B. (Eds.) Proceedings of an International Workshop. March. Kandy, Sri-Lanka Department of Tropical Animal. Production, Agricultural University Wageningen *The Netherlands. 225-237.*

Grace, N.D., and Healy, W.B. (1974). Effect of ingestion of soil on feacal losses and retention of Mg. Ca, P, K. and Na in sheep fed two levels of dried grass. *New Zealand Journal of Agricultural Research*, 17: 73-78.

Greene, L.W. (2000). Designing mineral supplementation of forage for beef cattle. *Journal of Animal Science, 77:1-9.*

Haggar, R.J. and Ahmed, M.B. (1970). Seasonal production of *Andropogon* gayanus. II: Seasonal changes in digestibility and feed intake. *Journal of Agricultural Science Cambridge, 75: 369-373.*

Haggar, R.J. and Ahmed, M.B. (1971). Seasonal changes of *Andropogon gayanus* III: Changes in crude protein content and in vitro dry matter digestibility of leaf and stem portions. *Journal of Agricultural Science Cambridge,* 77: 47-52.

Healy, W.B. (1973a). Nutritional aspects of soil ingestion by grazing animals: In Chemistry and biochemistry of herbage G.W. Bulter and R.W. Bailey (Eds.) London, Academic Press. 1:567-588.

Ikwuegbu, O.A. Gbodi, T.A. and Obgonnah, G.A (1985). Effects of Local (Kanwa) and proprietary mineral salt licks in the ration of milk cows. Nigerian Veterinary Journal, 14(1): 66-69.

Kapu, A.M. (1975). The native forage of Northern Nigeria. Nitrogen and mineral composition of grass have from different savannah zones. *Nigerian Journal of Animal Production 2:235-246.*

Kegley, E.B and Spears, J.W. (1994). Bioavailability of feed grade copper source for shipping stressed beef cattle. *Professional Animal Science, 28:313-318.*

Little, D.A. (1980). Observations on the phosphorus requirement of cattle for growth. *Research in Veterinary Science, 28: 250-260.*

Little, D.A. (1981). Utilization of minerals. In: Nutritional limits to animal production from pastures (J.B. Hacker Ed.,) Proceedings, Australia. August 24-28th 1981. Commonwealth Agricultural Bureaux, U.K., P. 259.

McDowell, L.R. (1985). Nutrition of grazing Ruminant in Warm Climates, 443p. Academic Press. New York.

McDowell, L.R. and Conrad, J.H. (1977) Trace mineral nutrition in Latin America. *World Animal Review: 24: 24-33.*

McDowell, L.R., Conrad, J.H. and Glen Hembry, F. (1993). Minerals for grazing ruminants in tropical countries 2nd Ed. Bull of Animal Science Department Centre for Tropical Agriculture, University of Florida. U.S.A.

NASEM (2016). Nutrient requirement of beef cattle. Ninth Revised Edition, NationalAcademy Press, Washington, D.C

Okeagu, M.U. (1981). Evaluation of nitrogen fertilized signal grass (*Bracharia decumbens*) pastures under cattle grazing.

M.Sc. Thesis, Ahmadu Bello University, Zaria.

Otchere, E.O. (1984). Traditional cattle production in sub humid zone of Nigeria. In: Proceeding of the Second ILCA/NAPRI Symposium, Kaduna, Nigeria, Von Kaufmann, S. Chater and R. Blench (Eds), ILCA, Addis Ababa, Ethiopia

Robinson, D.W. and Sageman, R. (1967). The nutritive value of some pasture species in North-Western Australia during the late dry season. *Australian Journal of Experimental Agriculture and Animal Husbandry, 7: 533-539.*

Shaw, N.H. (1978). Superphosphate and stocking rate effects on a native pasture overs own with stylosanthes humilis in central coastal Queensland. I. Pasture production. *Australian Journal of Experimental Agriculture and Animal Husbandry*, 18: 788-799.

Whiteside P.J. (1976). Pye Unicam Atomic Absorption Data Book. 2nd Ed. Pye Unicam Ltd Cambridge.