The influence of phosphorus supplementation on the performance of beef weaners overwintering on kikuyu foggage and Smutsfinger hay

ESMARI RAUTENBACH (neé Maritz)
(B.Sc. Agric. Hons.)
9330925

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I hereby certify that this research is the result of my own investigation. Where use was made of the work of others, it has been duly acknowledged in the text.

E. RAUTENBACH

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ESMARI RAUTENBACH (neé Maritz)

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Supervisors: J.B.J. van Ryssen and W.A. van Niekerk

ABSTRACT

A study was conducted during the period May to September, 1999 to determine the effect of phosphorus (P) supplementation to beef weaners grazing kikuyu (*Pennisetum clandestinum)* foggage during winter followed by hay towards the end of winter at Dundee in northern KwaZulu-Natal. Foggaging is defined as the practice of allowing herbage to accumulate on a pasture during the growing season (Gertenbach, 1998). This accumulated herbage is then utilized by grazing animals during the dormant season. A total of 200 crossbred beef weaners (average age six months and average weight 175 kg) was used in the trial. Animals were randomly allocated into five groups, each receiving a different supplemental treatment. The treatments were different levels of P supplementation, administered through free-choice P lick supplements, viz. at levels of 0 g P, 2 g P, 4 g P, 6 g P and 8 g P per animal per day. The experiment was divided into two phases. During the first phase (08-06-99 to 20-07-99) the weaners grazed kikuyu foggage and during the second phase (05-08-99 to 16-09-99) they received Smutsfinger (*Digitaria eriantha*) hay *ad libitum*. During phase 1 the average weight gain of the animals in Group 1 (receiving 8 g P/animal/day) was significant higher (6 kg/animal during trial) than that of the control group, which received 0 g P/day/animal. Phase 2 which represented a transition from winter to summer showed that Group 1 had an average weight loss of 0.88 kg/animal but the control group lost an average of 5.13 kg/animal.

Throughout the trial blood was collected from five animals randomly selected from each group. Plasma inorganic P (Pi) concentrations remained between 1.94 and 2.58 mmol/L. The average trend during phase 1 was that the Pi concentrations increased, while during phase 2, Pi concentrations dropped more ($P \leq 0.5$) in the animals of Group 1 (8 g P/animal/day) than in the

control. This resulted that during the entire experimental period plasma Pi in Group 5 increased while that in Group 1 decreased.

Before the animals entered a grazing strip, herbage samples were collected at 14 to 20 day intervals from the five strip grazed kikuyu camps. Samples were divided into leaves and stems which were analysed separately. Mean foggage calcium (Ca) and P concentrations ranged from 25.0 to 29.0 g/kg DM and 20.0 to 27.0 g/kg DM, respectively, while the Ca:P ratios ranged from 1.20:1 to 1.60:1. Calcium concentrations were significantly lower ($P = 0.0026$) in the stems than in the leaves of the kikuyu foggage, while P concentrations decreased significantly over time, resulting in extremely low foggage P concentrations towards the end of the grazing season. This decrease in P concentrations resulted in Ca:P ratios of above 1:1 instead of the reported ratios of below 1:1 in kikuyu herbage due to low herbage Ca concentrations.

The Ca concentrations in the kikuyu in this study were in the same range as herbage concentrations reported in the literature, but P concentrations were much lower than the reported herbage P concentrations. As with the summer pastures we found that magnesium (Mg) concentrations (ranging from 2.1 to 2.6 g/kg DM) were adequate in terms of the requirements of most classes of ruminants. However, potassium (K) concentrations (ranging from 11.4 to 20.3 g/kg DM) were well in excess of animal requirements, and Mg absorption could be severely inhibited by the oversupply of K.

The sodium (Na) concentration in kikuyu foggage was, as with herbage, inadequate in terms of animal requirements. Zinc (Zn) and manganese (Mn) concentrations were well above animal requirements but below toxic levels. Copper (Cu) concentrations was above animal requirements during May (onset of the study) but decreased significantly to levels below minimum animal requirements. Selenium (Se) concentrations were found to be largely inadequate in terms of animal requirements.

The neutral detergent fibre (NDF) levels in kikuyu foggage tended to increase with maturity while acid detergent fibre (ADF) levels did not vary significantly. Crude protein (CP) concentrations decreased as winter progressed to reach levels of < 60 g/kg DM in the dry foggage, indicating that supplementation of CP would be required by animals grazing the kikuyu foggage in mid-winter. It is concluded that if little or no gain is expected from weaners in winter, the Ca and P concentrations in the kikuyu foggage should be adequate. However, if even slight weight gains are required, supplementation of Ca and P would be necessary when the foggage is dry.

The P and CP composition of pastures in general were closely correlated and had a seasonal pattern with maximum levels during summer and minimum levels during winter. We can therefore expect that pastures and kikuyu foggage low on protein will also have a P deficiency. In the dry winter we should therefore firstly supplement for protein and energy and then P. The supplementation of P during winter has not only been very positive (in other studies) with positive results on weight gain during the winter period but also during the months thereafter.

It is concluded that beef weaners grazing kikuyu foggage in northern KwaZulu-Natal would require supplemental P to maintain their body weights during winter as well as beef weaners on Smutsfinger hay. The recommended level of P supplementation is 8 g P/animal/day.

INTRODUCTION

Research work dealing with the need for P supplementation to beef cattle on natural grazing in South Africa spans a period of nearly 80 years. Despite this, and surprisingly so, controversy still surrounds the question of P supplementation in winter. Many experiments conducted in southern Africa showed that P given as the only supplement during the dry season when animals in the grassveld areas are normally losing weight, has no beneficial effects on the economic performance of animals (Van Niekerk, 1990).

According to Van Niekerk (1990), this evidence is overwhelming and has been gathered not only in South Africa (Theiler *et al.,* 1927; Van Niekerk & Jacobs, 1985) but also in other African countries and in overseas countries (Winks *et al.,* 1977; Little, 1980). In later reports from Australia P supplemented directly through oral application or indirectly through the fertilization of the vegetation increased weight gains in growing cattle during the wet and/or growing season (Winter, 1988; Winter *et al*., 1990; Coates & Ternouth, 1992; Hendricksen *et al*., 1994; Mclean & Ternouth, 1994; Coates, 1995). In some situations weight gains were improved by increasing dietary P in both wet and dry seasons (Coates & Ternouth, 1992; Hendricksen *et al*., 1994) but in others, either weights were not affected (Winks *et al*., 1977; Winter *et al.*, 1990) or weight losses occurred (Winter, 1988; Coates, 1995).

In the highland sourveld areas (close to the mountains) of KwaZulu-Natal one of the major limiting factors to profitable beef production is overwintering. A practice that is still used but is gradually disappearing is to move cattle to a sweetveld farm in winter (Van Niekerk, 1990). On most sourveld farms, however, under dry land conditions, winter feed usually comprises the feeding of hay and/or silage or involves the grazing of crop residues. The planting of green feed (winter pasture and root crops) is a consideration where irrigation is available. The problem is that, apart from grazing crop residues, which is dependent on the presence of a cropping enterprise, these options are relatively expensive and are dependent on mechanization. In searching for a cheaper alternative to the above winter feeding systems, the use of foggage has been under investigation for a number of years (Van Niekerk, 1990).

Foggaging is defined as the practice of allowing herbage to accumulate on a pasture during the growing season (Gertenbach, 1998). This accumulated herbage is then utilized by grazing animals during the dormant season. Although it has been stated that the most elementary form of foggage is rested veld, the term foggage (also called standing hay) is usually associated with cultivated pastures. A number of grass species has been assessed for their foggaging value including *Digitaria eriantha* (Smutsfingergrass), *Acroceras macrum* (nilegrass), *Cynodon aethiopicus* (stargrass), *Festuca arundinaceae* (tall fescue), *Lotus corniculatus* (cocksfoot), *Eragrostis, Cynodon* and *Pennisetum clandestinum,* Hochst (kikuyu) (Gertenbach, 1998). It has been shown that compared to the foggage of other pasture species, kikuyu foggage is of average quality in terms of CP content (Gertenbach, 1998). However, since kikuyu is such a common pasture in the high rainfall areas, kikuyu foggage is potentially a major source of winter-feed.

Intensive pastures form a key component of animal production systems on many farms in the eastern regions of South Africa. With establishment costs being appreciable, and the pastures often being located on high potential land, emphasis is on maximizing forage yields through high rates of fertilization. Animal performances are, however, often below expectations on these highly productive pastures (Gertenbach, 1998).

Absence of clinical symptoms arising from mineral toxicities or imbalances is not proof that problems do not exist. Even marginal mineral deficiencies can reduce growth, reproduction or health in ruminants (Spears, 1991). Reservations regarding the adequacy of minerals in kikuyu in terms of the dietary requirements of grazing animals have over the years been expressed by researchers (Miles *et al.,* 1995). Mineral deficiency studies on kikuyu have been restricted mostly to fresh herbage. In this study we concentrate on mineral composition of kikuyu foggage.

In South Africa, research aimed at characterizing the quality of pastures has tended to focus on constituents such as protein, fibre and digestibility, with minerals receiving relatively little attention. The prevailing view appears to be that minerals provided in licks or supplementary feeds adequately compensate for imbalances in pasture herbage. In support of this is the general lack of clinical evidence of mineral problems in grazing animals. There is nonetheless, mounting evidence that gross mineral imbalances in forages may seriously impact animal performances and health regardless of other feeding practices (Brendon, 1980; Beede, 1992).

The first objective of this study was to investigate the response of beef weaners grazing kikuyu foggage to different levels of P supplementation during the winter months and the effect of P supplementation on weight gain or loss during the transition from winter to summer. Justification for the use of winter supplements will be based on the ability of such supplements to influence economically important parameters such as body mass.

The second objective of the investigation was to obtain detailed information on the mineral composition of kikuyu foggage and compare those concentrations with reported herbage mineral concentrations relative to dietary requirements of ruminants. The comparison of kikuyu herbage and foggage mineral concentrations was done because no data could be obtained for kikuyu mineral foggage concentrations. The limited amount of data that could be found on the mineral concentration of kikuyu foggage was restricted to a sample for only one month of the dry season, and nothing for changes during the dry season.

Miles *et al*. (1995) reported kikuyu to be a most unusual forage in that it contains more P than Ca. The study of Miles *et al*. (1995) was done on fresh kikuyu herbage. However, kikuyu foggage from the present research site, analysed in July, 1997, had a higher Ca than P concentration (Table 1). Unfortunately, only one sample was analysed, thus limiting its value as indication of the situation at Dundee. McDowell (1996) reported that for grazing livestock, P is the mineral most likely to be deficient, but mineral supplementation is relatively less important for cattle if their energy and protein requirements are not met. Therefore, protein supplements with no phosphorus and different levels of phosphorus (monocalcium phosphate) were given to crossbred beef weaners grazing kikuyu foggage during May to July. The criteria to measure response were animal weight changes, plasma inorganic P (Pi) levels and changes in chemical composition of the kikuyu foggage (stem and leaves separately) during the period of study.

Table 1 Composition of kikuyu pastures on Eversly Research station during July 1997 (data used with permission from Dr O'Donovan, Stockowners, P.O. Box 260, Howick 3290 South Africa)

CAMP	ADF g/kg DM	NDF g/kg DM	CP g/kg DM	Ca g/kg DM	P g/kg DM
1	444.3	793.5	52.0	3.3	2.8
2	375.1	699.4	88.0	3.1	1.8
3	464.7	785.0	111.3	5.1	1.6

ADF - acid detergent fibre; NDF - neutral detergent fibre; CP- crude protein

The changes in chemical composition of kikuyu (stem and leaves separately) during the period of study will help to determine if nutrient supplementation is required when cattle overwinter on kikuyu foggage.

CHAPTER ONE

LITERATURE REVIEW

1.1 UTILIZATION OF FOGGAGE BY BEEF WEANERS

With the utilization of foggage the most important objective is to feed animals to at least maintain body weight through the dry winter season. Since a foggage is generally not a high quality feed, it usually cannot be used without supplementation for producing animals (Rethman & De Witt, 1991). It is often necessary to make provision for an adaptation period. This could result in an initial decline in body weight, as the intake of such material may be low for a period of time. After this adaptation period intake improves but utilization can result in the trampling and wasting of the herbage. It is, therefore, generally recommended that grazing management be based on high utilization grazing (HUG) (Corbett, 1957). This can be done using rotational grazing or continuous grazing systems. With strip grazing (rotational grazing), an electrical fence is used to limit the forage available and thereby force animals to consume the material. Animals tend to first use the better material with continuous grazing, and performance declines when the residual material is used (Meaker & Coetzee, 1978). A supplemental protein can be supplied to adult animals when the nutritive value of foggage declines as the winter season progresses (Tainton, 2000).

Since animals always tend to consume the best quality material early in the winter their condition would tend to decline towards the end of winter and in early spring. This is due to the limited availability of new green material and the refusal or rejection of old frosted, soiled residues. Experience proofed that if the best profit is to be achieved when using kikuyu as a foggage, it is important to use the fresh grazing intensively during the middle summer months either by grazing or by cutting the grass for haymaking. The pasture has to be closed down from approximately the beginning of March to allow enough vegetative material of an acceptable physical composition to accumulate for utilization by the animals from approximately May onwards. Table 1.1 demonstrates the carrying capacity of kikuyu foggage when withdrawn from grazing (closing up) at different stages in summer.

Table 1.1 The carrying capacity of kikuyu foggage with different closing-up times or date of animal withdrawal from pasture (Rethman, 1983)

Date of closing-up kikuyu	Carrying capacity
15 January	18 sheep
1 March	16 sheep
15 April	6 sheep

Table 1.2 shows the carrying capacity and average daily gain (ADG) of weaner calves on kikuyu foggage.

Table 1.2 Carrying capacity of kikuyu foggage and average daily gain (ADG) of weaner calves grazing kikuyu foggage (Rethman, 1983)

Type of animal	Carrying capacity/ha	ADG in g
Weaner calves	6 for 6 weeks	430
Weaner calves	6.6 for 4 months	200
Weaner calves	7.7 for 3 months	1040 + concentrates
Weaner calves	6.7 for 10 weeks	570

According to Rethman (1983) grasses that tend to develop stems with plenty of fibre, for example K11 and Smutsfinger grass, will yield poorer results if they are to be rested for long periods. In spite of this, Smutsfinger grass that has been closed down in January will be an excellent grazing in the early and middle winter, especially for beef cows (Rethman, 1983). Where closing-up took place from the first of January a protein supplementation should be supplied after 30 days of grazing on the foggage. Smutsfinger grass can be a good source of foggage for sheep, especially in early winter. In Table 1.3 Rethman showed the value of this grass as a foggage.

Table 1.3 Quality (crude protein (CP) concentration in mid-winter) and carrying capacity of *Digitaria eriantha* foggage (Rethman, 1983)

Grazed till (closing-up date)	Crude protein concentration of the whole plant	Crude protein concentration of the leave	Sheep/ha/100 days. May till August
1 January	60	80	30
1 February	90	100	18
1 March	90	170	16

K11 grass that has been closed-up in February also supplied a good source of foggage for sheep. In the dry areas, *Panicum maximum, Anthephora pubescens* and *Cenchrus ciliaris* will all provide a good winter grazing in the form of foggage (Rethman, 1983).

1.2 FACTORS AFFECTING THE MINERAL COMPOSITION OF PLANTS

Cattle grazing on pasture can receive a certain proportion of their minerals from water and soil ingestion. However, forages would be the main source of minerals. Of the mineral elements in soils, only a small fraction is taken up by plants (McDowell, 1996). The mineral composition of plants depends on a number of factors, including soil type and composition, plant species, stage of maturity and dry matter yield of the plant, pasture management (including fertilizer regimen) and climatic conditions (McDowell, 1996).

Most naturally occurring mineral deficiencies in herbivores are associated with specific regions and are directly related to soil characteristics (McDowell, 1996). Young and alkaline geological formations are more abundant in most trace elements than the older, more acid, coarse, sandy formations. Trace element fertilization is quite effective in elevating mineral concentrations in crops. However, trace mineral deficiencies in grass, in particular Cu, cobalt (Co), Se, Mn and iodine (I), are becoming more common as increased non-trace element fertilizer (N, P, K) usage results in increasing amounts of grass being produced per hectare (McDowell, 1996). Poor drainage conditions often increase extractable trace elements (e.g. Mn and Co), thereby resulting in a corresponding increase in plant uptake. Almost all soils that produce plants containing sufficient molybdenum (Mo) to cause molybdenosis in animals are poorly drained (McDowell, 1996).

Jumba *et al.* (1995a,b) found that Cu values were particularly low in forages associated with tertiary volcanic bedrock (3.8 ± 0.34 mg/kg DM), but even the maximal values (5.4 ± 0.34 mg/kg DM on metamorphosed sedimentary material) were marginal for ruminants. Selenium and Cu concentrations were usually low at low altitudes but no other significant effects of altitude or geology on herbage trace element concentration were found (Jumba *et al.*, 1995a,b). For Cu and Se alone, geological maps may help to delineate areas where risks of deficiency are high or low. Herbage composition was poorly correlated with total Se or extractable (other trace elements) concentrations in the soil (Jumba *et al.*, 1995a,b). Jumba *et al.* (1995a,b) also found that soil bedrock influenced herbage concentrations of sulphur (S) significantly ($P < 0.001$) but not those of Ca, P or Mg. Mean herbage S concentrations were lowest on volcanic and metamorphic gneiss associations (1.2 g/kg DM) but only extreme values would be inadequate for grazing livestock (Jumba *et al.*, 1995a,b). Altitude appeared to affect the concentration of P significantly and not those of Ca, Mg and S in herbage, but the effect on P was dependent on soil P (Jumba *et al.*, 1995a,b).

As plants mature, mineral concentrations decline due to a natural dilution process and translocation of nutrients to the root system. In most circumstances Cu, Co, Fe, Se, Zn and Mo concentrations decline as the plant matures (McDowell, 1996). Pasture management, forage yield and climate can influence the species of forage predominating and also change the leaf:stem ratio radically, thereby having a direct bearing on the mineral concentration of the sward (McDowell, 1996).

Forages frequently show a decrease in leafiness and an increase in the stem-to-leaf ratio with age (Van Soest, 1994). Stems are often of a lower quality than leaves in mature forage. This generalization, however, is not universal and there are important exceptions. The quality of the stems compared with the leaves depends on the function of these structures in the particular plant species. Decline in quality is usually associated with an increase in the proportion of lignified structural tissue. In lucerne and browse species the stems are structural organs and the leaves are metabolic organs. In grasses, on the other hand the leaves have an important structural function through the lignified midrib (Van Soest, 1994). The result, in terms of nutritive value, is that lucerne leaves maintain their quality as they age, while grass leaves decline in quality, though not as rapidly as their stems. In some grasses (e.g. timothy and sugarcane) the stem is a reserve organ. This leads to the anomaly of stems having a higher nutritive quality than leaves, particularly at early stages of growth (Van Soest, 1994). Stem quality, furthermore, varies significantly among plant species. The leaf:stem ratio must therefore be used cautiously as an index of quality. It is more valuable in legumes than in grasses. If the digestibility of the leaf is equal to or lower than that of the stem, the ratio is useless as an index of quality (Van Soest, 1994).

Increasing crop yields remove minerals from the soil at a faster rate than in low crop production systems, so that mineral deficiencies are frequently found on the most progressive farms. Overliming can accentuate a Se or Mo toxicity in livestock by increasing plant concentrations of these elements and at the same time favour Co and Mn deficiencies due to lowered plant uptake (McDowell, 1996).

Not all forage species have the same digestibility when grown under identical conditions (Van Soest, 1994). The digestibility of legume stems is lower than that of most grasses at any stage of growth; and the digestibilities of respective grass species also vary, for example orchardgrass shows a lower stem digestibility and lower digestibility overall than timothy, brome, or ryegrass. Although orchardgrass is a productive grass, this feature has led to its virtual abandonment in western Europe, although it is still grown in North America (Van Soest, 1994).

Similar differences are apparent among tropical species: Pongola grass (*Digitaria decumbens*; a C_4 grass) declines in digestibility less than most other tropical grasses and tends to remain vegetative, in contrast to others such as *Panicum maximum*. Cogon grass (*Imperata cylindrica*) is poorer in quality than other forage species grown in the same environment. Tropical legumes tend to be higher in crude lignin and protein and lower in cell wall than tropical grasses, and higher in cell wall and lignin than most temperate legumes (Van Soest, 1994). The crude lignin value is elevated by the presence of tannins in most tropical legumes (Van Soest, 1994).

Jumba *et al.* (1995a,b) found that herbage species differed markedly in their concentrations of S ($P < 0.001$), Ca ($P < 0.001$) and Mg ($P < 0.05$) but not P. Calcium deficiency may arise on Setaria, S deficiency on some Napier grass pastures and P deficiency on some dry season pastures irrespective of botanical composition. Low herbage P concentrations may reflect advanced maturity rather than low soil P status (mean value 20 mg P/kg DM). The correlation between soil P and herbage P was significant and similar in slope and intercept for all herbage classes but not strong enough to predict deficient herbages (Jumba *et al.*, 1995a,b). Herbage Ca was not correlated with soil Ca (Jumba *et al.*, 1995a,b). Species differences were important for all trace elements (Co, Cu, Fe, Mn, Mo and Zn) except Se, with kikuyu grass the richest in all but Mn (Jumba *et al.*, 1995a,b). For Cu and Zn, deficiencies were most likely to occur with Rhodes grass (*Chloris gayana)* with 3.5 mg Cu and 19,5 mg Zn/kg DM and Setaria (*Setaria sphacelata*) with 3.9 mg Cu and 17.7 mg Zn/kg DM. Species differences in Mo were within a low range of values (derived means < 1.6 mg/kg DM) but may, in combination with S, influence Cu availability (Jumba *et al.*, 1995a,b). The lowest mean Se value (0.047 mg/kg DM in Setaria) was inadequate for ruminants (Jumba *et al.*, 1995a,b). Species variation in Co, Fe and Mn was significant but values were consistently above animal requirements and for Co and Fe were probably influenced by soil contamination (Jumba *et al.*, 1995a,b).

1.3 MINERAL REQUIREMENTS FOR CATTLE

Mineral requirements of livestock are highly dependent on the level of productivity. Increased growth rates and milk production will greatly increase mineral requirements. Improved management practices that lead to improved milk production and growth rates for cattle will necessitate more attention to mineral nutrition. Marginal mineral deficiencies under low levels of production, become more severe with increased levels of production, and previously unsuspected nutritional deficiency symptoms usually occur as production levels increase (McDowell, 1996).

The criterion of adequacy is important as illustrated by the fact that minimum Zn requirements for spermatogenesis and testicular development in male sheep are higher than for growth, and Mn requirements are similarly lower for growth than for fertility in sheep (McDowell, 1996). Many nutrient requirements have not accounted for relatively new information that describes the effect of nutrition on immune function, and many of the requirements have not been evaluated in terms of optimal reproduction. There is reason to suggest that optimal immune responsiveness and disease resistance is greater than needed for growth. The NRC requirements are often based on growth performance and quantities of a specific mineral sufficient to prevent clinical signs of a deficiency (McDowell, 1996). Selenium, Cu, Zn and Co deficiencies have been shown to alter various components of the immune system (McDowell, 1996). Selenium supplementation has decreased mortality rates in ruminants fed diets low in Se when clinical deficiency symptoms, such as muscular dystrophy, were not apparent. A 2 year study with beef cows and calves consuming pasture and maize silage marginally deficient in Se (0.03 – 0.05 mg/kg) indicated that bimonthly Se – vitamin E injections reduced calf death losses (4.2 % vs. 15.3%) from birth to weaning (McDowell, 1996). Most of the deaths were attributed to diarrhoea and subsequent unthriftiness.

For grazing livestock, P is the mineral most likely to be deficient. There are differences of opinion as to the P requirements of beef cattle. Phosphorus requirements recommended by the NRC may be too high for grazing beef cattle. From Utah, no difference in average weight gains (0.45 kg per day), feed efficiency or appetite were observed between Hereford heifers fed for 2 years a diet containing 1.4 g P/kg (66 % of NRC recommendation) and comparable heifers receiving the same diet supplemented with monosodium phosphate to provide a total of 3.6 g P/kg (McDowell, 1996). After 8 months on a 0.90 g P/kg diet, however, some appetite reduction and decreased bone density were observed. On the contrary, studies from Florida demonstrated that 1.20 – 1.30 g/kg P was inadequate for growing Angus heifers in a 525 – 772 day experiment. Animals receiving the low P diet had lower gains (205 *vs.* 257 kg), exhibited pica and had bone demineralization (McDowell, 1996).

Both the Utah and Florida studies could be criticized because they were done in dry-lot, feeding chopped or pelleted diets, and may not be indicative of requirements for cattle under grazing conditions. Animals required to walk to obtain forage would probably have greater requirements for structural minerals in bone. The recycling of P through the saliva would be mush less on a fine diet such as the pelleted diet than on a coarse diet in a grazing situation because of the differences in amount of rumination per unit DM taken in (Scott, 1981). Also, the Utah and Florida studies used beet pulp as major diet ingredients. Phosphorus availability from these feeds would seem to be higher when compared to forages (particularly tropical) with high cell wall contents (e.g. lignin).

Important differences in mineral metabolism can be attributed to breed. The effect of breed differences on mineral requirements has often been observed in ruminants. Marked ruminant animal variation within breeds in the efficiency of mineral absorption from the diet has been reported to be 5 – 35 % for Mg, 40 – 80 % for P, and 2 – 10 % for Cu (McDowell, 1996).

Adequate intake of forages by grazing ruminants is essential to meet mineral requirements. Factors which greatly reduce forage intake, such as a low protein (< 70 g/kg) content and an increased degree of lignification, likewise reduce total amount of minerals consumed (McDowell, 1996).

Mineral supplementation is significantly less important for cattle if energy and protein requirements are inadequate. However, when energy and protein supplies are adequate, livestock gain weight rapidly resulting in higher mineral requirements. In some countries during the dry winter season, unsupplemented cattle and sheep grazing extensive grasslands may lose 25 – 30 % of their maximum summer body weight. Research in Africa and Australia showed that the provision of mineral supplements when animals are losing weight due to a lack of protein in the diet served no purpose and might even have a negative effect on the animal (McDowell, 1996). Phosphorus supplementation was only beneficial when given in combination with sufficient both energy and protein, increasing both feed intake and body liveweight.

1.4 MINERAL SUPPLEMENTATION FOR GRAZING BEEF WEANERS

Mineral deficiencies and imbalances for grazing cattle are reported from almost all regions of the world. The mineral elements most likely to be lacking under grazing conditions for ruminants are Ca, P, Na, Co, Cu, I, Se and Zn (McDowell, 1996). In some regions, under specific conditions, Mg, K, Fe and Mn may be deficient and excesses of F, Mo and Se can be extremely detrimental. In most countries of the world the principal means by which cattle producers attempt to meet mineral requirements of their grazing herds are through use of free-choice dietary mineral supplements. As a low cost insurance to provide adequate mineral nutrition, a modified 'complete' mineral supplement should be available free-choice (McDowell, 1996).

Calcium, Cu or Se, when in excess, can be more detrimental to cattle production than any benefit derived by providing the mineral supplement. The major disadvantage to free-choice minerals is lack of uniform consumption by animals. Factors influencing consumption of mineral mixtures include: (1) soil fertility and forage type, (2) season of year, (3) available energy and protein, (4) individual requirements, (5) salt content of drinking water, (6) palatability of mineral mixture, (7) availability of fresh minerals and (8) physical form of minerals (McDowell, 1996). Safe, biologically available and palatable forms of minerals, at a fair price, allow both the producer and manufacturer to realize a profit from their use. Mineral supplements need to be evaluated for accuracy of formulation and suitability for cattle. Most studies have shown positive responses of mineral chelates and complexes when compared to inorganic sources (McDowell, 1996).

1.4.1 RESPONSE OF GRAZING – GROWING CATTLE TO PHOSPHORUS SUPPLEMENTATION

In the United States, naturally occurring P deficiency in grazing cattle was first reported in Texas (Karn, 2001). Following this report, there has been a distinct lack of P research with grazing cattle in the United States even though many areas were reported to be P deficient (Snapp & Neumann, 1960; Church *et al.*, 1971) and most forages produced in several western states were deficient or at best barely adequate in P. In 1943 in Texas, heifer weights at 18 months of age were increased by 57 kg with P supplementation (Karn, 2001). However, in later studies conducted near Mandan, North Dakota, Karn (1995b) reported that P supplementation had no effect on weight gains of Hereford and Hereford-Angus crossbred replacement heifers in one study, while in a subsequent study, when Hereford-Simmental crossbred heifers with a higher growth potential were used, P supplementation resulted in an immediate weight gain response. Yearling steers grazing the northern plains native rangelands also responded inconsistently to P supplementation (Karn, 1995a). In pen feeding studies using forage based diets, Call *et al.* (1978) indicated that a diet containing 1.40 g P/kg on an "as fed basis" was adequate for growing heifers while Williams *et al.* (1989) found that a dietary P concentration of 2.0 g/kg produced higher weight gains in heifers than a diet containing 1.2 g P/kg. Whether a weight gain response would have been obtained by Williams *et al.* (1989) if the 2.0 g P/kg diet had been compared with a 1.4 g P/kg "as fed basis" diet comparable to that used by Call *et al.* (1978) is unclear.

Phosphorus supplementation of growing cattle on rangelands or pastures in other areas of the world has also produced varying responses. In Australia yearling steers grazing an unfertilized predominantly carpet grass (*Axonopus affinis)* pasture with P levels ranging from 0.43 to 1.07 g/kg did not respond to P supplementation during either the wet or dry season over a 1-year period (Cohen, 1972). Forage crude protein concentrations were only 45 - 70 g/kg. Thus, protein and not P was probably the first limiting nutrient (Karn, 2001). In later reports from Australia both fertilizer P and supplemental P increased weight gains in growing cattle during the wet and growing season (Winks *et al.*, 1977; Winter, 1988; Winter *et al.*, 1990; Coates & Ternouth, 1992; Hendricksen *et al.*, 1994; McLean & Ternouth, 1994; Coates, 1995). Weight gains were improved by increasing dietary P in both the wet and dry seasons in some situations (Coates & Ternouth, 1992; Hendricksen *et al.*, 1994), but in others either weights were not affected (Winks *et al.*, 1977; Winter *et al.*, 1990) or weight losses occurred (Winter, 1988; Coates, 1995).

Generally, both fertilizer P and supplemental P have been effective in increasing dietary P levels, but McLean & Ternouth (1994) reported a response to P fertilizer but not to direct P supplementation. In northern Australia response differences to improved dietary P have occurred between locations (Winter *et al.*, 1990). Even when enhanced dietary P occurred during the wet season, there may be no response during the dry season even though forage P may be lower, because energy, protein or perhaps another mineral could have been the first limiting (Cohen, 1972; Hendricksen *et al.*, 1994). On the other hand, adding dietary nitrogen to a P - deficient diet may exacerbate a P deficiency, resulting in an adverse effect on liveweight change, feed intake, plasma inorganic P, and bone thickness and P concentration (Bortolussi *et al.*, 1996). In some situations where protein was first limiting, P supplementation might still be beneficial by reducing the incidence of “pegleg” and botulism even though it does not improve weight gains (Miller *et al.*, 1990).

It has been suggested that where dry season weight losses occur in P supplemented steers, a P induced copper deficiency might be the cause (Wadsworth *et al.*, 1988). Steers receiving supplemental P, especially from mono-ammonium phosphate had much lower liver copper levels (<50 mg/kg) than unsupplemented steers (>150 mg/kg) (Wadsworth *et al.*, 1988).

However, no mechanism to explain how dietary P might depress liver copper was proposed, and other instances of low bovine liver copper (<40 mg/kg) have been reported without any copper deficiency symptoms or impaired performance (Karn & Hofmann, 1990). Another explanation of an apparent lack of response to improved dietary P in grazing cattle could be the gastro-intestinal recycling of P and resorption of P from skeletal reserves (Ternouth, 1990). In pen studies it took many months before DMI was adversely affected by P-deficient diets (Gartner *et al.*, 1982; Call *et al.*, 1986).

In New Guinea P supplementation had no effect on weight gains of 18-month-old steers on native highland pastures (Leche, 1977). However, in Peru, Echevarria *et al.* (1987) reported P supplementation of yearling steers (5 g P/day), grazing a superphosphate fertilized grass-legume pasture, improved weight gains even though P concentration of the pasture was 0.16%. In Namibia, Grant *et al.* (1996) reported P supplementation of young cattle improved weight gains only when dietary protein concentrations were adequate.

Inconsistent responses to P supplementation in growing cattle indicate that in apparent P - deficient situations, if energy, protein or some other nutrient were first limiting, then P supplementation would not be beneficial (Karn, 2001). Research results have shown that P may be either a primary or a secondary limiting nutrient even at the same location. Thus P supplementation may increase weight gains, produce no response, or even result in weight losses depending on the P status of the animal and the adequacy of other nutrients (Karn, 2001).

1.4.2 PHOSPHORUS STATUS INDICATORS

Accurately measuring DM and P intake of grazing cattle and determining dietary P concentrations is not possible using current techniques (Read *et al.*, 1986c). Therefore, P status indicators must be developed which producers and researchers can use to reliably predict when P supplementation will benefit grazing cattle. Bone, blood, rumen fluid, forage, faeces, saliva, hair, and urine P levels have all been proposed as P status indicators (Read *et al.,* 1986c). In the present study blood and forage samples were used as P status indicators.

1.4.2.1 Blood

Blood serum and plasma P concentrations are quite similar and reflect inorganic P (Pi) levels in the blood (Read *et al.*, 1986c). Erythrocytes contain high concentrations of organically bound P which can increase serum or plasma P if whole blood samples are handled incorrectly (Read *et al.*, 1986c).

The use of inorganic plasma or serum P concentration as an indicator of an animal's P status has produced mixed results. Some reports indicated that it was of little value (Cohen, 1973 a,b; Committee on Mineral Nutrition, 1973; McLean & Ternouth, 1994). Other work suggested that blood plasma or serum P concentrations may be at least an indicator of diet P levels (Noller *et al.*, 1977; Winks *et al.*, 1977; Gartner *et al.*, 1982; Winter, 1988; Williams *et al.*, 1991b; Abdelrahman *et al.*, 1998).

Plasma P levels reflect the P intake of a cow but not necessarily her P status (Read *et al.*, 1986c; De Waal *et al.*, 1996). Plasma Pi levels below a critical level of 20 mg/L are considered to be indicative of a P deficiency, but levels above 40 mg P/L are of little value in determining an animal's P status (Read *et al.*, 1986c). After 56 weeks on a P-deficient diet, serum P levels in growing heifers had only dropped to 30 mg/L (Gartner *et al.*, 1982). However, in another report only four weeks after beef cows no longer received a P supplement serum P decreased to 21 mg/L, and after calving the level dropped to 15 mg/L (Fishwick *et al.*, 1977). Inorganic serum P concentration is directly affected by P intake in young calves (Challa & Braithwaite, 1988) and by DMI (g/kg LW) in weaning steers (Bortolussi *et al.*, 1996). Lower serum P levels in late lactation reflect the high P demands associated with milk production (Ternouth & Budhi, 1996).

Serum P levels may have more value as an indicator of dietary P levels, than as a P status indicator, because it is evident that age, the physiological stage of production and the length of time on a P-deficient diet all affect an animal's P status, and thus have a modulating effect on serum P levels (Karn, 2001).

1.4.2.2 Forage

The Committee on Mineral Nutrition (1973) suggested that dietary P concentration was probably the best indicator of P status. However, for grazing animals it is very difficult to collect samples as selectively as animals graze (Cohen, 1973a; Langlands, 1974) and extrusa samples collected with oesophageal fistulated animals are contaminated with salivary P (Langlands, 1966). Squeezing saliva from extrusa samples to reduce P contamination was suggested by Hoehne *et al.* (1967), while Little *et al.* (1977) and McLean & Little (1979) recommended correcting for salivary P contamination by injecting collecting animals with ^{32}P. This latter procedure is probably the best method, but is not practical in many situations especially at the producer level (Karn, 2001).

In New South Wales, yearling steers grazing a carpet grass pasture containing only 0.40 – 1.10 g P/kg did not respond to P supplementation even though a positive response would have been expected based on the pasture P content (Cohen, 1972). Phosphorus might not have been the first limiting nutrient even when animals were grazing forage with a very low P content (Winter, 1988). Coates (1995) obtained a response to P supplementation with heifers at a diet P level near

1.0 g/kg in the wet season, but during the dry season, when dietary P level dropped to near 0.5 g/kg, P supplemented heifers lost more weight than unsupplemented heifers. On the other hand, in Peru yearling steers grazing a grass-legume mixture containing 1.6 g P/kg responded to P supplementation (Echevarria *et al.*, 1987). Pasture analysis alone is an unreliable means of diagnosing a P deficiency according to Judson and McFarlane (1998), but if season, pasture composition, diet selection, soil contamination and class of animal are also considered, pasture analyses could be a useful diagnostic tool. Other problems with pasture forage analysis include lack of reliable methods of assessing dietary P concentrations, no clear agreement on P requirements and no dietary P concentration that clearly indicates when animals will respond to P supplementation (Karn, 2001).

1.4.3 AVAILABILITY OF PHOSPHORUS IN SUPPLEMENTS

Colloidal clay was found to be markedly inferior to dicalcium phosphate as a source of supplemental P (Karn, 2001). The colloidal clay contained a borderline toxic level of fluorine which may have masked its value as a P source. Karn (2001) found a slight difference in apparent digestibility between dicalcium phosphate and defluorinated rock phosphate fed to beef steers, but digestibility was not different.

Dicalcium phosphate, monocalcium phosphate, monoammonium phosphate, and monosodium phosphate were found by Fisher (1978) to have similar availabilities in cattle. The form of supplemental P did not influence metabolism in the gastrointestinal tract of sheep (Poppi & Ternouth, 1979). However, Witt & Owens (1983) found mono-dicalcium phosphate containing 210 g P/kg , mono- dicalcium phosphate containing 185 g P/kg and defluorinated rock phosphate were only 88%, 62%, and 40% as available in the rumen as sodium phosphate. Relative bioavailability differences for commonly used inorganic P sources were published by Soares (1995) and McDowell (1997).

1.4.4 METHODS OF PHOSPHORUS SUPPLEMENTATION

Supplemental P has been provided to grazing cattle in a variety of ways, such as direct feeding (Black *et al.*, 1943) through water (Winks *et al.*, 1977; Coates & Ternouth, 1992; Coates, 1995), free-choice as a lick or loose in a feeder (Judkins *et al.*, 1985; Echevarria *et al.*, 1987; Wadsworth *et al.,* 1988; Karn, 1992; McLean & Ternouth, 1994), hand fed in a mixture (Wadsworth *et al.*, 1988; Winter, 1988), through a drench (Cohen, 1972) or through P fertilized pastures (Winks *et al.*, 1977; Loxton *et al.*, 1983; Winter, 1988; Coates, 1995; Mclean & Ternouth, 1994). Phosphorus has been provided daily except on Sunday (Black *et al.*, 1943), or 2 to 3 days per week (Wadsworth *et al.*, 1988; Winter, 1988; Karn, 1995b; De Waal *et al.*, 1996) with apparent success for all three feeding intervals. Although benefits have been reported with various P supplementation methods and feeding frequencies, free-choice feeding is probably the least reliable because animals may not consume enough P by this method. Both direct and indirect supplementation methods have been discussed more thoroughly by McDowell (1997).

1.5 KIKUYU AS FOGGAGE

Kikuyu is a perennial summer grass usually found in high rainfall (750 mm and above) areas. Kikuyu has an extended growing season and is frost resistant. It recovers early and quickly after a severe winter. It also has a high resistance to dry periods (Dickinson, 1976).

1.5.1 SOIL AND CLIMATIC REQUIREMENTS

Rainfall of 700 mm or more is required by kikuyu. High temperatures are preferred. Well-drained, aerated, fertile soils are recommended. It should not be established in sandy soils of low fertility (Dickinson, 1976). Kikuyu has been established successfully in waterlogged soils (Dickinson, 1976).

1.5.2 PRODUCTION POTENTIAL

Dry matter yields of kikuyu range from 5-9 tons/ha. Under favourable conditions up to 25 tons DM/ha can be obtained. Kikuyu is essentially a grazing grass and for all practical purposes its potential as hay can be ignored (Dickinson, 1976). This is due to its high moisture content which makes drying difficult.

Kikuyu is a ‘sweet’ grass and maintains its palatability into late summer and even into winter (Dickinson, 1976). Its foggage value is approximately 50% TDN and can be utilized as such in winter. It could be used in late summer and winter in a pasture plan with *Eragrostis,* where kikuyu might be utilized in the early part of the season and *Eragrostis* thereafter.

Kikuyu, grown under dryland conditions is the predominant summer pasture in the KwaZulu-Natal Midlands, as well as in many other parts of the province and South Africa. Apart from its suitability as summer grazing, it can be used as foggage during the winter period of May to mid-August (Barnes & Dempsey, 1993). Cross (1979) found that the CP concentration of kikuyu varied between 118 and 147 g/kg DM during the period late-May to mid-June. Therefore, kikuyu foggage could play an important role in a fodder flow programme to maintain dry ewes during the winter in a system where their lambs were weaned onto green pastures. Although the published results of Rethman & Gouws (1973) and Rethman & De Witt (1991) engendered a degree of uncertainty, the overall evidence suggests that unsupplemented kikuyu foggage in the local environment is, at best, a maintenance feed for dry sheep (Barnes & Dempsey, 1993). De Villiers *et al.* (2002) found that the body weight loss of dry ewes during the grazing period suggested that the kikuyu foggage in the KwaZulu-Natal Midlands was unable to sustain the body weight of the dry ewe. While foggage produced with short rest periods in the late growing season will certainly be of higher quality than that produced with longer rest periods, the difference in nutritive value is likely to be small (Barnes & Dempsey, 1993). In addition, with short rest periods there is a risk that drought or cold weather could severely limit DM yields. In practice, a rest period beginning in mid- to late- January is suggested (Barnes & Dempsey, 1993).

1.5.3 PROBLEMS WITH KIKUYU

Kikuyu is a high producing pasture that has a high N requirement and becomes an expensive luxury if not utilized properly (Tainton, 1998).

Parasites in livestock are a problem on pastures especially those in wet areas and must be controlled by regular dosing. Dung concentration can cause palatability problems with intensive stocking and should therefore be spread. During September when kikuyu starts to green, problems may be encountered because animals graze selectively and may show a decrease in mass due to insufficient new material to meet their DM demands (Roos, 1975). In 1976 Dickinson recommended that kikuyu should not be grazed too soon after winter; since the new growth must be about 10 cm high before grazing starts. Dickinson (1976) reported that 500 g/kg of the CP value is not amino acids but a lignin type of N which is indigestible and therefore valueless.

Tainton (1998) summarised some problems with kikuyu which give rise to concern:

- its inverse Ca:P ratio,
- its deficiency of Na and Mg,
- the unacceptably high K: Ca and Mg ratio,
- its high oxalic acid content (which reduces the availability of Ca),
- its often high nitrate content,
- its low digestibility and energy value, and
- the tendency for soils under kikuyu pastures to immobilise large quantities of fertiliser nitrogen.

However, there remain a sufficient number of positive aspects of the grass as a forage producer to make its use widespread in many parts of the region. The main among them are that it is potentially very high yielding if well fertilized and well watered and its extremely tolerant to over utilization.

1.5.4 FERTILIZATION

With kikuyu establishment 600 kg limestone ammonium nitrate (LAN) should be applied. Every summer a minimum of 800 kg LAN should be applied. Before planting 300-350 kg superphosphate must be worked into the soil and from the third year on, depending on soil analysis, 250 kg superphosphate is recommended annually (Roos, 1975).

A large proportion of the nutrients ingested by grazing animals is returned to the pasture in the form of dung and urine. These by-products of animal digestion contain many ingredients necessary for plant growth including N, P and K (Gertenbach *et al.,* 2001). Disadvantages include a tendency for K levels to increase in soils where large quantities of animal waste are applied (Gertenbach *et al.,* 2001). A field study was undertaken by Gertenbach *et al.* (2001) on kikuyu pastures on the Cedara Research Station in the Midlands of KwaZulu-Natal in order to evaluate the effects of excretal returns on animal performance and soil properties. As expected, the K levels in the soils of the dunged pasture increased. Before N fertilisation of kikuyu pastures with a relatively high fertility status is undertaken, overwintering cattle on the pastures should be considered (Gertenbach *et al.,* 2001).

Fertiliser N should only be applied if the increased return in livestock sales is greater than the cost of the N fertilisation (Gertenbach *et al.,* 2001). Rethman (1984) found that the level of N applied – especially that applied closest to the rest period – has a confounding effect in that it increases the CP content of foggage and at the same time increases yield. This increase in yield has the counter effect of depressing nutritive value so that the response to fertilization - in terms of nutritional value is not as great as expected. Nevertheless, it was clear that both yield and CP content was markedly affected by level of N fertilization. Rethman (1984) concluded that adequate P and K fertilization together with N is necessary for optimum foggage nutritive value. Nitrogen levels in the range of 150 – 250 kg N/ha (depending on type of livestock, area available and production, potential of site) should be applied in mid-season. Animal withdrawal during January to February is essential to ensure good yields and adequate foggage nutritional value. When utilized, the pasture (foggage) should be rationed throughout the winter period. The results in spring (Sept – Oct) are disappointing and other provision should preferably be made for this period – especially for young stock and first calves (Rethman, 1984).

1.5.5 LIVESTOCK GAINS

Rethman *et al*. (1977) showed cattle gains of 0.2 kg/day on kikuyu foggage and 0.65 – 1.1 kg/day on grazing kikuyu in summer. Investigation to determine whether frosted kikuyu could supply better quality foggage than natural pasturage in sourveld areas during the winter months revealed that this grass was characterised by a CP concentration of 80 – 100 g/kg in the winter months (Rethman & Gouws*,* 1973). The performance of animals grazing such frosted kikuyu was highly satisfactory (Rethman & Gouws*,* 1973). Dickinson (1976) showed that 12 steers weighing 300 kg grazing a ha of kikuyu, which produced 15 tons DM, for 130 days gained an average of 0.8 kg/day.

In the study by De Villiers *et al.* (2002) it was found that body weight changes of ewes were not influenced by either the grazing system or date of animal withdrawal from kikuyu. Their data suggested that when the *in vitro* digestible organic matter (IVDOM) drops below 52%, the quality of unsupplemented kikuyu foggage in the local environment is insufficient to maintain the body weight of dry ewes. This suggested that kikuyu foggage should probably be grazed before mid-August. The optimal grazing period for kikuyu foggage and the introduction of supplements to optimize kikuyu foggage utilization need further investigation.

From the study of De Villiers *et al.* (2002) it is clear that the limitation regarding forage quality and the extend and period of utilization should be considered when kikuyu foggage is utilized for overwintering.

1.5.6 NUTRITIVE VALUE OF KIKUYU

1.5.6.1 Mineral content

Dickinson (1976) reported kikuyu compositions of 17.7 – 49.0 g N/kg DM, 110 – 300 g CP/kg DM, 1.8 – 5.2 g K/kg DM and 2.4 – 14.4 g Ca/kg DM. In high rainfall areas Ca may be deficient and should be supplemented (Dickinson, 1976).

Reservations regarding the adequacy of minerals in kikuyu in terms of the dietary requirements of grazing animals have over the years been expressed by both local and overseas researchers (Awad *et al.,* 1979; Brendon, 1980; Marais, 1990). Of particular concern is the supply of Ca to animals grazing kikuyu. Published dietary Ca requirements for various classes of ruminants are presented in Table 1.5. When the kikuyu Ca concentrations reported in Table 1.4 and Fig. 1.1 are compared with these requirements, it is evident that Ca was frequently very deficient in terms of the requirements of all the classes of animals considered, with the possible exception of maintenance ewes (Miles *et al.*, 1995). In research conducted on kikuyu-based commercial dairy operations in Australia (Reason *et al.*, 1989), where mean kikuyu Ca levels ranged from 2.90 to 3.10 g/kg, the reproductive performances of a number of herds was impaired by Ca deficiencies.

Table 1.4 Mean elemental concentrations and ratios in kikuyu herbage (dry matter basis) in three different camps (adapted from Miles *et al.*, 1995)

Element or ratio	Season	Cedara-sheep (CS camps)	Cedara-beef (CB camps)	Tabamhlope-beef (TB camps)
N g/kg	1987/88	37.1	33.3	34.9
	1988/89	38.0	31.4	32.0
P g/kg	1987/88	3.60	3.20	3.70
	1988/89	3.40	3.30	3.30
Ca g/kg	1987/88	2.80	2.50	3.00
	1988/89	2.30	3.10	3.10
K g/kg	1987/88	42.4	35.4	33.8
	1988/89	39.5	32.9	35.2
Mg g/kg	1987/88	3.00	3.30	3.10
	1988/89	2.50	3.10	3.20
Na g/kg	1987/88	0.30	0.20	0.40
	1988/89	0.50	0.50	0.30
Ca/P	1987/88	8.30	8.10	8.40
	1988/89	6.80	7.60	9.50
K/Ca+Mg*	1987/88	29.0	23.7	22.1
	1988/89	31.5	22.4	21.9

*equivalent basis

The severity of Ca insufficiencies in kikuyu pastures is aggravated not only by the fact that the bulk of pasture production is in the midsummer months when Ca levels are generally at their lowest (Fig. 1.1), but also by the tendency for much of the Ca in kikuyu to form insoluble complexes with oxalate (Reason *et al*., 1989; Marais, 1990), in which form Ca is essentially unavailable for absorption by animals (Miles *et al.*, 1995).

In the light of the latter aspect, total herbage Ca levels such as are reported in the paper of Miles *et al.* (1995), are most likely a gross exaggeration of the amounts of Ca available to animals.

Table 1.5 Reported dietary Ca and P requirements (g/kg in the ration DM) of various classes of ruminants (adapted from Miles *et al.,* 1995)

Class of animal	Ca requirements	P requirements	References
Lactating dairy cows (low to high yielding)	4.30 – 6.60	2.80 – 4.10	NRC, (1988)
Dry pregnant cows	3.90	2.40	NRC, (1988)
Growing heifers and bulls	2.90 – 5.20	2.30 – 3.10	NRC, (1988)
Ewe-maintenance (70 kg)	2.00	2.00	NRC, (1985)
Pregnant ewe (last 4 weeks gestation)	4.00	2.40	NRC, (1985)
Ewe-lactating (first 6 to 8 weeks; suckling singles)	3.00	2.20	NRC, (1985)
Ewe-lactating (first 6 to 8 weeks; suckling twins)	3.70	2.60	NRC, (1985)
Weaned lamb (30 kg)	5.10	2.40	NRC, (1985)

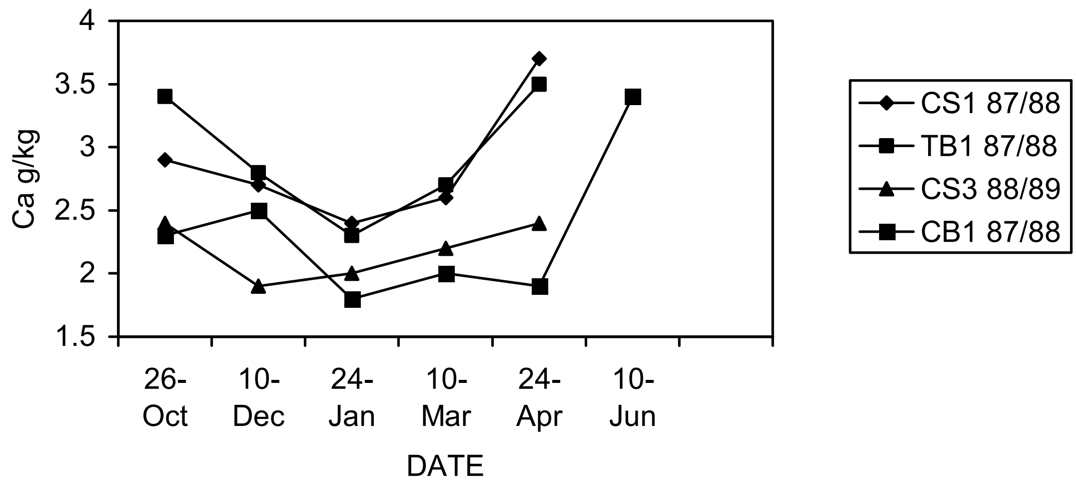


Figure 1.1 Within-season variations in kikuyu Ca concentrations in four camps (variations in CS3 were not significant)(adapted from Miles *et al.*, 1995)

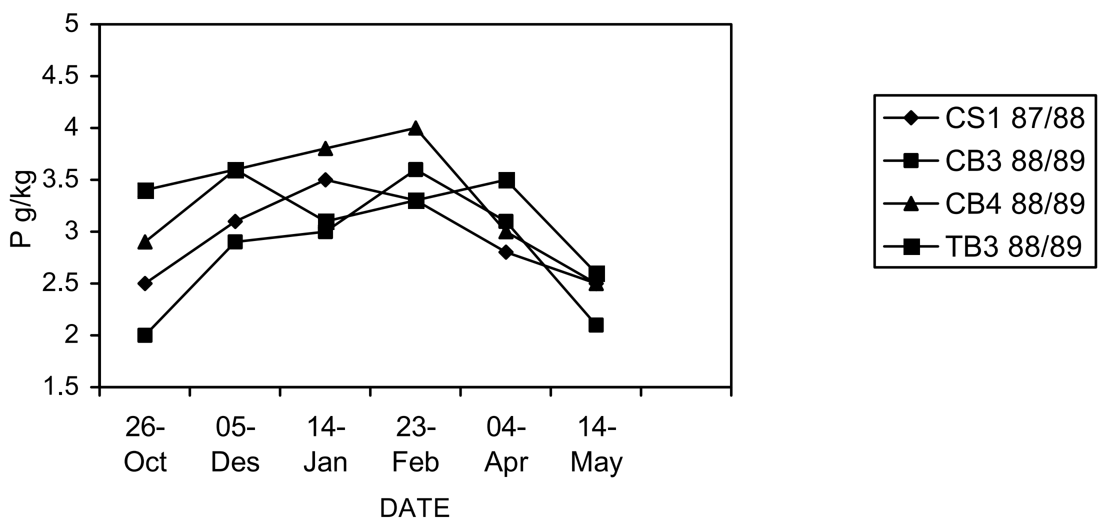


Figure 1.2 Within-season variations in kikuyu P concentrations in four camps (adapted from Miles *et al.*, 1995)

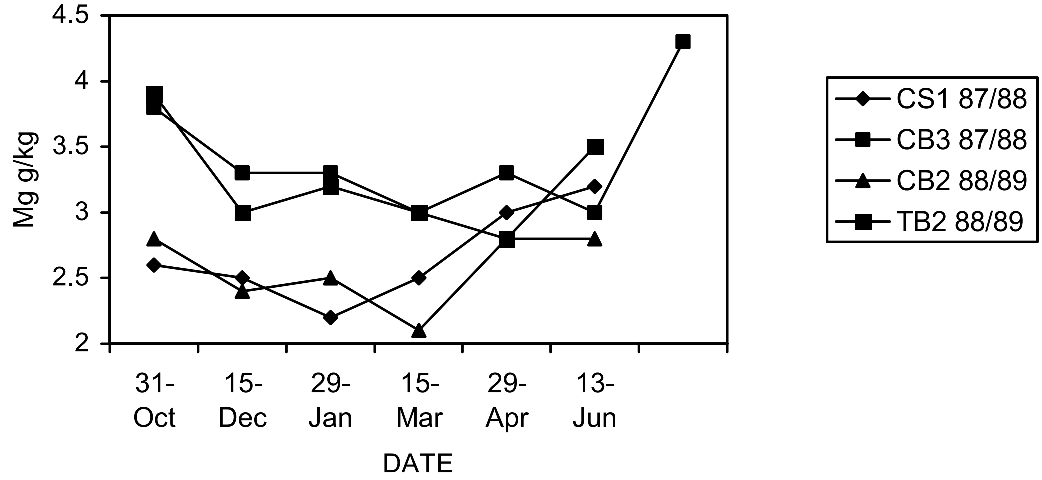


Figure 1.3 Within-season variations in kikuyu Mg concentrations in four camps (variations in Camp CB2 were not significant)(adapted from Miles *et al*., 1995)

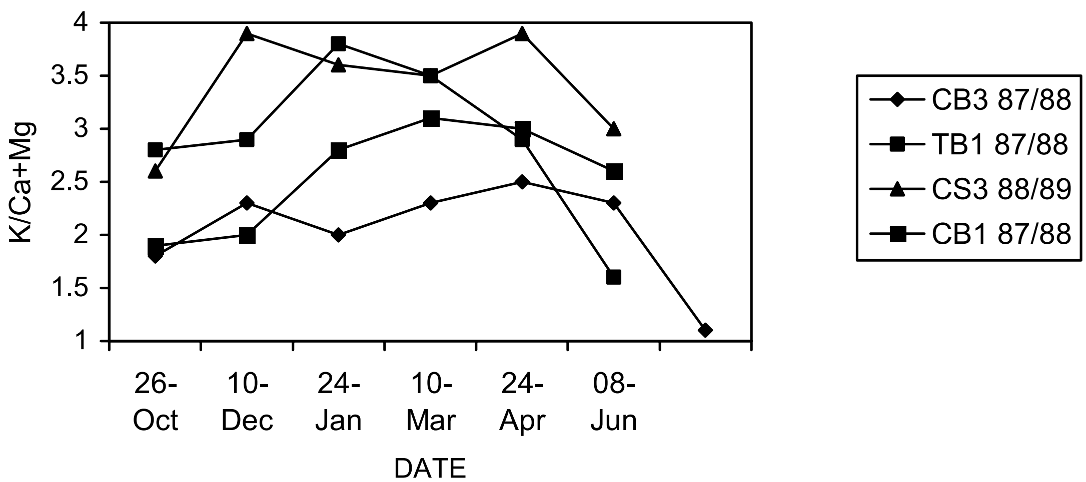


Figure 1.4 Within-season variations in kikuyu K:Ca+Mg ratio (ion concentrations expressed on an equivalent basis) in four camps (adapted from Miles *et al*., 1995)

Although the focus was on ruminant mineral requirements, it is possibly worth noting that with the dietary Ca requirement of yearling foals being approximately 4.30 g/kg (NRC, 1989), Ca levels in kikuyu are grossly inadequate for these animals, and the resistance to using kikuyu pastures for growing horses is thus entirely warranted (Miles *et al*., 1995).

Requirements for P of the various classes of ruminants are listed in Table 1.5 In light of these guidelines, P concentrations in kikuyu of Miles *et al.* (1995) study, in the midsummer months were adequate for ruminants (Figure 1.2). However, in spring and autumn the concentrations were possibly marginal with respect to animal requirements (McDowell *et al.,* 1983; NRC, 1985; NRC, 1988).

The Ca:P ratio in feeds is frequently referred to in assessing the adequacy of these minerals for ruminants. Attention has been drawn to the conflicting evidence regarding the effects of widely varying Ca:P ratios on animal performances (Little, 1982). Nevertheless, it remains the view of many animal nutritionists that this ratio should not be below 1:1. Kikuyu is a most unusual forage in this respect in that it invariably contains more P than Ca. In the study of Miles *et al.* (1995), Ca:P ratios in most camps were below 1:1 over the December to March peak growth period, and it is noteworthy that values as low as 0.4:1 to 0.5:1 occurred. Brendon (1980) has drawn attention to the difficulties involved in correcting the ratios of dairy cows where the forage has a Ca:P ratio as low as 0.5:1. Under these conditions, it is unlikely that sufficient feedlime (dolomitic limestone – limestone magnesium) (23% Ca m/m) could be supplied to correct the imbalance without the possibility of creating certain metabolic disturbances. With grains such as maize, oats and wheat typically containing 0.30 g/kg Ca and 3.0 g/kg P, supplying sufficient Ca to high producing dairy cows pastured on kikuyu presents a particular challenge. Sheep, too, appear to be sensitive to low Ca:P ratios. The NRC (1985) reported that a Ca:P ratio of less than 2:1 increases the incidence of urinary calculi in intact and castrated male sheep. The inclusion of Ca-rich legumes such as clovers in kikuyu pastures would undoubtedly assist in alleviating Ca insufficiencies in grazing animals (Brendon, 1980).

As is frequently the case with pastures, K levels in herbage were well in excess of animal requirements (Miles *et al*., 1995). A K concentration in the ration of 5.0 to 8.0 g/kg is considered adequate for ruminants (NRC, 1985; NRC, 1988), although the requirement may be somewhat higher than this under conditions of heat stress (McDowell *et al.*, 1983).

Kikuyu K concentrations of up to 50.0 g/kg were recorded in the investigation of Miles *et al.* (1995). Although excess K is rapidly excreted, mainly through the urine, high levels of K impact negatively on animal health and productivity. This is due to the inhibitory effect of K on Mg absorption (Little, 1982). Excess K has been linked to a range of animal health problems, including hypomagnesaemia (grass tetany), hypocalcaemia (milk fever) and delayed expulsion of foetal membranes (Breede, 1992). In formulating dry cow rations for high producing dairy cows, there is emphasis on selecting feeds with a low K content. The NRC (1988) reports a "maximum tolerable" K concentration in the diets of dairy cows and sheep of 30.0 g/kg. Increasing the level of dietary K from 7.0 to 30.0 g/kg linearly decreased energy and weight gains in lambs (NRC, 1985).

The close relationship between herbage N and K concentrations noted in the investigation of Miles *et al.* (1995) indicates that high N fertilisation rates promote luxury uptake of K. Clearly, judicious use of N fertilisers, together with regular soil testing to ensure that soil K is maintained at realistic levels (possibly below 200 mg/L), are important management considerations for kikuyu pastures.

A dietary Mg concentration of 2.0 g/kg is considered sufficient for high producing dairy cows (Holmes & Wilson, 1987; Kemp & Geurink, 1987), while the minimum requirement for the growth of sheep and beef cattle is 1.0 g/kg in the diet (McDowell *et al.*, 1983). In light of these guidelines, it would appear that Mg levels in kikuyu are adequate from an animal nutritional point of view (Figure 1.3). However, there is evidence that total Mg in herbage is an insensitive measure of the supply to animals since absorption of Mg is markedly influenced by a number of factors, an important one being, as indicated above, the level of K in the herbage (Little, 1982).

High K levels, particularly in young grass, greatly reduce the availability of Mg to animals. The propensity for excessive K uptake by kikuyu could thus impact negatively on the Mg nutrition of grazing animals. In this context, it is noteworthy that in research conducted in KwaZulu-Natal (Dugmore *et al.*, 1987) it was found that Mg supplementation (7.8 g Mg per day) of a dairy herd grazing kikuyu pastures in summer and Italian ryegrass pastures in winter resulted in a significant improvement in the fertility of the herd (intercalving period reduced from 394 to 373 days; services to conception reduced from 1.94 to 1.54). The K:Ca+Mg ratio has, over the years, been widely used as an indicator of the tetany potential of herbage, with values greater than 2.2 being linked to an increased incidence of tetany in grazing animals (Grunes & Welch, 1989).

As indicated by the data presented in Table 1.5 and Fig. 1.4 of Miles *et al.* (1995) study, this ratio was, particularly in midsummer, often much higher than the threshold of 2.2. Despite this finding, grass tetany is relatively unheard of in KwaZulu-Natal. In the case of dairy animals this may be due to the inclusion of supplementary Mg in concentrate feeds. However, the possibility of subclinical tetany impacting on animals grazing kikuyu pastures would seem to warrant attention.

The low Na levels in kikuyu are consistent with the classification of this grass as a natrophobe, or plants that accumulate only very small quantities of Na in the leaf tissues (Smith *et al.*, 1978). In this respect, kikuyu contrasts with temperate pasture species such as the ryegrasses and white clover, which, being natrophiles, accumulate relatively large amounts of Na in their leaves, provided Na soil supplies of this element are not limiting (Smith *et al*., 1978). The recommended Na requirement for grazing ruminants is 0.4 to 1.8 g/kg of the diet DM (McDowell *et al*., 1983). The higher level applies to lactating dairy cows, which are particularly susceptible to Na deficiency due to the large amounts of Na secreted in milk. Sodium concentrations in kikuyu are, therefore, largely inadequate in terms of animal requirements, and it is imperative that animals grazing kikuyu pastures have salt available to them at all times.

The findings reported in the paper of Miles *et al.* (1995) indicated that, relative to the requirements of most classes of cattle and sheep, kikuyu herbage is severely deficient in Ca and Na. In addition, the often prohibitively high levels of K in this grass are likely to induce Mg deficiencies in grazing ruminants. These observations of Miles *et al*. (1995) indicate that sufficient mineral supplementation to ruminants pastured on kikuyu is of cardinal importance in ensuring animal health and productivity.

1.5.6.2 Crude protein, energy and digestibility

The CP content of old established kikuyu pastures at Cedara, fertilized with 210 kg N/ha split into three dressings over the season, range from 160 to 240 g/kg DM (Dugmore, 1998). The structural carbohydrate (fibre) fractions comprise approximately 350 g ADF/kg DM and 650 g NDF/kg. The non-structural carbohydrate levels in kikuyu are very low, ranging from 30 to 80 g/kg of the DM. Good responses in livestock are therefore expected from supplementation with starch or other forms of highly available carbohydrate in the rumen. Kikuyu has relatively high ether extract (fat/oil) concentration for a roughage at 28 g/kg DM.

The non-protein nitrogen concentration of kikuyu ranges from 200 to 300 g/kg of the CP fraction. This is not unusually high for a high protein forage (Dugmore, 1998). The metabolisable energy concentration (MJ ME/kg DM) of kikuyu at Cedara has been determined by *in vivo* digestion trials to be 9.3 MJ in the spring, 9.0 MJ in summer and 8.8 MJ in the autumn (Dugmore, 1998). At Cedara these *in vivo* digestion trials have shown that high N levels in kikuyu have a negative impact on intake and digestibility, especially with very young material. The influence of N on DM intake (by steers) and digestibility (by sheep) to animals fed fresh kikuyu herbage is explained by the following regression equations (Dugmore, 1998).

Organic matter digestibility (%) = 71.6 - 0.62 (CP%); r = - 0.546

Dry matter intake (% of body weight) = 2.794 – 1.093 (NPN, % DM); r = - 0.781

Selection studies on kikuyu, using oesophageal fistulated steers, indicated that there was selection against high N (> 150 g CP/kg) in the herbage (Dugmore, 1998).

1.5.6.3 Protein quality

The CP concentration, determined as N x 6.25, of kikuyu varies from 180 g/kg in spring to 165 g/kg in summer and 160 g/kg in autumn on a DM basis (Brendon *et al.*, 1987). These levels are largely manipulated by the amount of N fertilizer applied. High crude protein concentrations (250 to 300 g/kg of herbage DM) are frequently recorded on high N fertilized kikuyu pasture. An interesting characteristic of kikuyu is that it has the ability to maintain its protein content, after N application, as the plant matures (Van der Merwe, 1998). Crude protein is further subdivided into true protein and non-protein N. The non-protein N concentration increases during the growing season, with a peak concentration during autumn. According to Marais (1980), the nitrate concentration, which forms part of the non-protein N fraction, also reaches peak levels during autumn. Dugmore *et al.* (1986) indicated that kikuyu with CP levels of 200 g/kg or greater contains nitrate levels which are potentially toxic to livestock. Minson (1973) observed that the voluntary intake of digestible organic matter was lower on kikuyu fertilized with a high (230 kg/ha) than with a low N application (57.5 kg/ha).

In line with these observations, Dugmore *et al*. (1986) indicated that CP levels in kikuyu were negatively related to the digestibility of crude fibre, ADF and nitrogen-free extract fractions in the herbage. Therefore, as the CP levels increase, the decrease in the abovementioned fractions will reduce the digestible organic matter content of the kikuyu.

The CP system of protein evaluation only serves as a rough guide when assessing protein quality (Van der Merwe, 1998). A more dynamic approach is obtained by determining the portion of protein which is degraded to ammonia in the rumen. Data obtained at Cedara indicated that kikuyu sampled at 20-, 30- and 40-days after nitrogen fertilizer application, had CP values (DM basis) of 290, 250 and 240 g/kg, respectively (Van der Merwe, 1998). The rumen degradability of these protein fractions was 74, 55 and 57%, respectively (Van der Merwe *et al.*, 1991). It is clear that highly N fertilized kikuyu at a three week regrowth stage has a high CP content which is also highly degradable in the rumen (Van der Merwe, 1998). Both these conditions result in excessive rumen ammonia which enters the blood stream across the rumen wall and is subsequently excreted via the urine and milk in the form of urea.

Monitoring milk urea levels is a method whereby the utilization of protein can be assessed. Milk urea levels above 385 mg milk urea/L of milk (18 mg milk urea N per dL) indicate excess CP in the diet, which is also highly rumen degradable, together with a shortage of rumen fermentable carbohydrates (Van der Merwe, 1998). Optimal milk urea levels are indicated as between 257 and 385 mg milk urea/L (18 mg milk urea N/dL). The milk urea status of Holstein-Friesian cows on day and night kikuyu grazing and receiving three kilograms of a maize based concentrate (120 g/kg CP on a DM basis) twice a day, was monitored by Van der Merwe *et al.* (1998) at Cedara. The milk urea status of these cows was within the optimal range as indicated above. Grazing management, together with strategic N fertilizer application and the feeding of a low protein, high carbohydrate concentrate will all contribute to more efficient utilization of expensive pasture protein (Van der Merwe, 1998).

1.5.6.4 Anti quality factors

Grasses have co-evolved with herbivores over a period of many millions of years, and their structure and chemical composition are the result of evolutionary pressure to survive as components of a specific ecosystem. Most plants, have, therefore developed mechanisms which favour self preservation and impede predation, and kikuyu grass in no exception.

Optimisation of animal production on kikuyu pastures requires an understanding of the nature of these mechanisms. The effect of anti-predatory or anti-quality factors can often be reduced by good farm management, supplementation or by breeding and selection. Selection against anti-quality factors may reduce the plant's ability to compete or survive in its normal habitat, but the benefits of the removal of anti-quality factors usually far outweigh the negative effect of reduced competitiveness, especially when the grass is grown in monoculture as a cultivated pasture.

The most important chemical factors reducing the nutritive value of kikuyu are the low level of readily available energy in the grass, the low digestibility of structural components, the presence of oxalic acid in the plant, the low sodium content, and the high nitrate content of kikuyu when heavily fertilized with N (Marais, 1998). Marais (1998) found that with the exception of high nitrate levels, none of the known anti-quality factors in kikuyu can be eliminated by good farm management practices. Inadequate amounts of readily available energy, Na and Ca in the diet of animals on kikuyu can be corrected by supplementation. However, more attention should be given to the study of kikuyu ecotypes having more favourable chemical compositions.

1.5.7 OVERWINTERING ON KIKUYU

In searching for a cheaper alternative to winter feeding systems, the use of foggage has been under investigation for a number of years. This accumulated herbage is then utilized by grazing animals during the dormant season.

1.5.7.1 The foggage niche

Experience gained with foggage research at Dundee (where Smutsfinger grass and nilegrass foggage were investigated) and Cedara (where the foggage value of kikuyu was examined), indicated that consideration of the following factors can be used to decide whether to foggage or not (Gertenbach, 1998):

- Where conserved feeds are not produced and crop residues are unavailable in early winter and where the quality of summer grazing declines rapidly in autumn, foggaged pastures are useful.
- Where a lack of arable land precludes or limits the production of fodder crops or make crop residues unavailable, foggage is often the only alternative to cutting veld grass for hay.
- Foggaging is possible where wet conditions make hay production impossible or difficult.
- Foggage can be advised to farmers who want to simplify their production systems or do not want to mechanize.
- Foggaging is useful and often necessary to retain surplus summer growth for later use, especially where a relatively large proportion of grazing on a farm comprises summer pasture species.

The last point is especially true for kikuyu foggage because the growth curve of kikuyu is characterized by a high summer peak which usually results in the production of excess fodder during November, December and January (Gertenbach, 1998). However, costs must be evaluated with care, based on answers to the following two questions:

- Can the fertilizer be used more cost effectively elsewhere?
- Is input lower than return?

Profits can be missed if only the latter question is considered.

1.5.7.2 Losses

When comparing winter feeding systems, allowance must be made for losses through trampling and weathering of grazed foggage. It has been stated that when kikuyu is grazed under wet conditions, as much as 60% DM is lost, whereas under dryland conditions losses of 17% have been reported (Gertenbach, 1998). For fodder budgeting where kikuyu foggage is involved, a loss of 50% DM is usually allowed for, although wet conditions during the grazing period can increase fodder loss significantly. Furthermore, especially under lower rainfall and relatively cold conditions, kikuyu foggage does not provide feed during the latter part of winter or early summer. Once summer growth commences, livestock tend to graze the new growth and leave the old herbage to rot (Gertenbach, 1998).

1.5.7.3 Quantity and quality of foggage

Research at Cedara, Dundee and at Nooitgedacht has shown that the quantity and quality of foggage produced depend on the level of fertilization (Gertenbach, 1998). Furthermore, there is an inverse relationship between quantity and quality, dependent on closing date. Foggage harvested from kikuyu pastures in June at Cedara declined from 6000 kg/ha, through 4200 kg/ha to 1092 kg/ha at closing dates of 1 January, 1 February and 1 March respectively. At the same respective closing dates, CP concentration increased from 58.0 g/kg to 67.0 g/kg to 87.0 g/kg (Gertenbach, 1998). The crude fibre concentration declined from 355 g/kg to 325 g/kg between the January and March closing dates, which is an indication that kikuyu does not produce a foggage with as high a proportion of stem material as do some other pasture species, notably Smutsfinger grass (Gertenbach, 1998).

1.5.7.4 Animal performance

In a study at Cedara where the performance of weaner calves was used to compare strip and continuous grazing of kikuyu foggage, it was found that at a stocking rate of 6 weaners per ha, live mass gain was 127.8 kg/ha for continuous grazing compared to 168.0 kg/ha for strip grazing (Gertenbach, 1998). Over the 96 day grazing period (27 June to 1 October), the steers subjected to continuous grazing had average daily gains of 0.22 kg/day compared to 0.29 kg/day for the strip grazing treatment (Gertenbach, 1998). However, for the first 39 days of grazing, the live mass gains were 0.44 kg/day and 0.26 kg/day for the continuous and strip grazing treatments respectively (Gertenbach, 1998).

The study procedure was as follows (Gertenbach, 1998):

- The kikuyu pastures were fertilized and grazed during the preceding spring and summer periods. Soil P and K levels were maintained above 20 and 150 mg/kg respectively and nitrogen was applied twice at a rate of 83 kg N/ha (September and November).
- Prior to closing off, the pastures were grazed heavily.
- Closing date was mid-February.
- At closing off the pastures were top-dressed with 83 kg N/ha (*i.e.* total summer N = 250 kg)
- The animals were provided with a supplement comprising 45% salt, 45% dicalcium phosphate and 10% molasses powder.
- Strip grazing was achieved by moving an electric fence across the pasture daily. No back fencing was applied.
- At the start of the trial the two groups of weaners were balanced for weight and age.

Based on existing research findings, it is concluded that a longer autumn rest (earlier closing date) is better in situations where more fodder is needed and quality is less important or the intention is to feed older cattle at maintenance. For young growing animals a later closing date (better quality foggage) is advised. Although closing dates between 1 January and the beginning of March are recommended for kikuyu foggage in the Midlands of KwaZulu-Natal, each situation must be evaluated independently because foggage production is highly dependent on the amount of rain that falls between the closing off date and the onset of winter dormancy. Poor rainfall during this period can drastically reduce winter feed available from kikuyu foggage.

From the above review of literature, it is clear that an important area which requires further study is the mineral content and nutritive value of kikuyu foggage and furthermore the mineral content of the stems and leaves of kikuyu foggage. In addition a great deal of confusion and disagreement still exist concerning levels of P supplementation during the winter months and the effect of supplementation on weight gain or loss during the transition from winter to summer. This study attempts to discuss these and justification for the use of winter supplements will be based on the ability of such supplements to influence economically important parameters.

The first objective of this study was to investigate the response of animals to different levels of P supplementation during the winter months and the effect of supplementation on weight gain or loss during the transition from winter to summer. Miles (1991) stated that P supplementation of young growing cattle gives an increase in mass gain. Justification for the use of winter supplements will be based on the ability of such supplements to influence economically important parameters such as body mass.

The second objective of the investigation was to obtain detailed information on the mineral composition of kikuyu and compare those concentrations with reported herbage mineral concentrations with dietary requirements of ruminants. The composition of the kikuyu pastures, on the research site, during July 1997 (two years prior to trial) is listed in Table 1. These values were one of the motivations for this study as Miles *et al*. (1995) reported kikuyu to be a most unusual forage in this respect that it contains more P than Ca. Kikuyu on this research site, however, showed higher Ca than P values. Whether one should have a different mineral and protein supplementation program for kikuyu foggage and herbage will also be discussed.

CHAPTER TWO

MATERIALS AND METHODS

2.1 INTRODUCTION

The investigation was carried out during the period May to September, 1999. The main objective was to investigate the effect of phosphorus supplementation of beef weaners grazing kikuyu foggage during the first months of winter (08-06-99 to 20-07-99), and thereafter receiving Smutsfinger hay during late winter (21-07-99 to 16-09-99). The criteria were animal weight changes, animal serum inorganic P (Pi) levels and changes in chemical composition of kikuyu during the period of study.

2.2 EXPERIMENTAL SITE

The experiment was conducted at the Eversly Research Station (Dundee, KwaZulu-Natal) (28^{o}12' S, 30^{o}10' E). The mean annual rainfall is 790 mm and rain falls mainly from October to March. Winters are cold with regular frosts (mean daily minimum of 2.1 °C) while the growing season is warm (mean daily maximum of 24.5 °C). The pastures were established approximately 10 years before commencement of the study and used since then for animal grazing. The kikuyu pastures received 400 kg LAN (limestone ammonium nitrate) and ± 150 mm rainfall after animal withdrawal at the end of January. The five camps used in this study were approximately of similar size (five hectares each) and the pastures were all pure kikuyu pastures. The camps were strip grazed using an electric fence.

2.3 THE ANIMALS AND ALLOCATION TO TREATMENTS

A total of 200 crossbred beef (male and female) weaners (average age six months and average weight 175 kg) was used in the trial. Animals were balanced for sex and randomly allocated into five groups. The sex ratio was 50% male and 50% female.

The animals strip grazed five kikuyu camps at the recommended stocking rate of 10 animals/ha. The period of stay in one strip was dependent on the size of the camps and the quantity of herbage available. The group allocated to a particular grazing camp was moved to another camp before entering a new strip. This procedure was carried out to minimize “camp effects”.

The experiment was divided into two phases because the kikuyu foggage reserves were not sufficient for the animals to graze until September. The first phase (day 1 to day 63) were the grazing of the kikuyu foggage and the second phase (day 64 to day 121) the feeding of Smutsfinger hay *ad libitum*, cut from a land adequately fertilized (70 kg N/ha). The effect of P supplementation of the weaners receiving Smutsfinger hay during late winter (the transition period) was tested.

Each group received a winter supplement supplying one of the following amounts of P per animal per day:

Group 1	8 g P per animal/day
Group 2	6 g P per animal/day
Group 3	4 g P per animal/day
Group 4	2 g P per animal/day
Group 5	0 g P per animal/day

The lick ingredients and approximate nutrient composition of the five different winter supplements with no phosphorus and different levels of phosphorus are given in Table 2.1 and Table 2.2.

Table 2.1 The feed ingredients per ton used in the free-choice winter supplements during the trial

Ingredients	8 g P/ day	6 g P/day	4 g P/day	2 g P/day	0 g P/day
Ammonium sulphate	50	50	50	50	50
Feedlime	26	36	47	57	65
Molasses meal	200	212	225	240	250
Urea	84	84	84	84	84
Salt	150	150	150	150	150
Maize meal	400	400	400	400	400
Trace minerals and Vitamin (ruminant)	1.5	1.5	1.5	1.5	1.5
MCP*	90	66	42	18	-
Total	1001.5	999.5	999.5	1000.5	1000.5

*MCP = Mono calcium phosphate

Table 2.2 The approximate nutrient composition of the winter supplements (data used with permission of Dr O' Donovan, Stockowners, Dundee, South Africa)

	8 g P/day	6 g P/day	4 g P/day	2 g P/day	0 g P/day
Dry matter	90.9	90.7	90.6	90.3	90.2
Crude protein (g/kg)	350.0	350.0	350.0	350.0	350.0
Fat (g/kg)	16.1	16.2	16.2	16.2	16.3
Crude fibre (g/kg)	32.6	34.1	35.6	37.1	38.2
Calcium (g/kg)	25.0	25.0	25.0	25.0	25.0
Phosphorus (g/kg)	20.0	15.0	10.0	5.0	1.2
Ca to P ratio	1.3	1.7	2.5	5.0	20.8
Digestible energy (MJ/kg) – calculated	7.2	7.3	7.4	7.5	7.6
Total digestible nutrients (g/kg) – calculated	438.8	446.5	454.2	461.8	467.6
Metabolisable energy (MJ/kg) – calculated	6.5	6.7	6.8	6.9	7.0
Sodium (g/kg)	59.4	59.4	59.4	59.4	59.5
Potassium (g/kg)	5.4	5.7	6.0	6.3	6.5
Magnesium (g/kg)	1.2	1.3	1.3	1.4	1.5
Sulphur (g/kg)	13.1	13.2	13.2	13.3	13.3
Zinc (mg/kg)	167.1	167.3	167.6	167.8	168.0
Iron (mg/kg)	337.1	342.6	348.1	353.6	357.8
Copper (mg/kg)	110.9	111.8	112.6	113.5	114.1
Manganese (mg/kg)	129.5	132.8	136.1	139.4	142.0
Cobalt (mg/kg)	2.2	2.2	2.2	2.2	2.2
Iodine (mg/kg)	2.2	2.3	2.3	2.3	2.3
Selenium (mg/kg)	0.02	0.02	0.02	0.02	0.02

2.4 MANAGEMENT

Prior to the onset of the trial the animals were given a three week period to adapt to the kikuyu foggage by grazing separate kikuyu pastures on the Eversly farm. They were given an anthelmintic remedy with Ivomac injection from Merial SA (Pty) Ltd , dipped with Amipor pour on remedy from Virbac Animal Health for ectoparasides and received a vitamin A, D and E injection (Vit-A-dex from Bayer Animal Health Division) to ensure that they were in good health and not deficient in these vitamins.

2.5 SAMPLING

2.5.1 ANIMAL SAMPLING PROCEDURE (PHASE 1 AND 2)

Weighing of animals was done at approximately two week intervals. The animals were withdrawn from the kikuyu pasture (or in phase 2 - Smutsfinger hay) the afternoon before weighing. They stayed without food or water overnight in holding pens ready to be weighed the next day. On the same day blood samples were collected from five randomly selected animals (irrespective of their sex) out of each treatment group. The same steers were bled for the duration of the experiment.

Samples of blood (approximately 10 mL were obtained via jugular venipuncture, and were obtained immediately upon restraining to prevent variation of serum inorganic P (Pi) due to handling. Samples were allowed to clot, centrifuged within 3 h, and serum was harvested into clean, plastic tubes and frozen at – 20 °C for subsequent Pi analysis.

2.5.2 SUPPLEMENT INTAKE (PHASE 1 AND 2)

Supplement intake was measured by weighing the lick before it was offered to a group of animals. The left-overs in the containers were weighed on the day of refilling. The containers were filled before they were empty. Average lick intakes over periods of two weeks were determined for phase 1 and phase 2 of the trial.

2.5.3 PASTURE SAMPLING (PHASE 1)

Within each camp, four quadrant herbage samples were taken before commencement of the study (in the first strip of the camp) and thereafter each time the animals entered a new strip (Figure 2.1)(Rethman, personal communication). The quadrant herbage samples were taken randomly in each strip. The sampling procedure involved handplucking of a quadrant, with the height of defoliation matching as closely as possible the defoliation intensity carried out by the grazing animals.

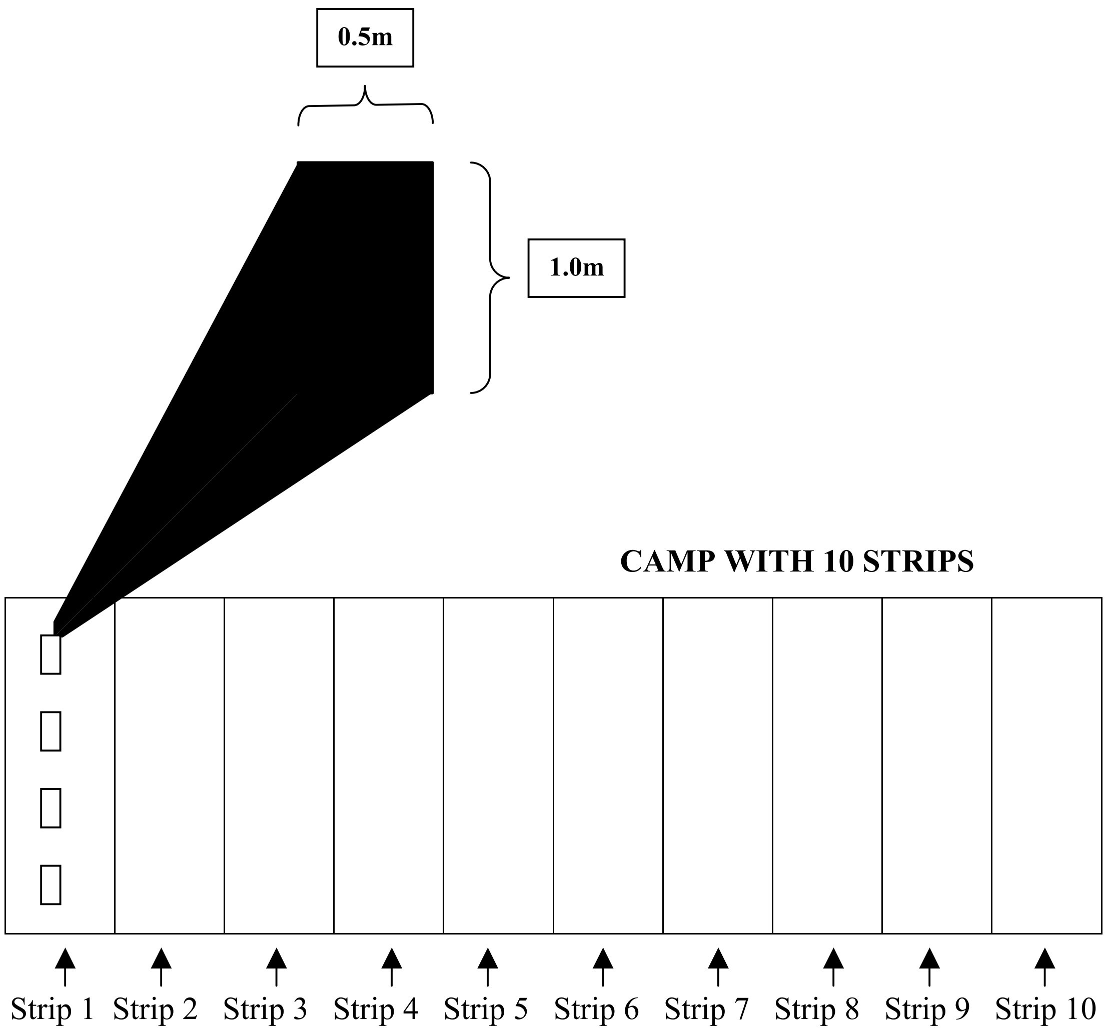


Figure 2.1 Schematized illustration of the quadrant sampling method in one camp

Each handplucked quadrant in a strip was weighed to determine dry matter (DM) content per hectare. The four handplucked quadrants per strip were pooled and out of each pooled sample three grab samples were taken.

The three grab-samples were used as follows:

Grab sample 1: The fresh grab sample was weighed and then dried at 100 ºC to determine DM content. Thereafter the following calculation were done:

Quadrant herbage fresh mass X %DM

= DM/quadrant

Rewrite DM/quadrant to DM/ha

Grab sample 2: This sample was separated into leaves and stems. The leaves and stems were dried separately and weighed to determine leaf to stem ratio, and used for further *in situ* degradability determination and chemical analyses. Whole sample (leaf and stem) composition was calculated from the composition of the material and the leaf:stem ratio.

Grab sample 3: This sample was separated into green and dry material and dried separately to determine green to dry ratio.

2.5.4 SMUTSFINGER HAY SAMPLING (PHASE 2)

Grab samples of the Smutsfinger hay were taken every second week during phase 2 of the trial and separated into leaves and stems. The leaves and stems were dried separately and analysed for CP, ADF, NDF, P, Ca, Mg, Na, K, Zn, Mn, Cu and Se.

2.6 SAMPLE PREPARATION AND ANALYTICAL TECHNIQUES

2.6.1 FEED

Foggage samples from each strip in a particular camp and on each sampling date were divided into leaves and stems (grab sample 2). Leaves and stems were separately analysed for CP, ADF, NDF, P, Ca, Mg, Na, K, Zn, Mn, Cu and Se. The stem and leaf samples were oven-dried (at

90 ^{0}C) and further divided into a coarsely milled (4 mm screen) sample for the *in situ* degradability determination and finely milled sample (1 mm screen) for chemical analyses. The coarse samples were stored in plastic bags while the fine samples were stored in capped bottles.

All chemical analyses were carried out in triplicate. Dry matter was determined by drying the samples at 105 ºC overnight and ashed by igniting the samples in a muffle furnace at 525 ºC for 8 h. Nitrogen content was measured by the Kjeldahl method (AOAC, 1995). Crude protein was calculated as N x 6.25. The NDF was determined using the method of Robertson & Van Soest (1981) and ADF according to the method of Goering & Van Soest (1970).

Sample digestion was accomplished by wet acid digestion. For the former technique, a known amount of dried sample was placed in a muffle furnace (500 ^{o}C), after which the ash was dissolved in nitric acid. Samples were then heated (100 to 140 ^{o}C) until a reduction in volume was obtained. Wet digestion involved the addition of nitric, perchloric and sulphuric acid to a known amount of dried sample. Samples were then heated on a hotplate until white perchloric fumes evolved and volume was reduced substantially. Samples were made up to the required volume with deionised water, following digestion. Mineral concentrations were measured by means of one of the analytical techniques presented below.

After wet digestion with a nitric-perchloric acid mixture, the Ca, Mg, Mn, Cu and Zn concentrations were measured using atomic absorption spectrophotometry and the Na and K concentrations using flame emission spectrophotometer. A combined standard was used to verify the accuracy of mineral concentrations (Na: 143.50 mmol/L, K: 3.84 mmol/L and Ca 2.50 mmol/L). The photometric method using molybdovanadate was used to measure P concentrations in the samples (AOAC, 1990). After digestion, a hydride generator attached to an atomic absorption spectrophotometer (Perkin-Elmer 2380) was used in the assay of Se in the samples. A peach leaf sample from the National Institute of Standards and Technology (NIST, US Department of Commerce, Gaithersburg, MD) was used as Standard Reference Material (SRM 1572) to verify the accuracy of the Se analysis.

2.6.2 BLOOD

Blood was collected from each beef weaner by jugular venipuncture into sterile, heparinised VAC-U-TEST collection tubes. The samples were immediately stored on ice. Within a few hours of collection the sample was centrifuged at 3000 rpm (Heraeus Sepatech, Labofuge 200 centrifuge) for 20 minutes, and the plasma removed and purified by centrifuging a second time, at 2500 rpm (Sorvall RC3B refrigerated centrifuge). Plasma was stored in the refrigerator for further analysis. Phosphate analysis on the plasma samples was done by Onderstepoort Pathology Laboratory. The calorimetric method of Goldberg & Fernandes (1974) was used for P determination.

2.6.3 THE RUMEN DEGRADABILITY TRIAL (in situ DIGESTION)

The rumen degradability of DM was determined according to the technique standardized by the AFRC (1992).

2.6.3.1 Sample and nylon bag preparation

Freeze-dried samples were milled through a 4 mm screen. Synthetic polyester fibre bags of 53 µm pore size and approximately 26% open area and 10 x 21 cm dimension were used. Bags were dried for 2 h at 60 ^{0}C and their mass was recorded for the calculations.

2.6.3.2 Animals preparation

Three mature wether sheep fitted with rumen cannulae were used. They were fed a diet of 100% lucerne *ad lib*. They were adapted to the lucerne for a period of two weeks before the trial commenced.

2.6.3.3 Incubation

Approximately 5 g of a sample, in triplicates, were weighed out and put into bags. A DM determination was done on a separate sample. The bags with samples were securely tied with fish lines onto metal rings. The rings with bags were securely tied by nylon twines, which were held outside the cannula. Samples were incubated for 0, 4, 8, 24 and 48 h using sequential withdrawal method. On removal the bags were immediately hand-washed under running water until the rinse water was clean, and finally with distilled water.

The zero time disappearance was obtained by applying the same wash procedure on to the unincubated bags. *Pannicum maximum* was used as a standard and it was included in every incubation period. Post washing, the bags were dried in a 60 ^{0}C oven for 48 h or until reaching a constant weight. Bags plus residues were placed in a desiccator for 30 min and then weighed.

2.6.3.4 Parameters

The following variable was calculated: percentage disappearance DM (DMD)

$$\% \text{ DMD} = \{(\text{A-C})/\text{A}\} \times 100$$

Where: A = Wt of DM

C = Residual DM

The DM disappearance percentages (indicative of the herbage degradation kinetics) with time were fitted, using the iterative least squares method in a nonlinear procedure (NLIN, SAS, 1994), to an exponential equation (Ørskov & McDonald, 1979):

$$p = a + b\,[1 - \exp^{-ct}]$$

where:

p = the percentage herbage DM degraded after time t (h);

a = washing losses, soluble or rapidly degradable DM fraction. This value is the intercept of the degradation curve at time 0 h;

b = the insoluble but potentially fermentable DM fraction which will degrade with time;

c = rate (/h) at which b is degraded

2.7 STATISTICAL ANALYSIS

Foggage samples from each strip in a particular camp and on each sampling date were treated as replications. Procedure GLM (General Linear Modelling) in SAS (SAS, 1994) with repeated measures was used to determine whether concentrations of individual nutrients or nutrient ratios in foggage varied significantly during the winter months. Significant differences were quoted at the $P < 0.05$ levels. The model was Date 1 (D1), Date 2 (D2), Date 3 (D3) and Date 4 (D4). The repeated model was of repeated dates (18-05-99; 08-06-99; 22-06-99; 06-07-99).

Procedures used in General Linear Modelling analysis were as follows:

GLM procedures with appropriate CLASSIFICATION variables and MODEL of DEP VARIABLES = INDEPENDENT VARIABLES with LSMEANS, (i.e. MEANS corrected for unbalanced data and adjusted for other terms in the MODEL), for Standard Error and P-Value information were employed. These procedures use the method of least squares to fit general linear models. Simple regression, multiple regression, ANOVA for unbalanced data, analysis of covariance, MANOVA, partial correlation and repeated measures analysis of variance were tested using continuous dependent variables to one or more independent variable. The independent variables were either classification variables (those variables dividing the observations into discrete groups) or continuous variables.

The GLM procedures incorporated the REPEATED statement that enables specification of effects in the model that represent repeated measurements on the same experimental unit for the same response and that provides both univariate and multivariate tests of hypotheses.

The statistical software employed was SAS (SAS, 1994), running under z/VM 3.1.0 on a PERSETEL 9/94-312 mainframe computer.

To compare the two sample means (leaves[μ_L] and stems[μ_S]) for variable concentrations in each period (D1 - D4) a confidence interval was constructed for the difference in the population means – that is, a confidence interval for the quantity (μ_L - μ_S).

The following formula was used to construct a confidence interval for the population:

$$D = t \text{ x } \sqrt{2 \text{ x (standard error)}^2}$$

D = Period

The critical value $t_{0.5}$ is determined from Students's t distribution using a 95% confidence for (μ_L - μ_S).

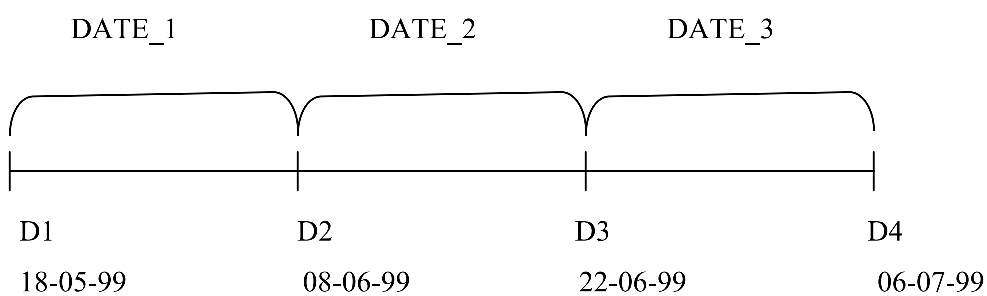
And the 95% confidence interval for (μ_L - μ_S) is

$$\alpha \left\{ a < \mu_L - \mu_S < b \right\} = 0.95$$

a = (μ_L - μ_S) - D

b = (μ_L - μ_S) + D

In order to determine the effect of time on variable percentages in leaves and stems the following time scale was used:



The time effect over D1 and D2 is DATE_1

The time effect over D2 and D3 is DATE_2

The time effect over D3 and D4 is DATE_3

The *in situ* degradation data were subjected to the iterative least squares method using the nonlinear procedure, NLIN (SAS, 1994) to estimate the nonlinear variables a, b, and c.

CHAPTER THREE

EXPERIMENTAL RESULTS

3.1 ANIMAL SUPPLEMENT INTAKE

Throughout phase 1 and 2 the supplement intake in all groups was sufficient to reach the targeted P intake. Therefore, the animals in group 1 consumed 8 g P/day/animal, those in group 2 an average of 6 g P/day/animal, those in group 3 an average of 4 g P/day/animal, those in group 4 an average of 2 g P/day/animal and those in group 5 nothing (Table 3.1, 3.2, 3.3 and 3.4).

Table 3.1 Supplement intake of the 40 steer per treatment during different stages of phase 1 of the trial (64 days)

Group	Required supplemental P intake/day	Supplement intake (kg) per 40 steers				Total Intake (kg): 64 days
		Intake (kg): first 22 days	Intake (kg): Next 13 days	Intake (kg): Next 14 days	Intake (kg): Next 15 days	
1	8 g P/day	560	208	153.6	179.2	1100.8
2	6 g P/day	427.5	222.5	187.5	267.5	1105.0
3	4 g P/day	427.5	250.8	210.9	222.3	1111.5
4	2 g P/day	286	210	232	252	980.0
5	0 g P/day	288	200	202	260.3	950.3

Table 3.2 Supplement intake of the 40 steer per treatment during different stages of phase 2 of the trial (58 days)

Group	Required supplemental P intake/day	Supplement intake (kg) per 40 steers				Total
		Intake (kg): first 16 days	Intake (kg): Next 14 days	Intake (kg): Next 15 days	Intake (kg): Next 13 days	Intake (kg): 58 days
1	8 g P/day	300	270	275	300	1145
2	6 g P/day	310	280	230	300	1120
3	4 g P/day	340	250	300	240	1130
4	2 g P/day	299	280	270	288	1137
5	0 g P/day	288	280	300	270	1138

Table 3.3 Intake of phosphorus (P) derived from the supplement of the steers per day during phase 1 of the trial

Group	Required P intake/day	Kg lick/day/40 animals	g lick/day/ animal	% P in lick	Total P intake/day/ Animal (g)
1	8 g P/day	17.2	430	2	8.6
2	6 g P/day	17.3	433	1.5	6.5
3	4 g P/day	17.4	435	1	4.4
4	2 g P/day	15.3	383	0.5	1.9
5	0 g P/day	14.8	379	0	0

Table 3.4 Intake of phosphorus (P) derived from the supplement of the steers per day during phase 2 of the trial

Group	Required P intake/day	Kg lick/day/40 animals	g lick/day/ animal	% P in lick	Total P intake/day/ Animal (g)
1	8 g P/day	19.7	493	2	9.9
2	6 g P/day	19.3	483	1.5	7.2
3	4 g P/day	19.5	488	1	4.9
4	2 g P/day	19.6	490	0.5	2.5
5	0 g P/day	19.6	490	0	0

During phase 1, the CP intake from the supplement was above 140 g/animal/day (minimum CP intake from lick/animal/day) for groups 1, 2 and 3, but not for groups 4 and 5 (Table 3.5). During phase 2 the CP intake from the supplement were above 140 g/animal/day for all groups of animals (Table 3.6).

Table 3.5 Crude protein (CP) intake/animal/day over total period during phase 1 from supplement

Group	kg lick /day/40 animals	g lick /day/animal	% CP in lick	Total CP Intake/day/ animal (g)
1	17.2	430	35	151
2	17.3	433	35	152
3	17.4	435	35	152
4	15.3	383	35	134
5	14.8	370	35	130

Table 3.6 Crude protein (CP) intake/animal/day over total period during phase 2 from supplement

Group	kg lick /day/40 animals	g lick /day/animal	% CP in lick	Total CP Intake/day/ Animal (g)
1	19.7	493	35	173
2	19.3	483	35	169
3	19.5	488	35	171
4	19.6	490	35	172
5	19.6	490	35	172

3.2 ANIMAL BODY WEIGHT CHANGES

The average weight changes of heifers and oxen during phase 1 and phase 2 are presented in Tables 3.7 and 3.8.

Table 3.7 Average body weights during different stages of phase 1 of the trial

			Body weights (kg)				
Group	Sex	n	Day 0	Day 21	Day 34	Day 48	Day 63
1	Heifer	20	160 ± 0.253	170 ± 0.300	173 ± 0.448	171 ± 0.488	172 ± 0.344
	Oxen	20	185 ± 0.274	191 ± 0.295	190 ± 0.225	192 ± 0.344	189 ± 0.234
2	Heifer	20	171 ± 0.543	187 ± 0.450	188 ± 0.233	188 ± 0.237	184 ± 0.455
	Oxen	20	195 ± 0.298	198 ± 0.336	203 ± 0.324	200 ± 0.345	198 ± 0.349
3	Heifer	20	159 ± 0.234	169 ± 0.299	170 ± 0.307	170 ± 0.355	166 ± 0.345
	Oxen	20	179 ± 0.298	181 ± 0.360	182 ± 0.387	182 ± 0.450	177 ± 0.345
4	Heifer	20	168 ± 0.295	177 ± 0.245	178 ± 0.333	179 ± 0.267	179 ± 0.344
	Oxen	20	190 ± 0.239	191 ± 0.295	193 ± 0.455	195 ± 0.235	194 ± 0.256
5	Heifer	20	145 ± 0.300	150 ± 0.222	150 ± 0.244	155 ± 0.277	150 ± 0.344
	Oxen	20	175 ± 0.500	200 ± 0.295	195 ± 0.365	190 ± 0.266	190 ± 0.234

Table 3.8 Average body weights during different stages of phase 2 of the trial

			Body weights (kg)			
Group	Sex	n	Day 78	Day 93	Day 108	Day 121
1	Heifer	20	167 ± 0.344	166 ± 0.345	162 ± 0.457	171 ± 0.453
	Oxen	20	185 ± 0.233	186 ± 0.366	180 ± 0.300	188 ± 0.342
2	Heifer	20	181 ± 0.455	180 ± 0.344	180 ± 0.345	182 ± 0.232
	Oxen	20	194 ± 0.344	193 ± 0.567	185 ± 0.324	185 ± 0.348
3	Heifer	20	160 ± 0.233	165 ± 0.347	161 ± 0.435	160 ± 0.349
	Oxen	20	172 ± 0.456	175 ± 0.233	171 ± 0.345	172 ± 0.453
4	Heifer	20	177 ± 0.345	171 ± 0.446	173 ± 0.342	177 ± 0.493
	Oxen	20	185 ± 0.333	183 ± 0.344	180 ± 0.322	188 ± 0.395
5	Heifer	20	150 ± 0.300	151 ± 0.355	148 ± 0.422	161 ± 0.377
	Oxen	20	190 ± 0.233	191 ± 0.247	188 ± 0.432	197 ± 0.289

The average gain/loss in body weight during phase 1 of the trial showed a higher gain ($P < 0,05$) for group 1 that received 8 g P/day/animal than the control group, which received 0 g P/day/animal (Table 3.9). Phase 2 showed that group 1 had an average weight loss of 0.88 kg/animal, but the control group lost an average of 5.13 kg/animal ($P < 0.05$).

Table 3.9 Average body weight gain or (loss) ± standard deviation during phase 1 and 2 of the trial

GROUP* P intake/animal/day	PHASE 1** Average gain/(loss) Kg ā ± SD		PHASE 2*** Average gain/(loss) Kg ā ± SD		TOTAL Average gain/(loss) kg ā ± SD	
Group 1: 8 g P/day	9.1[a]	± 0.384	(-0.9)[a]	± 0.194	8.0[a]	± 0.373
Group 2: 6 g P/day	8.0[a]	± 0.360	(-7.0)[b]	± 0.543	1.0[b]	± 0.564
Group 3: 4 g P/day	2.4[b]	± 0.336	(-5.3)[c]	± 0.227	(-2.9)[c]	± 0.298
Group 4: 2 g P/day	8.6[a]	± 0.295	(-4.9)[c]	± 0.239	3.8[d]	± 0.274
Group 5: 0 g P/day	7.3[a]	± 0.300	(-5.1)[c]	± 0.234	2.1[e]	± 0.253

* 40 animals per group

** 63 days in phase 1

*** 58 days in phase 2

( ) average body weight loss

[a,b,c,d,e] Column means with common superscripts do not differ significantly ($P < 0.05$)

In this study the animals from group 1 (8 g P/day supplementation) gained an average of 8 kg LW during the trial, while that of group 5 (0 g P/day supplementation) gained an average of only 2.1 kg LW (Table 3.4). It was also observed that animals from group 5 lost on average more weight ($P < 0.05$) (5.1 kg LW) during phase 2 of the trial than animals from group 1 who only lost an average of 0.9 kg LW. The average weight gain during phase 1 of the trial was also higher for animals in group1 than group 5. The animals of group 3 gained only 2.4 kg LW during phase 1 and were the only group that had an average weight loss over the whole period.

3.3 PLASMA INORGANIC P (Pi) CONCENTRATIONS

Serum inorganic P (Pi) levels of sampled animals maintained levels of between 1.94 and 2.58 mmol/L (Appendix 1 and 2). The average trend during phase 1 of the trial was that the average Pi level increased. During phase 2 however, Pi levels dropped more in group 1 than in group 5 (Table 3.10). Therefore, an average increase in Pi in group 5 and an average decrease in the group1 of Pi levels during the trial (phase 1 and phase 2) (Table 3.10).

Table 3.10 Average increase or decrease of plasma inorganic P (Pi) levels (mmol/L) ± standard deviation of sample animals at the end of phase 1 and 2 of the trail

GROUP P intake/animal/day	PHASE 1* Average change in Pi levels (mmol/L) (ā ± SD)		PHASE 2** Average change in Pi levels (mmol/L) (ā ± SD)		TOTAL: Phase 1 & 2 Average change in Pi levels (mmol/L)
8 g P/day	0.41[a]	± 0.225	(0.54)[a]	± 0.448	(0.07)[a]
6 g P/day	(0.45)[b]	± 0.868	(0.21)[b]	± 0.246	(0.33)[b]
4 g P/day	0.32[c]	± 0.233	(0.11)[c]	± 0.307	0.10[c]
2 g P/day	0.48[d]	± 0.324	(0.35)[b]	± 1.243	0.07[c]
0 g P/day	0.33[c]	± 0.522	(0.10)[c]	± 0.387	0.12[c]

* 63 days in phase 1

** 58 days in phase 2

( ) average decrease in Pi levels

[a,b,c,d,e] Column means with common superscripts do not differ significantly ($P < 0.05$)

The average change (increase or decrease) over time in Pi levels (mmol/L) of sampled animals during phase 1 and 2 are illustrated in Figure 3.1.

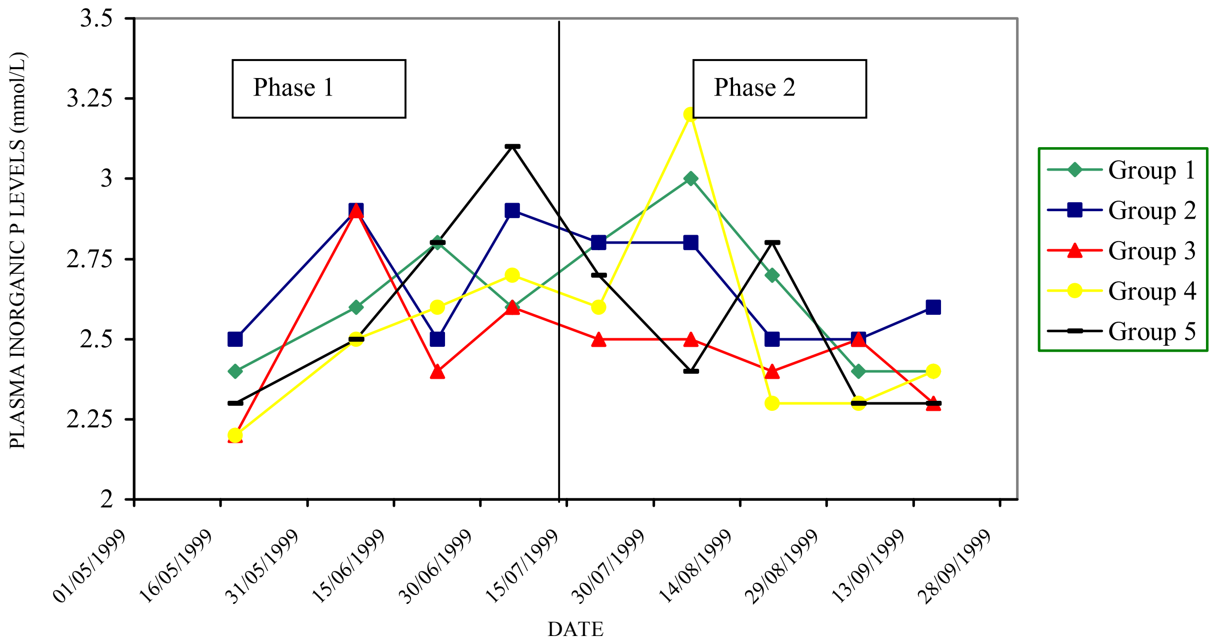


Figure 3.1 Average changes in Pi levels over time of sampled animals during phases 1 and 2 of the trial

3.4 COMPOSITION OF KIKUYU FOGGAGE AND SMUTSFINGER HAY

3.4.1 GREEN : DRY AND LEAF : STEM

The green to dry material ratio in kikuyu changed from 3.0 to 0.04 on a DM basis, and the leaf to stem ratio from 1.83 to 1.33 between the first and the last collections during phase 1 of the trial (Table 3.11).

Table 3.11 Green : dry material ratio and leaf : stem ratio (± standard deviation) of kikuyu foggage as winter progressed (phase 1) (DM basis)

	Number of samples (n)	DAYS 1*	17	37	55
Date		18-05-99	08-06-99	22-06-99	06-07-99
Green : Dry ratio	25	$3.0^{a} \pm 0.57$	$1.1^{b} \pm 0.69$	$0.2^{c} \pm 0.83$	$0.04^{d} \pm 0.46$
Leaf : Stem ratio	25	$1.8^{a} \pm 0.09$	$1.4^{b} \pm 0.35$	$1.4^{b} \pm 0.61$	$1.3^{c} \pm 0.64$

* First day, 18 May 1999

a,b,c,d,e Row means with common superscripts do not differ significantly ($P < 0.05$)

3.4.2 CALCIUM (Ca)

In this study mean Ca concentrations ranged from 3.06 g/kg to 3.86 g/kg DM in the leaves and from 1.76 g/kg to 2.15 g/kg DM in the stems of kikuyu foggage (Table 3.12). Calcium concentrations tended to be significantly ($P \leq 0.05$) higher in the leaves than in the stems of foggage (Figure 3.2). There was no significant variation in Ca concentration over time in kikuyu foggage as the winter progressed. Calcium values for Smutsfinger hay during phase 2 of the trial ranged between 3.5 g/kg to 4.4 g/kg DM for leaves and from 0.56 g/kg to 1.20 g/kg DM for stems (Table 3.13).

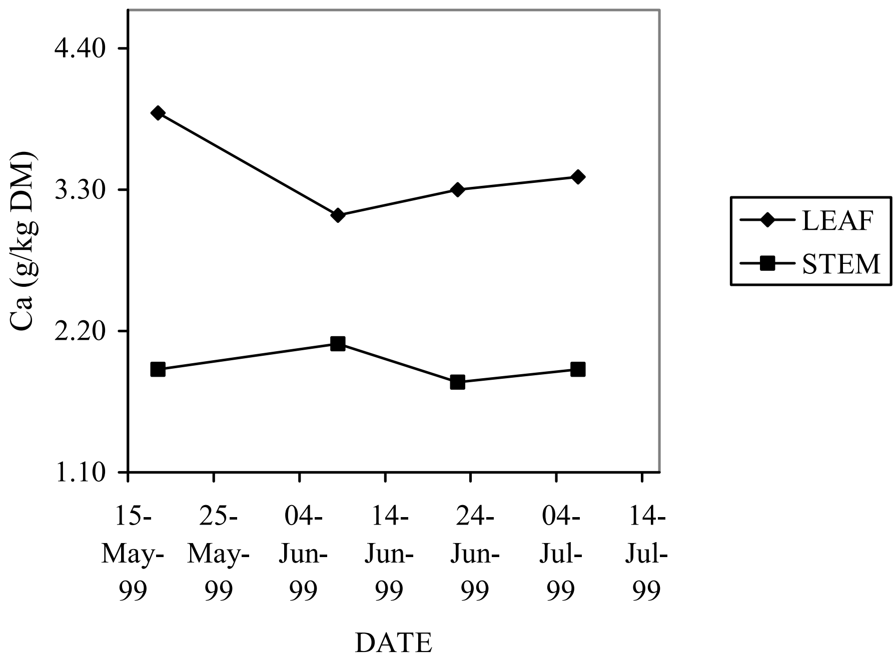


Figure 3.2 Within season variations in Ca concentrations of kikuyu stems and leaves

Table 3.12 Calcium (Ca) concentration (± standard deviation) in kikuyu foggage (phase 1) during winter

Day	Calcium (g/kg DM)		
	Leaf and stem**	Leaf	Stem
1*	3.2	$3.9^{a} \pm 0.8$	$1.9^{b} \pm 0.7$
17	2.7	$3.1^{a} \pm 0.6$	$2.2^{b} \pm 0.9$
37	2.7	$3.2^{a} \pm 0.6$	$1.8^{b} \pm 0.2$
55	2.7	$3.4^{a} \pm 0.3$	$1.9^{b} \pm 0.3$

* First day, 15 May 1999

^{a,b} Means within rows with different superscripts differ at $P < 0.05$

** Calculated from leaf : stem ratio and average Ca concentrations in the leaves and stems

Table 3.13 Calcium (Ca) concentration (± standard deviation) in Smutsfinger hay during phase 2

	Calcium (g/kg DM)	
Day	Leaf	Stem
1*	4.4 ± 0.3	0.6 ± 0.2
14	3.5 ± 0.6	0.8 ± 0.3
28	4.1 ± 0.4	1.2 ± 0.3
41	4.0 ± 0.3	0.8 ± 0.5

* First day 5 August 1999

** Differences within columns not statistically significant

Ca concentrations of the leaves and stems of the kikuyu foggage were significantly different in periods D1 ($P = 0.0027$), D3 ($P = 0.0004$) and D4 ($P = < 0.0001$), but not in period D2 ($P = 0.0944$). The time effect over DATE_1 ($P = 0.3392$), DATE_2 ($P = 0.7940$) and DATE_3 ($P = 0.5038$) for kikuyu was not significant ($P < 0.05$) (time scale discussed in section 2.7).

3.4.3 PHOSPHORUS (P)

Mean P concentrations ranged from 1.75 g/kg to 2.43 g/kg DM in the leaves and from 2.20 g/kg to 2.97 g/kg DM in the stems of kikuyu foggage (Table 3.14). Significant ($P \leq 0.05$) within season variation in P concentrations of the foggage occurred. The overriding was a maximum during May and decreasing towards July (Figure 3.3). Phosphorus values for phase 2 of the trial were from 0.54 g/kg to 0.99 g/kg for leaves and from 0.25 g/kg to 0.60 g/kg for the stems of Smutsfinger hay (Table 3.15).

Table 3.14 Phosphorus (P) concentrations (± standard deviation) in kikuyu foggage (phase 1) during winter

Day	Phosphorus (g/kg DM)		
	Leaf and stem***	Leaf	Stem
1*	2.6	2.4 ± 0.5	3.0 ± 0.8
17	2.2	2.1 ± 0.6	2.3 ± 1.2
37	2.0	1.8 ± 0.7	2.2 ± 0.9
55	2.2	1.9 ± 0.7	2.5 ± 0.8

* First day, 15 May 1999

** Differences within columns and rows not statistically significant

*** Calculated from leaf : stem ratio and average P concentrations in the leaves and stems

Table 3.15 Phosphorus (P) concentration (± standard deviation) in Smutsfinger hay during phase 2

Day	Phosphorus(g/kg DM)	
	Leaf	Stem
1*	1.0 ± 0.7	0.6 ± 0.4
14	0.8 ± 0.6	0.5 ± 0.5
28	0.8 ± 0.6	0.5 ± 0.6
41	0.5 ± 0.6	0.3 ± 0.6

* First day 5 August 1999

** Differences within columns and rows not statistically significant

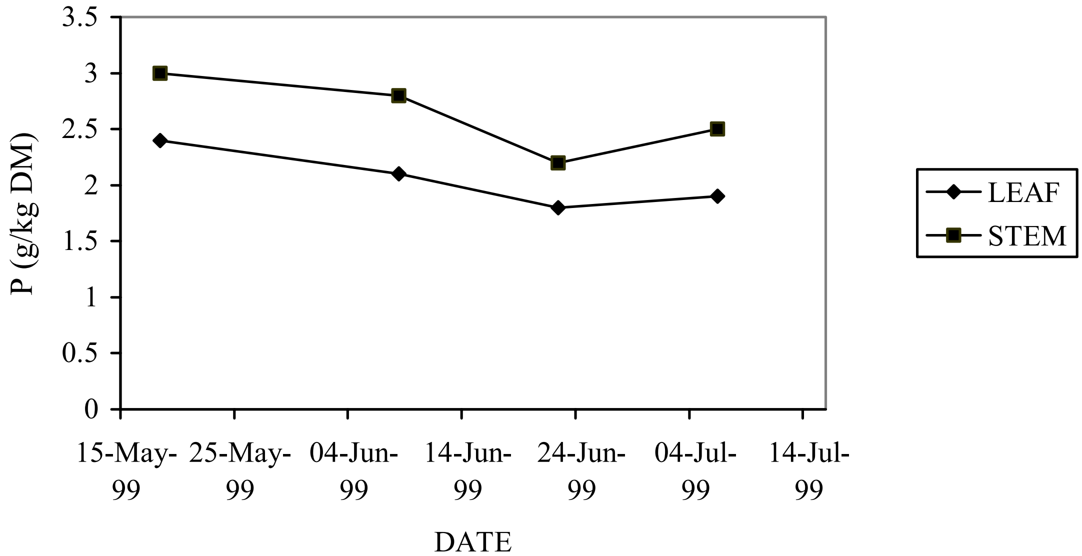


Figure 3.3 Within season variations in kikuyu stem and leave P concentrations

P concentrations of the leaves and stems were not significantly different for kikuyu foggage in periods D1 (P = 0.2360), D2 (P = 0.7317), D3 (P = 0.3989) or D4 (P = 0.2137). The time effect over DATE_1 (P = 0.0135) and DATE_3 (P = 0.0184) was significant but the time effect over DATE_2 (P = 0.3928) were not significant for kikuyu foggage (the period DATE_1 to DATE_3 was explained in section 2.7). A significant within season variation in P percentage for kikuyu foggage occurred (P < 0.05).

3.4.4 CALCIUM:PHOSPHORUS (Ca:P)

In phase 1 mean leave Ca:P ratios ranged from 1.61 to 2.20 and from 0.71 to 1.59 in the stems in kikuyu foggage (Table 3.16). The Ca:P ratios in the leaves were significantly higher ($P \leq 0.05$) than those in the stems (Figure 3.4). No significant within season variation occurred in these kikuyu ratios although the trend seemed to be an increase in the Ca:P ratio as the P concentration decreased. No significant seasonal variations in kikuyu Ca:P ratio occurred, although P concentrations decreased significantly.

In phase 2 mean leave Ca:P ratios ranged from 42.5 to 53.0 and from 9.4 to 31.5 in the stems of Smutsfinger hay (Table 3.17).

Table 3.16 Calcium (Ca) and P ratios (± standard deviation) in kikuyu foggage (phase 1) during winter

Days	Ca : P ratio		
	Leaf and stem**	Leaf	Stem
1*	1.4	$1.7^a \pm 0.68$	$0.7^b \pm 0.42$
17	1.6	$1.6^a \pm 0.67$	$1.6^a \pm 1.84$
37	1.7	$2.2^a \pm 1.13$	$0.9^b \pm 0.43$
55	1.4	$2.0^a \pm 0.57$	$0.8^b \pm 0.31$

* First day, 15 May 1999

^{a,b} Mean within rows with different superscripts differ at $P < 0.05$

** Calculated from leaf : stem ratio and average Ca : P concentrations in the leaves and stems

Table 3.17 Calcium (Ca) and P ratios (± standard deviation) in Smutsfinger hay during phase 2

Day	Ca : P ratio	
	Leaf	Stem
1*	$44.1^a \pm 0.6$	$9.4^b \pm 0.5$
14	$42.5^a \pm 0.5$	$16.2^b \pm 0.4$
28	$52.8^a \pm 0.7$	$22.8^b \pm 0.7$
41	$53.0^a \pm 0.6$	$31.5^b \pm 0.7$

* First day 5 August 1999

^{a,b} Mean within rows with different superscripts differ at $P < 0.05$

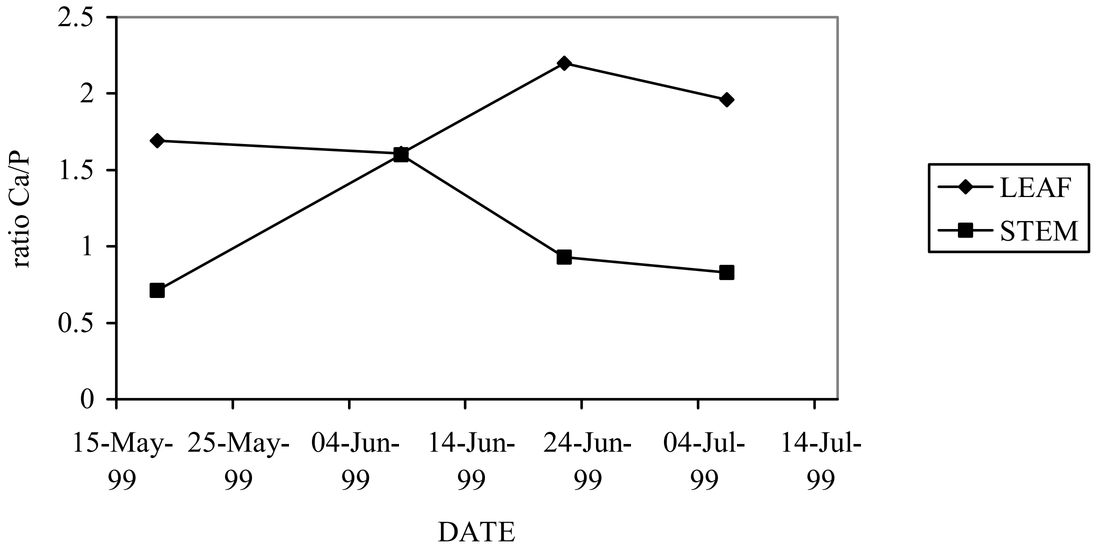


Figure 3.4 Within season variations in Ca and P ratios of kikuyu stems and leaves

Ca/P ratios of the leaves and stems of the kikuyu were significantly different in periods D1 ($P = 0.0244$), D3 (P = 0.0.0473) and D4 ($P = 0.0046$), but not significantly different in period D2 ($P = 0.9910$). The time effect over DATE_1 ($P = 0.3302$), DATE_2 ($P = 0.9378$) and DATE_3 ($P = 0.3204$) in kikuyu was not significant (the period DATE_1 to DATE_3 was explained in section 2.7). Therefore no significant within season variation in Ca/P ratio of kikuyu occurred ($P < 0.05$).

3.4.5 CRUDE PROTEIN (CP)

In this study (phase 1) CP concentration ranged from 56 g/kg to 112 g/kg DM in the leaves and from 52 g/kg to 98 g/kg DM in the stems of kikuyu foggage (Table 3.18). The CP levels of the Smutsfinger hay ranged from 34.70 g/kg to 45.02 g/kg in the leaves and from 12.62 g/kg to 23.15 g/kg DM in the stems (Table 3.19). Crude protein concentrations decreased significantly in kikuyu between day one and day 17 ($P \leq 0.0055$) and day 17 to day 36 ($P \leq 0.059$), but not from day 37 to day 55 ($P > 0.2555$) (Figure 3.5). Stem and leave CP concentrations in kikuyu did not vary significantly (Table 3.18).

Table 3.18 Crude protein (CP) concentration (± standard deviation) of kikuyu foggage as winter progressed (phase 1)

		DAYS			
		1*	17	37	55
Date		18-05-99	08-06-99	22-06-99	06-07-99
C P	Leaf	112 ± 16.0	70 ± 17.3	61 ± 13.6	56 ± 9.8
(g/kg DM)	Stem	98 ± 17.4	64 ± 28.9	59 ± 19.9	52 ± 9.2
Leaf and stem***		107	68	61	55

* First day, 15 May 1999; ** Differences within columns not statistically significant;

*** Calculated from leaf : stem ratio and average CP concentrations in the leaves and stems

Table 3.19 Crude protein (CP) concentration (± standard deviation) of Smutsfinger hay during phase 2

		DAYS			
		1*	14	28	41
C P	Leaf	39.2 ± 16.0	34.7 ± 17.2	45.0 ± 9.7	38.4 ± 13.4
(g/kg DM)	Stem	11.9 ± 19.9	13.5 ± 20.2	23.2 ± 6.0	12.6 ± 26.3

* First day, 5 August 1999

** Differences within columns not statistically significant

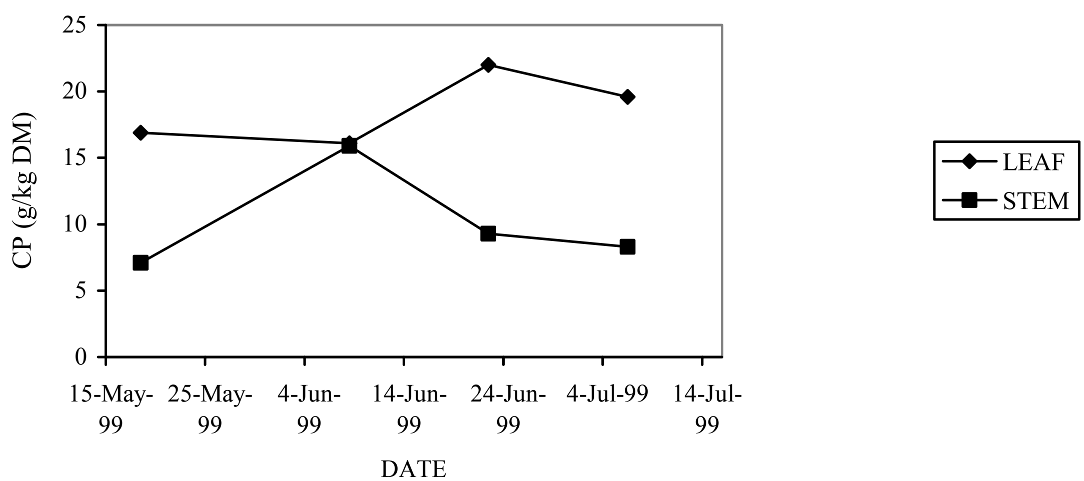


Figure 3.5 Within season variations of CP concentrations in kikuyu stems and leaves

Leaf and stem CP concentrations of kikuyu were not significantly different in periods D1

(P = 0.2209), D2 (P = 0.6890), D3 (P = 0.8436) or D4 (P = 0.5731). The time effect over DATE_1 (P = 0.0055) and DATE_2 (P = 0.0598) was significant, but the time effect over DATE_3 (P = 0.2555) was not significant in kikuyu foggage (time scale discussed in section 2.7). Therefore a significant within season variation in kikuyu CP concentration occurred ($P < 0.05$).

3.4.6 NEUTRAL DETERGENT FIBRE (NDF)

During phase 1 of this study the NDF concentrations ranged from 712 g/kg to 772 g/kg DM in the leaves and from 688 g/kg to 767 g/kg DM in the stems of the kikuyu foggage (Table 3.20). The Smutsfinger hay values were from 761 g/kg to 800 g/kg DM in the leaves and from 851 g/kg to 883 g/kg DM in the stems (Table 3.21). The NDF concentrations in the kikuyu foggage did vary significantly during the period day one to day 17 (P = 0.0208) and day 17 to day 37 (P = 0.0017), but not during the period day 37 to day 55 (P = 0.8184)(Figure 3.6).

Table 3.20 Neutral detergent fibre (NDF) concentrations (± standard deviation) of kikuyu foggage as winter progressed (phase 1)

		DAYS			
		1*	17	37	55
Date		18-05-99	08-06-99	22-06-99	06-07-99
NDF	Leaf	712 ± 29.0	751 ± 15.7	784 ± 22.9	772 ± 6.3
(g/kg DM)	Stem	688 ± 30.3	724 ± 45.7	758 ± 60.6	767 ± 36.4
Leaf and stem***		704	740	773	769

* First day, 15 May 1999; ** Differences within columns not statistically significant;

*** Calculated from leaf : stem ratio and average NDF concentrations in the leaves and stems

Table 3.21 Neutral detergent fibre concentrations (± standard deviation) of Smutsfinger hay during phase 2

		DAYS			
		1*	14	28	41
NDF	Leaf	758.7 ± 45.6	800.9 ± 17.0	761.2 ± 23.0	772.5 ± 30.0
(g/kg DM)	Stem	851.1 ± 30.0	868.0 ± 20.0	859.0 ± 30.0	883.9 ± 30.0

* First day, 5 August 1999

** Differences within columns not statistically significant

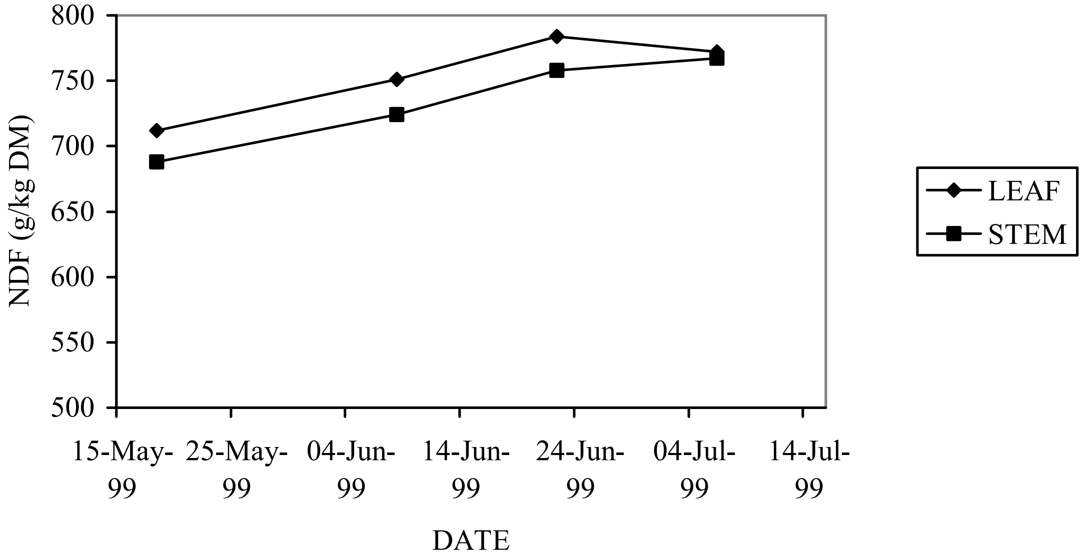


Figure 3.6 Within season variations in NDF concentrations of kikuyu stems and leaves

Leaf and stem kikuyu NDF concentrations were not significantly different in periods D1 (P = 0.2425), D2 (P = 0.2588), D3 (P = 0.3949) or D4 (P = 0.7592). The time effect over DATE_1 (P = 0.0208) and DATE_2 (P = 0.0017) was significant, but the time effect over DATE_3 (P = 0.8184) was not significant for kikuyu foggage (the period DATE_1 to DATE_3 was explained in section 2.7). A significant within season variation in kikuyu NDF concentrations occurred (P < 0.05).

3.4.7 ACID DETERGENT FIBRE (ADF)

During phase 1 of this study the ADF concentrations ranged from 341 g/kg to 391 g/kg DM in the leaves and from 329 g/kg to 391 g/kg DM in the stems of kikuyu foggage (Table 3.22). For phase 2 of the trial the values for Smutsfinger hay were from 486 g/kg to 511 g/kg DM for the leaves and from 554 g/kg to 602 g/kg DM for the stems (Table 3.23). The ADF concentrations in kikuyu did not vary significantly during the sampling period (Figure 3.7).

Table 3.22 Acid detergent fibre (ADF) concentration (± standard deviation) of kikuyu foggage as winter progressed (phase 1)

		DAYS			
		1*	17	37	55
Date		18-05-99	08-06-99	22-06-99	06-07-99
ADF	Leaf	341 ± 11.6	361 ± 5.2	383 ± 29.4	391 ± 13.7
(g/kg DM)	Stem	329 ± 16.9	370 ± 61.4	371 ± 51.8	391 ± 25.1
Leaf and stem***		337	365	378	391

* First day, 15 May 1999

** Differences within columns not statistically significant

*** Calculated from leaf : stem ratio and average ADF concentrations in the leaves and stems

Table 3.23 Acid detergent fibre (ADF) concentration (± standard deviation) of Smutsfinger hay during phase 2

		DAYS			
		1*	14	28	41
ADF	Leaf	486.8 ± 13.3	511.7 ± 5.3	487.8 ± 20.1	495.4 ± 11.3
(g/kg DM)	Stem	601.6 ± 14.5	602.9 ±16.9	554.6 ± 23.2	601.5 ± 17.0

* First day, 5 August 1999

** Differences within columns not statistically significant

Leaf and stem ADF concentrations of kikuyu foggage were not significantly different in periods D1 (P = 0.2253), D2 (P = 0.7715), D3 (P = 0.6436) or D4 (P = 0.9709). The time effect for kikuyu foggage over DATE_1 (P = 0.0637), DATE_2 (P = 0.2440) and DATE_3 (P = 0.1933) was not significant (the period DATE_1 to DATE_3 was explained in section 2.7). A significant within season variation in ADF concentration occurred for kikuyu foggage (P < 0.05).

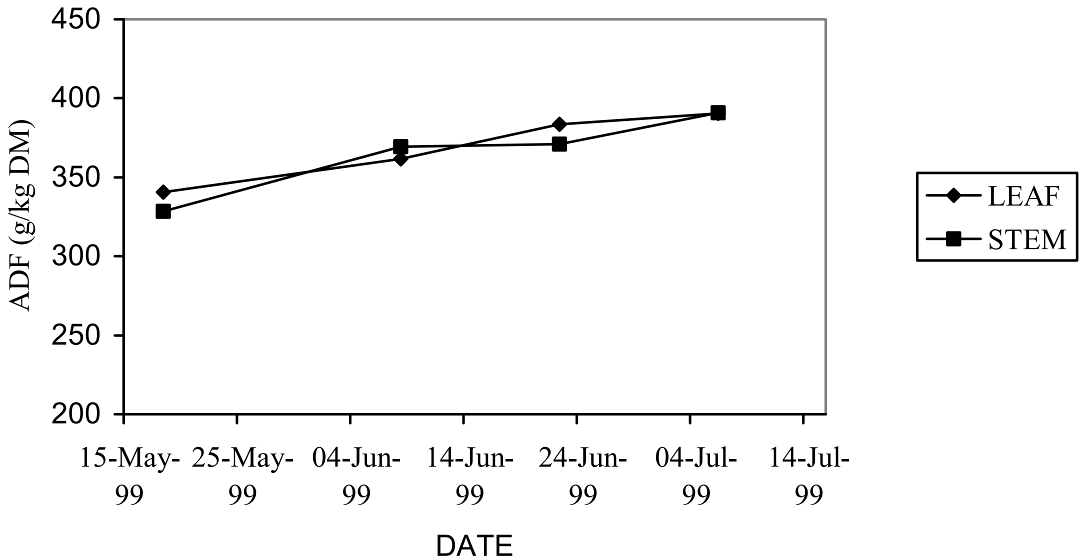


Figure 3.7 Within season variations in ADF concentrations of kikuyu stems and leaves

3.4.8 MAGNESIUM (Mg)

Mean foggage Mg concentrations ranged from 2.00 g/kg to 2.40 g/kg DM in the leaves and from 2.10 g/kg to 2.70 g/kg DM in the stems of kikuyu foggage (Table 3.24). No significant ($P \leq 0.05$) within season variation in kikuyu Mg concentrations occurred (Figure 3.8). Magnesium values for phase 2 were from 21.1 g/kg to 26.6 g/kg DM for leaves and from 13.2 g/kg to 14.6 g/kg DM for the stems of Smutsfinger hay (Table 3.25).

Table 3.24 Magnesium (Mg) concentration (± standard deviation) in kikuyu (phase 1) during winter

Day	Mg (g/kg DM)		
	Leaf and stem	Leaf	Stem
1*	2.5	2.4 ± 0.5	2.7 ± 0.6
17	2.3	2.3 ± 0.2	2.4 ± 0.4
37	2.1	2.0 ± 0.4	2.2 ± 0.5
55	2.0	2.0 ± 0.1	2.1 ± 0.3

* First day, 15 May 1999

** Differences within columns not statistically significant

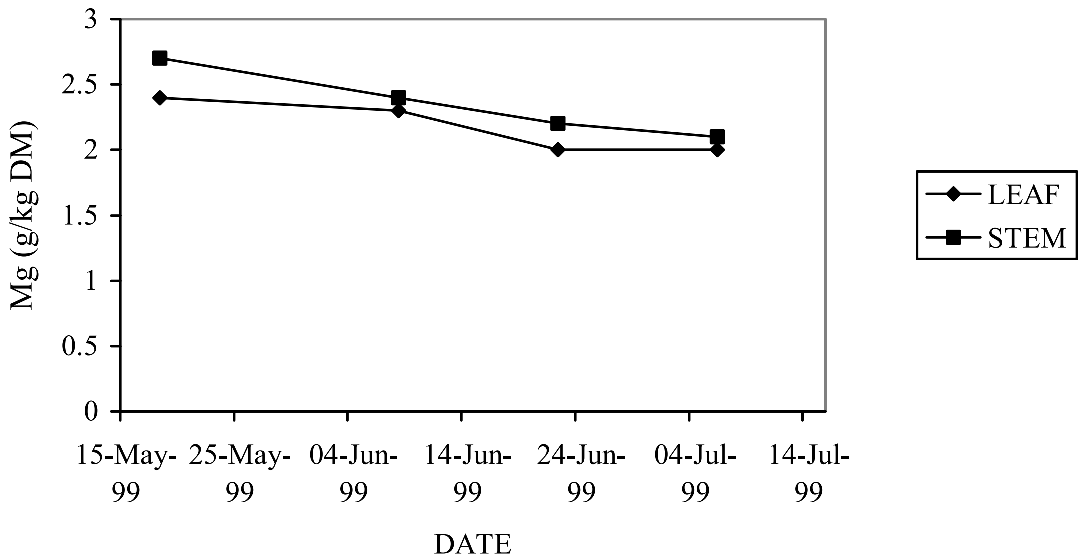


Figure 3.8 Within season variations in Mg concentrations in kikuyu stems and leaves

Table 3.25 Smutsfinger hay Mg concentration (± standard deviation) during phase 2

Day	Magnesium(g/kg DM)	
	Leaf	Stem
1*	$26.6^{a} \pm 0.4$	$13.3^{b} \pm 0.5$
14	$21.1^{a} \pm 0.3$	$13.2^{b} \pm 0.4$
28	$23.9^{a} \pm 0.4$	$14.6^{b} \pm 0.4$
41	$21.3^{a} \pm 0.4$	$14.6^{b} \pm 0.3$

* Fist day 5 August 1999

^{a,b} Means within rows with different superscripts differ at $P < 0.05$

Leaf and stem Mg concentrations in kikuyu are not significantly different in periods D1 (P = 0.4211), D2 (P = 0.6088), D3 (P = 0.6668) or D4 (P = 0.3569). The time effect over DATE_1 (P = 0.2238), DATE_2 (P = 0.1848) and DATE_3 (P = 0.8386) in kikuyu was not significant (the period DATE_1 to DATE_3 was explained in section 2.7). Therefore no significant within season variation in kikuyu Mg percentage occurred ($P < 0.05$).

3.4.9 POTASSIUM (K)

Mean foggage K concentrations ranged from 10.1 g/kg to 17.7 g/kg DM in the leaves and from 12.6 g/kg to 23.0 g/kg DM in the stems of kikuyu foggage (Table 3.26). Significant ($P \leq 0.05$) within season variation in K concentrations occurred in kikuyu foggage (Figure 3.9). Phosphorus values for phase 2 of the trial were from 5.3 g/kg to 8.0 g/kg DM for leaves and from 10.6 g/kg to 13.3 g/kg DM for the stems of Smutsfinger hay (Table 3.27).

Table 3.26 Potassium (K) concentration (± standard deviation) in kikuyu foggage (phase 1) during winter

Day	K (g/kg DM)		
	Leaf and stem***	Leaf	Stem
1*	19.6	17.7 ± 3.8	23.0 ± 6.5
17	12.4	12.1 ± 3.6	12.6 ± 7.8
37	11.2	10.1 ± 3.3	12.8 ± 5.6
55	17.6	14.9 ± 5.5	21.1 ± 7.2

* First day, 15 May 1999

** Differences within columns not statistically significant

*** Calculated from leaf : stem ratio and average K concentration in the leaves and stems

Table 3.27 Potassium (K) concentration (± standard deviation) in Smutsfinger hay (phase 2)

	K (g/kg DM)	
Day	Leaf	Stem
1*	8.0 ± 4.0	13.3 ± 3.4
14	8.0 ± 3.5	10.6 ± 3.4
28	8.0 ± 5.3	10.6 ± 5.3
41	5.3 ± 3.0	10.7 ± 4.2

* Fist day 5 August 1999

** Differences within columns not statistically significant

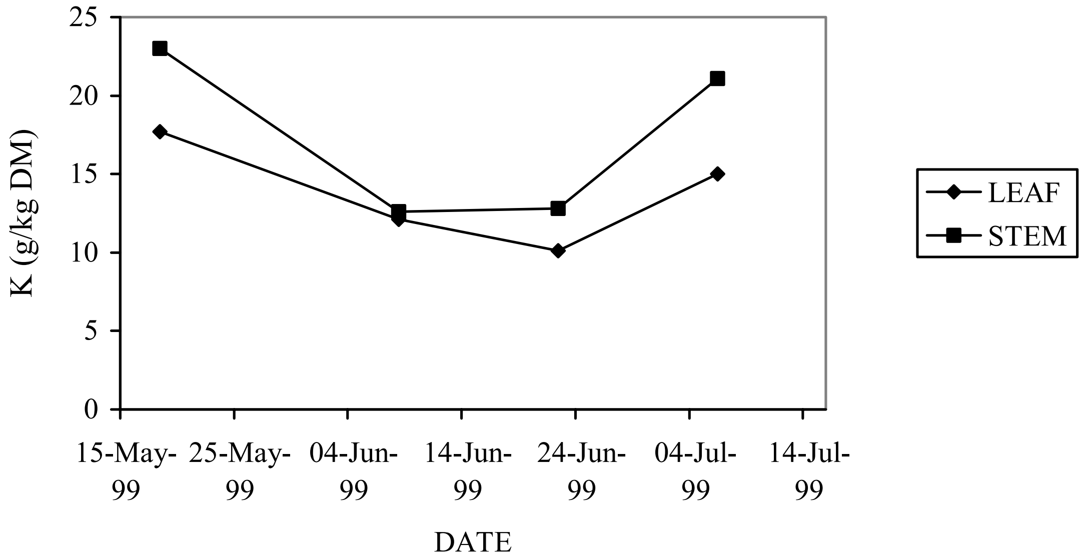


Figure 3.9 Within season variations in kikuyu stem and leave K concentrations

Leaf and stem K percentages are not significantly different in periods D1 ($P = 0.1505$), D2 ($P = 0.8967$), D3 ($P = 0.3824$) or D4 ($P = 0.1648$) for kikuyu foggage. That the time effect for kikuyu foggage over DATE_1 ($P = 0.0004$) and DATE_3 ($P = 0.0008$) was significant but the time effect over DATE_3 ($P = 0.0008$) was not significant (the period DATE_1 to DATE_3 was explained in section 2.7). Therefore a significant within season variation in kikuyu K percentage occurred ($P < 0.05$).

3.4.10 K:Ca +Mg (tetany potential indicator)

The seasonal mean K:Ca+Mg ratio ranged from 19.29 to 29.50 in the leaves and from 31.62 to 54.33 in the stems of kikuyu foggage (Table 3.28) for phase 1 of the trial. In most camps, the magnitude of this ratio varied significantly (P ≤ 0.05) within the season and between leafs and stems of kikuyu foggage (Figure 3.10). The K:Ca+Mg ratio in phase 2 of the trial ranged from 8.70 to 14.35 in the leaves and from 23.53 to 70.43 in the stems of Smutsfinger hay (Table 3.29).

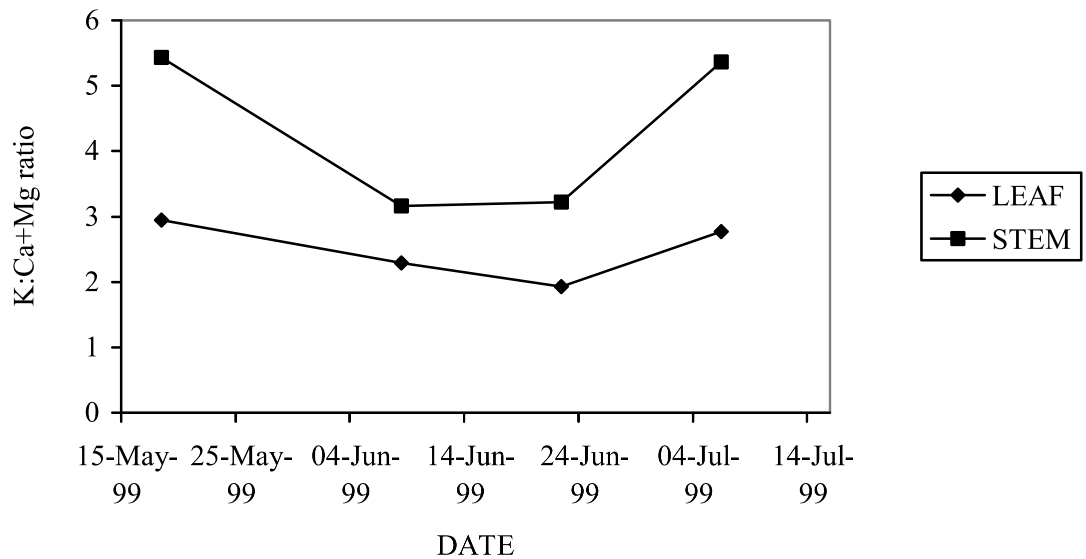


Figure 3.10 Within season variations in kikuyu stem and leave K:Ca+Mg ratio

Table 3.28 Kikuyu K:Ca+Mg ratio ± standard deviation (phase 1) during winter

Day	K:Ca+Mg		
	Leaf and stem**	Leaf	Stem
1*	3.8	$2.95^{a} \pm 1.01$	$5.43^{a} \pm 2.44$
17	2.6	$2.29^{a} \pm 0.74$	$3.16^{a} \pm 2.56$
37	2.4	$1.93^{a} \pm 0.72$	$3.22^{a} \pm 1.36$
55	3.9	$2.77^{a} \pm 0.93$	$5.36^{b} \pm 2.14$

* First day, 15 May 1999

^{a,b} Means within rows with different superscripts differ at P < 0.05

** Calculated from leaf : stem ratio and average K:Ca+Mg ratios in the leaves and stems

Table 3.29 Smutsfinger hay K:Ca+Mg ratio ± standard deviation during phase 2

	K:Ca+Mg	
Day	Leaf	Stem
1*	$1.13^{a} \pm 1.01$	$7.04^{b} \pm 1.03$
14	$1.44^{a} \pm 0.80$	$5.00^{b} \pm 0.90$
28	$1.24^{a} \pm 0.90$	$4.00^{b} \pm 0.90$
41	$0.87^{a} \pm 1.02$	$2.35^{a} \pm 0.70$

* Fist day, 5 August 1999

[a,b] Means within rows with different superscripts differ at $P < 0.05$

Leaf and stem kikuyu K:Ca+Mg percentages were significantly different in period D4 (P = 0.0401) and not significantly different periods in D1 (P = 0.0684), D2 (P = 0.4860) and D3 (P = 0.0969. The time effect over DATE_1 (P = 0.0009) and DATE_3 (P = 0.0195) was significant but the time effect over DATE_2 (P = 0.7510) was not significant in kikuyu foggage (the period DATE_1 to DATE_3 was explained in section 2.7).

3.4.11 SODIUM (Na)

Sodium concentrations in kikuyu foggage ranged from 0.15 g/kg to 0.19 g/kg DM in the leaves and from 0.18 g/kg to 0.42 g/kg DM in the stems (Table 3.30). There was no significant within season variation or significant variation between leaf and stem Na percentages in the kikuyu foggage (Figure 3.11). Leave and stem Na concentrations of Smutsfinger hay in phase 2 of the trial stayed the same (Table 3.31).

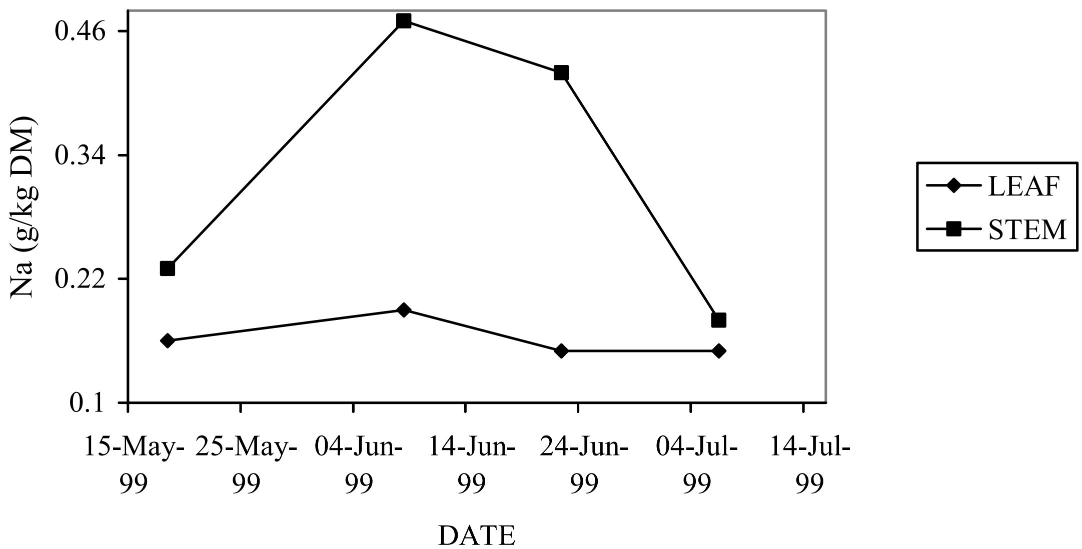


Figure 3.11 Within season variations in kikuyu stem and leave Na concentrations

Table 3.30 Kikuyu foggage Na concentrations (± standard deviation) during winter (phase 1)

Day	Na (g/kg DM)		
	Leaf and stem***	Leaf	Stem
1*	0.2	0.2 ± 0.1	0.2 ± 0.1
17	0.3	0.2 ± 0.1	0.5 ± 0.4
37	0.3	0.2 ± 0.1	0.4 ± 0.5
55	0.2	0.2 ± 0.1	0.2 ± 0.1

* First day, 15 May 1999

** Differences within columns not statistically significant

*** Calculated from leaf : stem ratio and average Na concentrations in the leaves and stems

Table 3.31 Smutsvinger hay Na concentrations (± standard deviation) during winter (phase 2)

Day	Na (g/kg DM)	
	Leaf	Stem
1*	0.1 ± 0.1	0.1 ± 0.1
14	0.1 ± 0.1	0.1 ± 0.1
28	0.1 ± 0.1	0.1 ± 0.1
41	0.1 ± 0.1	0.1 ± 0.1

* First day, 5 August 1999

** Differences within columns not statistically significant

Leaf and stem Na percentages were not significantly different in periods D1 (P = 0.1622), D2 (P = 0.1828), D3 (P = 0.2800) and D4 (P = 0.6160) for kikuyu foggage. The time effect over DATE_1 (P = 0.1555), DATE_2 (P = 0.5512) and DATE_3 (P = 0.3259) was not significant for kikuyu foggage (the period DATE_1 to DATE_3 was explained in section 2.7)

3.4.12 ZINC (Zn)

Mean foggage Zn concentration ranged from 114 mg/kg to 164 mg/kg DM in the leaves and from 113 mg/kg to 164 mg/kg DM in the stems of kikuyu foggage (Table 3.32). The only significant within season variation in kikuyu foggage of Zn concentration occurred during day 37 to day 55 ($P \leq 0.0060$) (Figure 3.12). There was no significant variation between leaf and stem Zn concentration in kikuyu foggage. Zinc values for phase 2 were from 87.8 to 157.7 mg/kg DM for the leaves and from 88.0 to 156.2 mg/kg DM for the stems of Smutsfinger hay (Table 3.33).

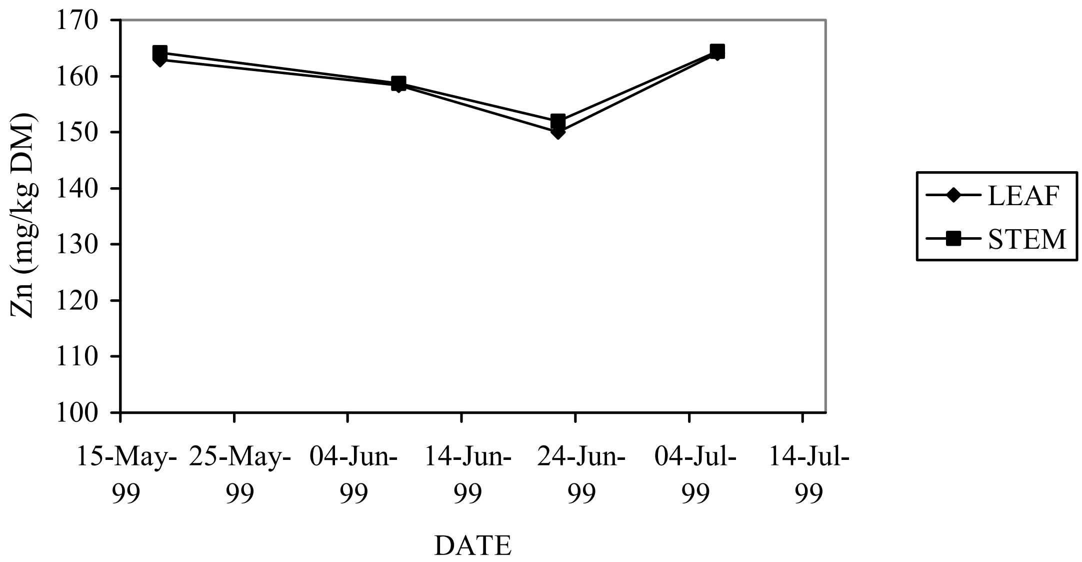


Figure 3.12 Within season variations in kikuyu stem and leave Zn concentration

Table 3.32 Effect of stage of winter on the Zn concentration (± standard deviation) of kikuyu foggage (phase 1)

Day	Zn (mg/kg DM)		
	Leaf and stem***	Leaf	Stem
1*	164	163.0 ± 21.35	164.2 ± 21.64
17	159	158.4 ± 60.09	158.8 ± 59.36
37	114	150.0 ± 32.11	152.0 ± 32.02
55	164	164.0 ± 37.46	164.4 ± 37.39

* First day, 15 May 1999

** Differences within columns not statistically significant

*** Calculated from leaf : stem ratio and average Zn concentration in the leaves and stems

Table 3.33 Zn concentration (± standard deviation) of Smutsfinger hay (phase 2)

Day	Zn (mg/kg DM)	
	Leaf	Stem
1*	87.8 ± 32.0	88.0 ± 33.4
14	157.7 ± 40.0	156.2 ± 41.0
28	140.8 ± 37.2	140.9 ± 37.0
41	143.9 ± 29.0	143.3 ± 28.0

* First day, 5 August 1999

** Differences within columns not statistically significant

Leaf and stem Zn concentrations (mg/kg) DM was not significantly different in periods D1 ($P = 0.9293$), D2 ($P = 0.9924$), D3 ($P = 0.9895$) and D4 ($P = 0.9870$) for kikuyu foggage. The time effect over DATE_1 ($P = 0.8349$) and DATE_2 ($P = 0.1556$) was not significant but the time effect over DATE_3 ($P = 0.0060$) was significant for kikuyu foggage (the period DATE_1 to DATE_3 was explained in section 2.7)

3.4.13 MANGANESE (Mn)

Mean Mn concentration ranged from 121 mg/kg to 128 mg/kg DM in the leaves and from 122 mg/kg to 128 mg/kg DM in the stems of kikuyu foggage (Table 3.34). As with Zn, the only significant within season variation in kikuyu foggage occurred during day 37 and day 55 ($P \leq 0.0577$) (Figure 3.13). There was no significant variation between leaf and stem Mn concentrations in kikuyu foggage. Manganese values for phase 2 were from 217.8 to 274.1 mg/kg DM for the leaves and from 218.0 to 274.7 mg/kg DM for the stems of Smutsfinger hay (Table 3.35).

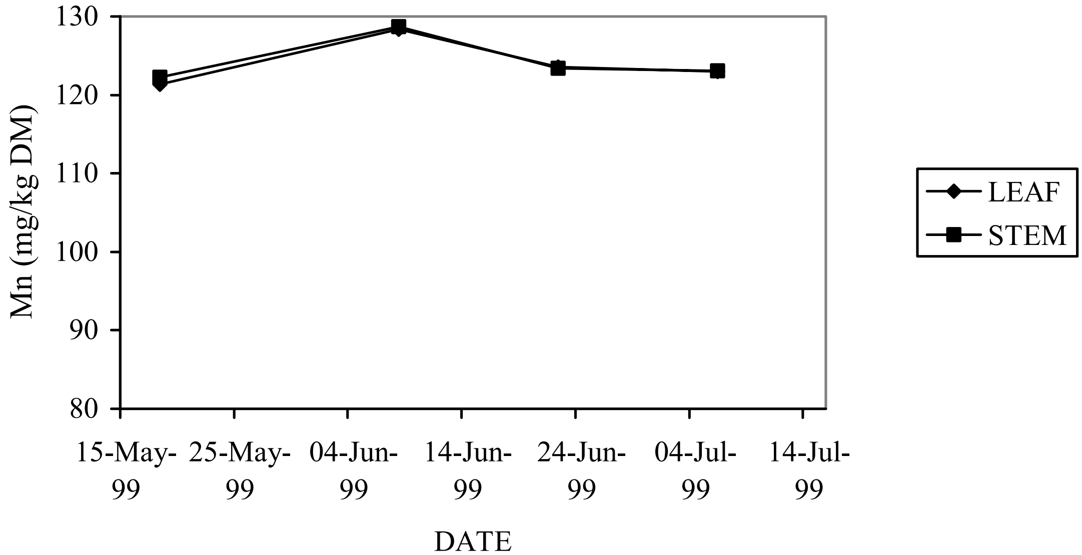


Figure 3.13 Within season variations in kikuyu stem and leave Mn concentration

Table 3.34 Kikuyu foggage Mn concentrations (± standard deviation) during winter (phase 1)

Day	Mn (mg/kg DM)		
	Leaf and stem***	Leaf	Stem
1*	121.6	121.4 ± 62.59	122.2 ± 62.79
17	128.5	128.4 ± 57.28	128.7 ± 56.78
37	123.5	123.6 ± 43.20	123.4 ± 43.69
55	123.0	123.0 ± 45.82	123.1 ± 45.65

* First day, 15 May 1999; ** Differences within columns not statistically significant;

*** Calculated from leaf : stem ratio and average Mn concentration in the leaves and stems

Table 3.35 Manganese concentrations (± standard deviation) of Smutsfinger hay (phase 2)

Day	Mn (mg/kg DM)	
	Leaf	Stem
1*	274.1 ± 45.3	274.7 ± 43.2
14	253.9 ± 46.2	251.5 ± 45.4
28	217.8 ± 43.2	218.0 ± 42.3
41	226.4 ± 44.5	225.5 ± 51.0

*   First day, 5 August 1999

** Differences within columns not statistically significant

Leaf and stem Mn concentrations (mg/kg) are not significantly different in periods D1 (P = 0.9838), D2 (P = 0.9938), D3 (P = 0.9941) or D4 (P = 0.9949) for kikuyu foggage. The time effect over DATE_1 (P = 0.7513) and DATE_2 (P = 0.7575) was not significant but the time effect over DATE_3 (P = 0.0577) was significant for kikuyu foggage (the period DATE_1 to DATE_3 was explained in section 2.7).

3.4.14 COPPER (Cu)

Mean Cu concentrations ranged from 6.39 mg/kg to 10.38 mg/kg DM in the leaves and from 6.41 mg/kg to 10.46 mg/kg DM in the stems of kikuyu foggage (Table 3.36). There was no significant variation between kikuyu leaf and stem Cu concentrations. The only significant within season variation for kikuyu foggage occurred during day one and 17 ($P \leq 0.0121$) (Figure 3.14). Copper values for phase 2 were the same for leaves and stems of Smutsfinger hay (Table 3.37).

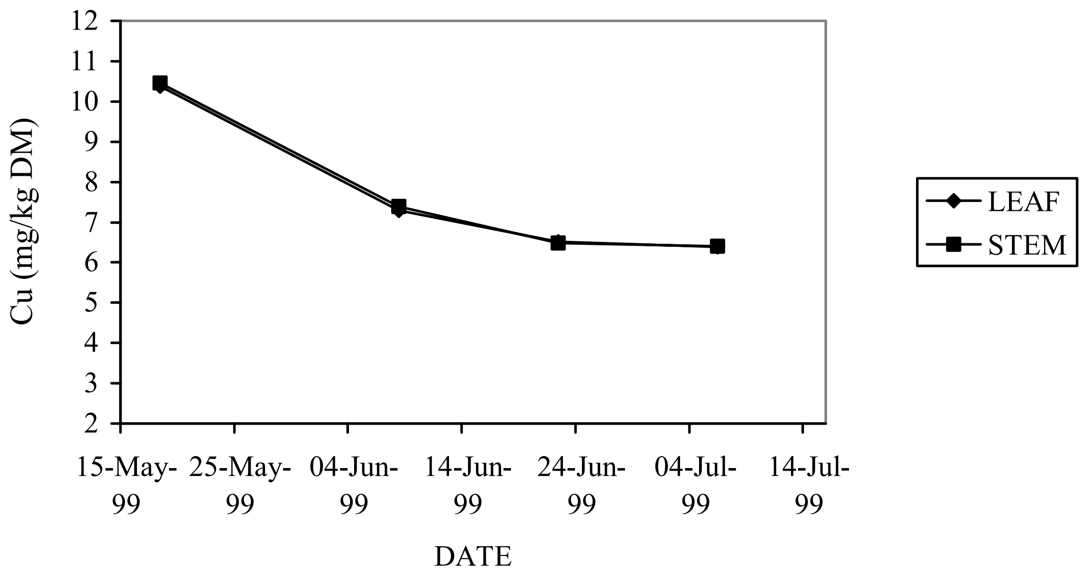


Figure 3.14 Within season variations in kikuyu stem and leave Cu concentration

Table 3.36 Kikuyu foggage Cu concentrations (± standard deviation) during winter (phase 1)

Day	Cu (mg/kg DM)		
	Leaf and stem***	Leaf	Stem
1*	10.5	10.4 ± 0.10	10.5 ± 0.09
17	7.4	7.4 ± 2.90	7.4 ± 2.94
37	6.5	6.5 ± 2.30	6.5 ± 2.36
55	6.4	6.4 ± 2.38	6.4 ± 2.40

* First day, 15 May 1999

** Differences within columns not statistically significant

*** Calculated from leaf : stem ratio and average Cu concentrations in the leaves and stems

Table 3.37 Copper concentration (± standard deviation) of Smutsvinger hay (phase 2)

Day	Cu (mg/kg DM)	
	Leaf	Stem
1*	5.3 ± 2.4	5.3 ± 2.4
14	5.3 ± 2.4	5.3 ± 2.4
28	5.3 ± 2.4	5.3 ± 2.4
41	5.3 ± 2.4	5.3 ± 2.4

* First day, 5 August 1999

** Differences within columns not statistically significant

Leaf and stem Cu concentrations (mg/kg) in kikuyu foggage were not significantly different in periods D1 (P = 0.2346), D2 (P = 0.9842), D3 (P = 0.9887) or D4 (P = 0.9906). The time effect over DATE_1 (P = 0.0121) was significant for kikuyu foggage but not the time effect over DATE_2 (P = 0.5542) and DATE_3 (P = 0.9344) (the period DATE_1 to DATE_3 was explained in section 2.7).

3.4.15 SELENIUM (Se)

Mean foggage Se concentrations ranged from 21 ng/g to 30 ng/g DM in the leaves and from 21 ng/g to 31 ng/g DM in the stems of kikuyu foggage (Table 3.38). There was no significant variation between leaf and stem Se concentrations in kikuyu foggage. The only significant within season variation for kikuyu foggage occurred during day 17 and 55 (P ≤ 0.0306) (Figure 3.15). Selenium values for phase 2 were almost the same for leaves and stems of Smutsfinger hay (Table 3.39).

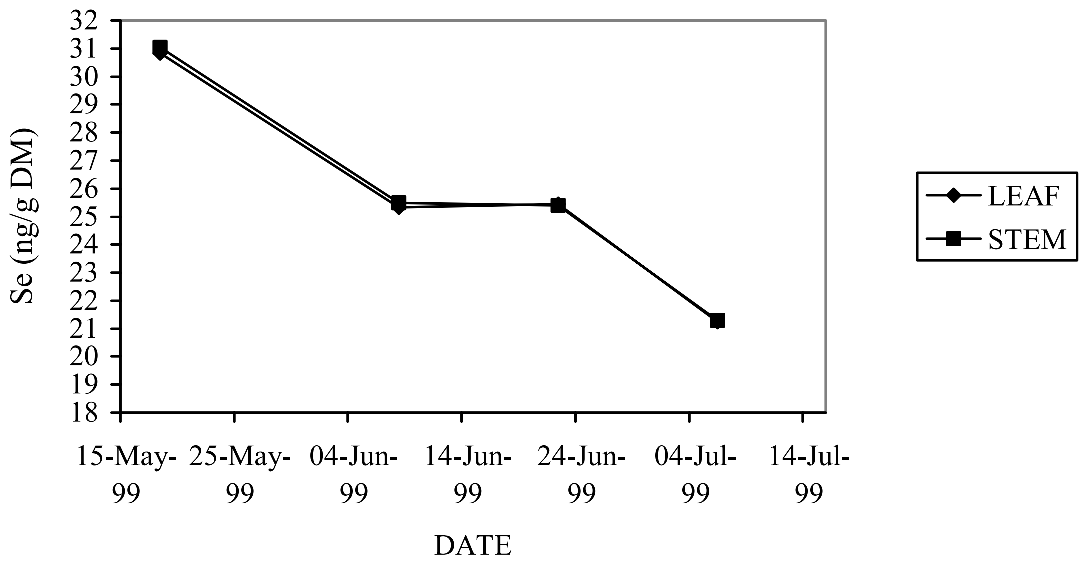


Figure 3.15 Within season variations in kikuyu stem and leave Se concentration

Table 3.38 Kikuyu foggage Se concentrations (± standard deviation) during winter (phase 1)

Day	Se (ng/g DM)		
	Leaf and stem***	Leaf	Stem
1*	30.9	30.8 ± 16.8	31.0 ± 16.9
17	25.4	25.3 ± 13.2	25.5 ± 13.4
37	25.5	25.5 ± 7.8	25.4 ± 7.8
55	21.3	21.3 ± 4.6	21.3 ± 4.5

* First day, 15 May 1999

** Differences within columns not statistically significant

*** Calculated from leaf : stem ratio and average Se concentrations in the leaves and stems

Table 3.39 Selenium concentration (± standard deviation) of Smutsfinger hay (phase 2)

Day	Se (ng/g DM)	
	Leaf	Stem
1*	15.8 ± 5.6	15.8 ± 5.6
14	20.2 ± 7.4	20.0 ± 7.4
28	20.9 ± 7.4	20.9 ± 7.4
41	20.5 ± 7.4	20.4 ± 7.4

* First day, 5 August 1999

** Differences within columns not statistically significant

Leaf and stem Se concentrations (ng/g) were not significantly different in kikuyu foggage for periods D1 ($P = 0.9843$), D2 ($P = 0.9861$), D3 ($P = 0.9912$) or D4 ($P = 0.9863$). The time effect over DATE_1 ($P = 0.5498$) and DATE_2 ($P = 0.9981$) for kikuyu foggage was not significant but the time effect over DATE_3 ($P = 0.0306$) was significant (the period DATE_1 to DATE_3 was explained in section 2.7).

3.5 KIKUYU *IN SITU* DM DEGRADABILITY

Dry matter degradability results are presented in Table 3.40 and illustrated in Figure 3.16, 3.17, 3.18, 3.19 and 3.20. The data for period 1, camp 1 was left out, as results were inconsistent. The DM degradability decreased marginally significantly between period 1 and 2 ($P < 0.10$). The DM degradability decreased as winter progressed and plants mature. The average DM degradability over time were 65.77% (18-05-99), 54.53% (08-06-99), 54.99% (22-06-99) and 54.99% (06-07-99). The average DM degradability in the different camps over time were 52.45% (camp 1), 63.72% (camp 2), 48.22% (camp 3), 62.56% (camp 4) and 62.36% (camp 5).

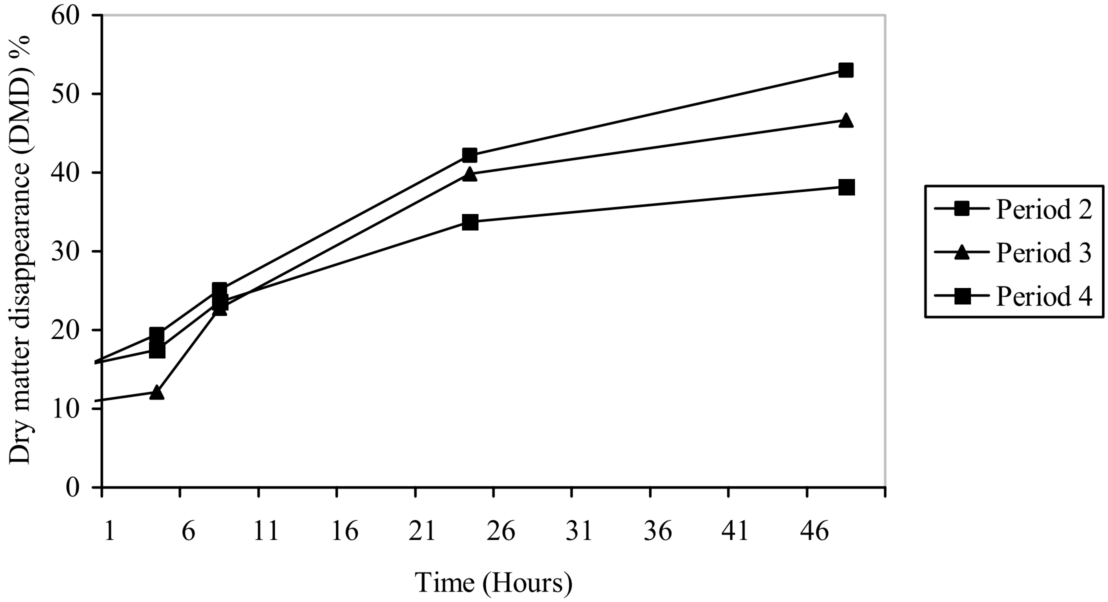


Figure 3.16 Disappearance of DM for kikuyu in camp 1 as winter progressed

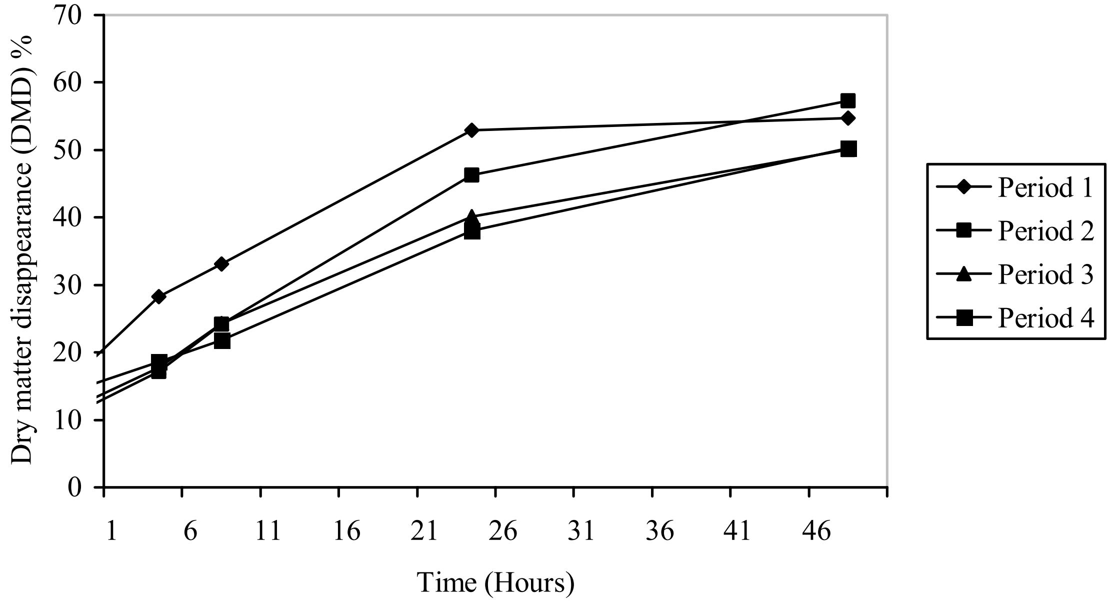


Figure 3.17 Disappearance of DM for kikuyu in camp 2 as winter progressed

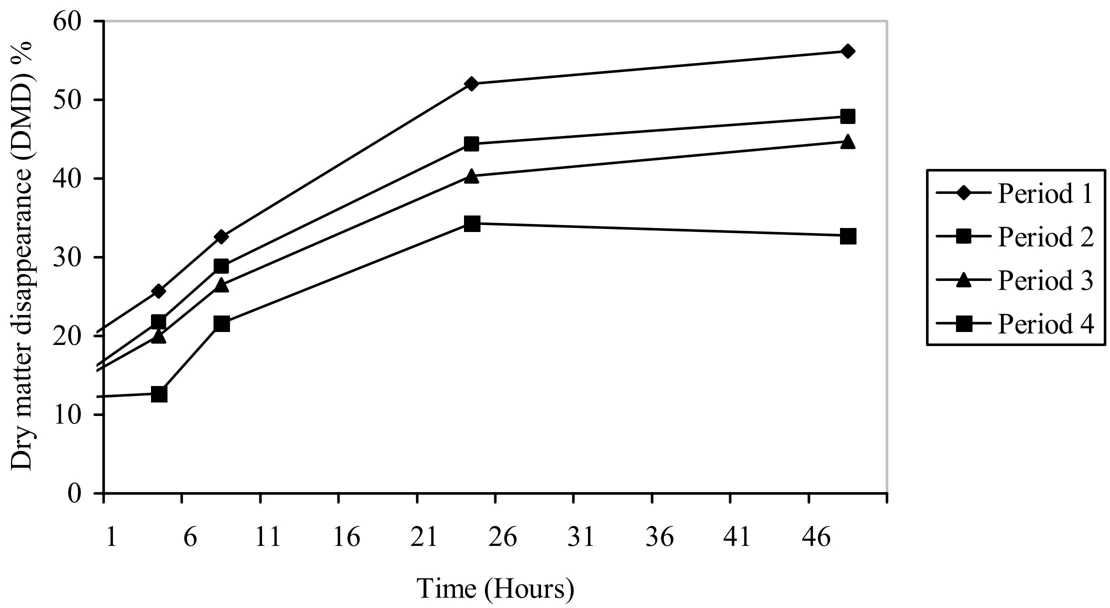


Figure 3.18 Disappearance of DM for kikuyu in camp 3 as winter progressed

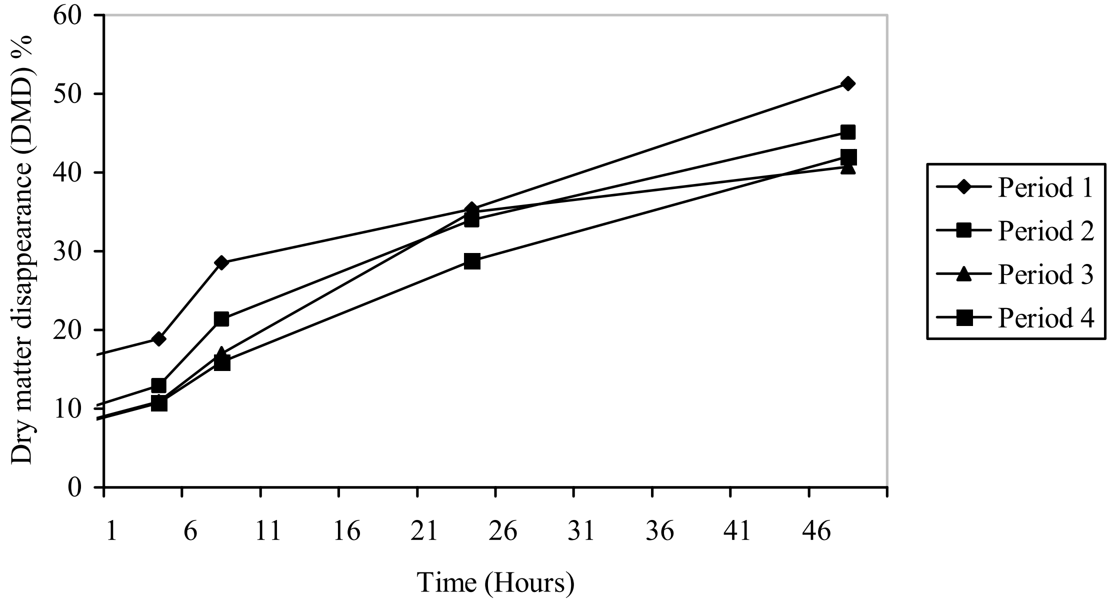


Figure 3.19 Disappearance of DM for kikuyu in camp 4 as winter progressed

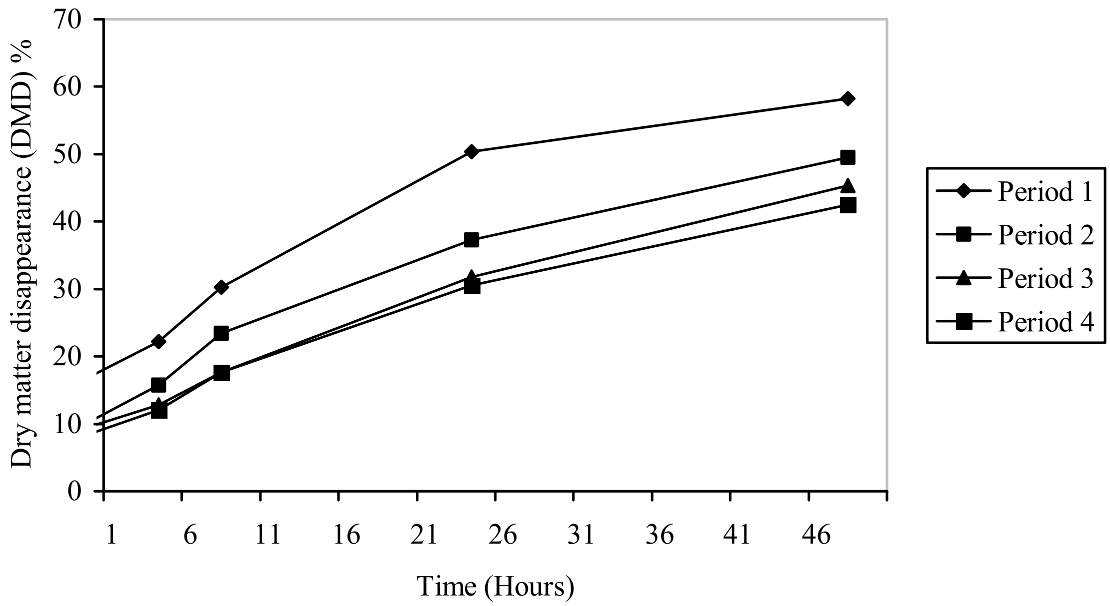


Figure 3.20 Disappearance of DM for kikuyu in camp 5 as winter progressed

Table 3.40 *In situ* DM degradation characteristics of kikuyu in different camps and periods

Camp	Period[5]	$a^1 \pm$ SE (%)	$b^2 \pm$ SE (%)	$c^3 \pm$ SE	Potential Degradability (PD)[4]	Effective Degradability (%) (ED)	P
1	2	14.7 ± 1.30	49.5 ± 6.17	0.031 ± 0.008	64.19	40.14	0.0047
1	3	8.6 ± 3.12	43.4 ± 7.27	0.047 ± 0.021	52.06	35.13	0.0245
1	4	14.7 ± 1.47	26.4 ± 3.25	0.049 ± 0.012	41.11	31.05	0.0144
2	1	18.7 ± 2.46	38.6 ± 3.66	0.070 ± 0.019	57.32	45.79	0.0151
2	2	10.9 ± 1.99	56.4 ± 6.80	0.038 ± 0.011	67.25	42.24	0.0073
2	3	12.6 ± 0.97	45.2 ± 3.30	0.038 ± 0.007	57.75	37.72	0.0027
2	4	14.5 ± 1.22	58.1 ± 14.6	0.020 ± 0.008	72.56	37.91	0.0051
3	1	18.9 ± 2.35	41.1 ± 4.23	0.057 ± 0.017	59.99	45.81	0.0137
3	2	15.2 ± 1.60	35.1 ± 2.53	0.065 ± 0.014	50.27	39.14	0.0081
3	3	14.6 ± 1.32	32.7 ± 2.32	0.058 ± 0.012	47.27	36.12	0.0068
3	4	10.0 ± 3.77	25.3 ± 5.42	0.074 ± 0.046	35.35	28.07	0.0753
4	1	17.2 ± 2.70	64.7 ± 57.2	0.015 ± 0.020	81.84	39.07	0.0288
4	2	9.5 ± 1.65	44.6 ± 7.11	0.033 ± 0.012	54.13	32.99	0.0089
4	3	5.9 ± 4.39	39.8 ± 8.48	0.054 ± 0.033	45.74	31.46	0.0510
4	4	7.8 ± 0.84	60.7 ± 13.90	0.017 ± 0.006	68.52	30.05	0.0028
5	1	15.9 ± 2.07	48.0 ± 4.76	0.047 ± 0.013	63.92	45.29	0.0089
5	2	10.6 ± 1.00	47.7 ± 3.92	0.035 ± 0.007	58.23	36.27	0.0028
5	3	9.2 ± 0.68	60.6 ± 9.30	0.019 ± 0.005	69.85	32.69	0.0016
5	4	8.3 ± 0.68	49.1 ± 5.30	0.025 ± 0.005	57.45	30.58	0.0017

[1] Rapidly soluble fraction (Intercept), [2] Insoluble but fermentable fraction in time, [3] Degradation rate constant of the b^2 fraction, [4] PD – extend of degradation (a + b),

[5] Period 1 (18-05-99)

Period 2 (08-06-99)

Period 3 (22-06-99)

Period 4 (06-07-99)

CHAPTER FOUR

DISCUSSION

The primary objective of this study was to investigate the response of beef weaners overwintering on kikuyu foggage to different levels of P supplementation. This extended into an investigation on the effect of P supplementation on weight changes in the weaners consuming Smutsvinger hay during the transition stage from winter to summer. Simultaneously, chemical analyses were carried out on the leaves and stems of the kikuyu foggage to obtain detailed information on the macro nutrient and mineral composition of the foggage as winter progressed, to get an indication of any shortages of nutrients in kikuyu foggage that could limit animal performance during winter.

The following results were obtained from which some conclusions could be drawn: In all the experimental groups serum Pi levels of sampled animals remained above 1.29 mmol/L throughout the trial. This suggested that the P intakes of the weaners were adequate in all treatments. This is supported during phase 1 by the fact that the P concentrations in the kikuyu foggage were above minimum animal requirements (> 1.2 g/kg) for growing steers. However, during phase 2 the P concentration in Smutsfinger hay was well below the minimum requirements for weaners. The general trend during phase 1 of the trial was that the serum Pi levels of the weaners increased. However, during phase 2, serum Pi levels dropped more in the animals in group 1 (8 g P/day) than in those in group 5 (0 g P/day)(Table 3.10). This could be because of low levels of dietary N that will increase Pi (Ternouth, 2001). The weaners in group 1 (8 g P/day) gained an average of 8 kg LW during the trial while the control group receiving no supplemental P, gained an average only 2 kg LW (Table 3.9). During the entire trial the average weight gain was the highest in the group receiving 8 g P supplement/day

It is concluded that 8 g P/supplement/day resulted in the highest weight gains during most of the winter, provided that dietary energy and protein are not the first limiting nutrients. In terms of animal requirements, the chemical composition of the kikuyu foggage indicated that CP, Na, Cu, Se and stem Ca:P could be limiting factors in maintaining beef cattle during winter on kikuyu foggage.

4.1 PHOSPHORUS SUPPLEMENTATION DURING WINTER

Controversy still surrounds the supplementation of P to beef cattle during the winter months in KwaZulu-Natal. Phosphorus licks are not very palatable and intakes during the summer months was not enough to counterbalance the deficiencies which occur during the winter period. A limited period of deficiency occurs normally during the dry period when the standard practice was not to supplement P. Consequently continuing and large negative P balances may eventually result in the more serious depletion of bone and soft tissue reserves of the animal - a P deficiency status (Read *et al.,* 1986b,c; Shupe *et al.,* 1988; Ternouth & Sevilla, 1990a; Blair-West *et al.,* 1992). This supports the argument of winter P supplementation. Therefore, protein-energy licks containing phosphorus or different levels of phosphorus (monocalcium phosphate) were given to crossbred beef weaners grazing kikuyu foggage during May to July.

A comparison of the effect of offering growing steers diets with low levels of P and/or N found that the low-N and low-P+N diets resulted in immediate decreases in food intake, but the low-P alone diet reduce intake after a period of seven weeks (Bortolussi *et al*., 1996). A similar slow onset of the effects of a low P diet has been observed in sheep by Field *et al.* (1975), Ternouth & Sevilla (1990a) and Ternouth & Budhi (1996). In our study, we extended the study period with phase 2 (August to September) of the trial on Smutsfinger hay, to get a good indication of the impact of different levels of phosphorus supplementation on the transition of animals from the winter to summer period and the impact on economical factors such as weight gain or loss.

Miles *et al.* (1995) reported kikuyu to be a most unusual forage since it contains more P than Ca. The study of Miles *et al*. (1995), however, was done on green kikuyu. However, in a previous (July 1997) test kikuyu foggage on our research site at Dundee, showed higher Ca than P concentrations in kikuyu. This 1997 analysis gave an indication of Ca and P concentrations in kikuyu foggage with ratios that were not less than 1:1. However, they did not indicate if the values were adequate and available for animal production over the period May to July. No further information on kikuyu foggage Ca and P concentrations during the period May to July could be found in the literature. McDowell (1996) reported that for grazing livestock, P is the mineral most likely to be deficient, but empasized that mineral supplementation is less important for cattle if energy and protein intakes are adequate. As productivity of animals increases there is an increase in the relative requirements of Ca and P but it is noteworthy that proportionately, the increased requirements are usually higher for P than for Ca (AFRC, 1991). In the 1997 test at Dundee the kikuyu foggage sample contained more Ca than P. This prompted the present investigation to supplement P during winter to beef weaner grazing kikuyu foggage.

Regardless of whether animals are grazing or are fed indoors, the need and quantity of P to be supplemented would depend on the P content of the basal diet. Phosphorus concentration of pastures varies with plant maturity and the ability of the plants to extract P from the soil. In this study, the P concentration did not vary significantly ($P < 0.05$) over time in the stems or leaves of the kikuyu foggage, but the rumen degradability of DM decreased over time. In low quality diets the P requirements slightly exceed the Ca requirements for most classes of sheep and cattle (AFRC, 1992). For highly digestible diets, requirements are generally reduced but for less digestible diets there are increases, particularly in early growth and lactation (AFRC, 1992). Therefore, although P concentrations did not vary significantly with time, P availability to the animal may decrease during winter. Substantial funds have been expended in Australia on soil mapping exercises, which included definition of the areas where soil P is low. This has lead to recommendations for the supply of P supplements (Ternouth, 2001). Such recommendations aim to take into account both the P and N intake of the animals, in particularly to the dry season, especially in areas where there are no legumes (Winter *et al.*, 1990). However, these Australian conclusions are clearly at variance with the results of De Waal *et al.* (1996). In their experiment they found that breeder cows were 33 kg heavier and had 20% higher weaning rates when supplemented for 12 months of the year as compared with those supplemented for only 6 months. In a recent paper on the supplementation of breeder cow throughout the year, it was concluded that breeder cows require a supplement of 9 g P/day throughout the year (De Brouwer *et al*., 2000). This amount represents almost the complete P requirement of such cows (Call *et al.,* 1986). In the present study steers which received 8 g P/day gained more weight (8 kg LW) than steers which received P supplement at 6, 4, 2 or 0 g P/day, with the steers receiving 0 g P/day, gained the least (2 kg LW).

Lochner (1999) found that a phosphate deficiency during the winter could not in most cases be compensated for in summer licks because of inadequate phosphate intakes during the summer. Table 4.1 describes the phosphorus balance of grazing cattle during winter and summer. The following results were obtained by O'Donovan (personal communication) in a trial from 1989 to 1992 on the same farm and kikuyu grazing where our study was done (Eversly research farm of

Stockowners). According to their results it is very important to supplement phosphorus during winter and summer.

It has been found that low dietary P is associated with reduced microbial protein flow into the small intestine (Petri *et al.*, 1988), even when food intake was not reduced (Gunn & Ternouth, 1994a,b). This suggests that the long term effects of digesting low P diets may be similar to the effects of low nitrogen (N) diets.

Unlike the measurement of the energy requirements of animals, there is a substantial difference between the apparent and true absorption of P, and there is not a predictable relationship between the two. The feeding of these low levels of P resulted in an appreciation that when endogenous faecal P was minimal, the absorption of dietary P would be maximal (Ternouth, 1989; Ternouth & Sevilla, 1990a; Coates & Ternouth, 1992).

Table 4.1 Phosphorus balance of grazing cattle

	Winter	**Summer**
P-requirement, NRC, 1984 (g/animal/day)	16	23
P-content of pastures(%)	0.06	0.11
Foggage intake (% of bodymass)	2.0	2.5
Foggage intake (kg/day)	9.0	11.3
P-intake from foggage (g/day)	5.4	12.4
P-shortage relative to requirement (g/day)	10.6	10.6

From Lochner (1999)

Adequate P supplementation will guarantee performance and profitability throughout the year (Lochner, 1999). According to our results, if little or no gain is expected from weaners in winter, the Ca and P concentrations in kikuyu foggage should be adequate. However, if even slight weight gains were required, supplementation of Ca and P would be necessary when the foggage is dry.

According to Lochner (1999) cattle receiving phosphorus supplementation during the dry period will perform better in the following months. In our study phosphate supplementation had definite advantages since animals from group 1 (8 g P/day) lost less weight during our transitional phase (phase 2) than animals from group 5 (0 g P/day) (Table 3.9). Meaker & Coetzee (1978) extended their trial 4 months after the winter phase where all animals received phosphorus supplementation. They found that cattle that received phosphorus during the winter phase could gain the 11.9 kg weight loss in one month after winter, where cattle that received no supplementation during winter could not gain the winter weight loss and even showed a further weight loss of 1.4 kg. It was also found that even after four months the animals receiving no winter phosphate supplementation showed not enough compensatory weight gain to equal weights of animals that received winter P supplementation.

The provision of a diet to sheep with a high level of Ca and a low level of P resulted in a more rapid decrease in the food intake and plasma inorganic P (Pi) than when the Ca level was normal (Field *et al.,* 1975; Ternouth & Sevilla, 1990a). When the level of dietary P was extremely low but Ca was high, P absorption was reduced (Schneider *et al.,* 1985). Subsequent research with the same sheep has shown that repletion with Ca but not P resulted in a further decrease in serum Pi and food intake (Ternouth & Sevilla, 1990b). Thus, extreme Ca:P ratios resulted in an exacerbation of the P deficiency. This result has implications for industry as the provision of P without adequate Ca in a repletion diet is likely to be unsuccessful (Ternouth, 2001). In the present study not only P but also Ca was supplemented at a fixed rate of 25 g/kg. The reason was that if little or no gain was expected from weaners on the kikuyu foggage at Eversly Research Station in the winter, Ca and P concentrations in the foggage should be adequate. However, if even slight weight gains were required, supplementation of Ca and P would be necessary when the foggage is dry.

Ternouth (2001) reported that when serum Pi is > 1.94 mmol/L there is a substantial increase in urinary losses of P. Serum Pi levels represents, in a small labile pool, the balance between the absorption/reabsorption and deposition/excretion of the mineral (Ternouth, 2001). Generally, serum Pi levels reflect dietary P levels so that levels below 1.29 mmol/L or 0.65 mmol/L are said to be indicative of an inadequate dietary P (Ternouth, 2001). The differences in the proposed level of deficiency may be because (Ternouth, 2001):

- Animal house research has shown that high dietary Ca may reduce serum Pi;

- Other animal house research has shown that high levels of dietary N will reduce serum Pi whilst low levels of dietary N will increase Pi;
- Stress, dehydration and not eating will increase Pi;
- Coccygeal blood will be higher in serum Pi than jugular blood, although the difference is likely to be in the order of 0.097 mmol/L.

Despite these limitations, serum Pi remains the most useful although somewhat imprecise indicator of a dietary P deficiency. In production terms, it is suggested that Pi levels below 1.29 mmol/L are indicative that cattle are likely to be suffering from reduced food intake. Both Ternouth & Sevilla (1990a) and Bortolussi *et al.* (1996) have reported a direct linear relationship between serum Pi and dry matter intake in sheep and cattle being depleted of P. In this study plasma inorganic P was not below 1.94 mmol/L, even in the control group.

Serum Pi levels of sample animals remained between 1.94 and 2.58 mmol/L (Appendix 1 and 2). The average trend during phase 1 of the trial was that average serum Pi level increased. During phase 2, however, serum Pi levels dropped more in the animals of group 1 (8 g P/day) than in those of group 5 (0 g P/day)(Table 3.10). The decrease in Pi levels during phase 2 could be due to the extremely low (between 0.3 and 1.0 g P/kg DM) concentration of P in the Smutsfinger hay while that of kikuyu foggage was between 1.8 and 2.4 g/kg DM. Considering minimal requirements of an animal, P concentrations in kikuyu foggage were adequate but not in Smutsfinger hay (Table 4.3). The Ca concentrations in the leaves of the Smutsfinger hay were higher (3.5 g/kg DM) than in kikuyu foggage leaves (3.1 to 3.9 g/kg DM). Therefore there were an average gain (0.12 mmol/L) in the group 5 (0 g P/day) sample animals and an average drop (0.07 mmol/L) in the group1 (8 g P/day) sample animals of Pi levels during the trial (phase 1 and phase 2)(Table 3.9).

In this study the average weight gain during phase 1 of the trial was higher (9.135 kg LW) for group 1 that received 8 g P/day/animal in comparison with the control group, which received 0 g P/day/animal (7.25 kg LW)(Table 3.9). Phase 2 represented a transition from winter to summer and clearly showed that group 1 (8 g P/day/animal) had a average weight loss of 0.880 kg/animal but the control group (0 g P/day/animal) lost a average of 5.125 kg/animal. Therefore we concluded that phosphorus supplementation during winter (phase 1) and during the transition from winter to summer (phase 2) had definite economical advantages.

Simulation of dry season conditions for growing cattle by Van Niekerk & Jacobs (1985) and Bortolussi *et al.* (1996; 1999) have shown that the effects of low dietary P is likely to be secondary to low dietary N. In our study we found that CP concentrations decreased with time to reach levels of < 60 g/kg DM in the dry foggage, indicating that supplementation of CP would be required by animals grazing the kikuyu foggage in mid-winter. Therefore we supplemented 350 g CP/kg (as fed basis) in all the licks. No positive effect of P supplementation could be expected when CP concentrations are below 70 g/kg DM (Bortolussi *et al.*, 1996). However, there are known to be interactions between dietary N and P. Bortolussi *et al.* (1996) have shown that cattle offered diets with higher levels of P not only have higher food intakes but their plasma urea N levels were low. This is again indicative that there are significant changes in either the metabolism of ruminal microbes or the intermediary metabolism of the animal offered a low P diet.

In conclusion, P supplementation at a rate of 8 g P/animal/day is recommended for steers during winter for weight gain if protein, energy and other minerals are not limiting factors.

4.2 KIKUYU AS FOGGAGE

Kikuyu grazing has its limitations in terms of mineral composition, which need to be addressed in any feeding program utilizing kikuyu. However, these can easily be addressed at no great cost to the producer. Reservations regarding the adequacy of minerals in kikuyu in terms of the dietary requirements of grazing animals have over the years been expressed by both local and overseas researchers (Miles *et al.,* 1995). The focus in terms of macromineral composition of kikuyu was mostly on summer and autumn pastures. Here we would like to focus more on kikuyu as foggage and we are looking at stems and leaves separately in terms of their mineral composition to compare the values against minimal animal requirements for specific minerals.

As plants mature, mineral content declines due to a natural dilution process and translocation of nutrients to the root system. In most circumstances, Cu, Co, Fe, Se, Zn, and Mo concentrations decline as the plant matures (Reid & Horvath, 1980). Cattle on pastures can receive a certain proportion of their required minerals from water and soil ingestion. However, forages would be the main dietary source of minerals. Of the mineral elements in soil, only a fraction is taken up by plants (Reid & Hovath, 1980).

However, Zimmer (2000) reported that trace element fertilization is quite effective in elevating mineral concentrations in crops. Soil chemistry is complex. An excess of one element can cause a deficiency of another (Zimmer, 2000). The other factor that influences nutrient availability and interactions is the soil's pH, or acidity and alkalinity. The availability of many elements to the plant can reduce or increase at a low or high soil pH. That is partly why the "ideal" pH range is usually given as slightly acid, approximately from 6.0 to 6.8 (Zimmer, 2000).
Some nutrient interactions and effects on crops include (Zimmer, 2000):

- Excessive nitrogen makes poor quality feed (nitrates).
- Excessive nitrogen (ammonia) can "burn up" humus.
- Excessive nitrogen can cause a K deficiency.
- Excessive magnesium can cause a K, P and nitrogen deficiency.
- Excessive K, Na and Mg can cause a Ca deficiency.
- Excessive Ca can cause P and trace element deficiencies.
- Excessive Mn can cause effects similar to Fe deficiency.
- Excessive boron can cause signs of K and Mg deficiency.
- Excessive Na and/or Cl can cause signs of K deficiency.

However, trace mineral deficiencies in grass, in particular Cu, Co, Se, Mn and I, are becoming more common as increased non-trace element fertilizer (N, P, K) usage results in increasing amounts of grass being produced per hectare (McDowell, 1996). Poor drainage conditions often increase extractable trace elements (e.g. Mn and Co), thereby resulting in a corresponding increase in plant uptake. Almost all soils that produce plants containing sufficient Mo to cause molybdenosis in animals are poorly drained. Overliming can accentuate a Se or Mo toxicity in livestock by increasing plant concentrations of these elements and at the same time favouring Co and Mn deficiencies due to lowered plant uptake (McDowell, 1996). Therefore more attention needs to be given to soil trace element fertilization.

In the following paragraphs a detailed discussion of the trace mineral status of the kikuyu in our study area are given (Table 4.2, 4.3, 4.4) and the mineral status of kikuyu foggage are compared with mineral requirements and toxicity for ruminants (Table 4.5). Compared to minimum mineral requirements for growing beef cattle, the kikuyu foggage in the present study seems to be deficient in Na (0.2 g/kg DM), Cu (6.4 to 10.4 g/kg DM) and Se (0.0213 to 0.308 µg/kg DM).

Table 4.6 gives an indication as to how our results on chemical composition of kikuyu during the winter months compare with other chemical composition results during summer months. The results of this study were compared with summer pastures because no information of chemical compositions of winter foggage and especially leaf and stem analysis could be found.

Our P values are much lower that the P values of Dugmore (1998) and Miles *et al.* (1995) because of the significant decrease in P% over time. Therefore we can speculate as to whether the P concentrations in the kikuyu analysed by Dugmore (1998) and Miles *et al.* (1995) would have decreased during the period May to July.

The prohibitively high K levels of the kikuyu foggage in this study are likely to induce Mg deficiencies in grazing ruminants. The inverse ratio of Ca:P for which green kikuyu are notorious are not the case in our study.

We found a higher K/(Ca+Mg) ratio than Dugmore (1998) and Miles *et al.* (1995). Therefore there might have been a greater potential for hypomagnesaemia during the winter months. These observations indicate that sufficient mineral supplementation to ruminants pastured on kikuyu is of cardinal importance in ensuring animal health and productivity, and that seasonal differences in the mineral supplementation program may occur. It is suggested that one should have a different mineral and protein supplementation program for kikuyu foggage and herbage during winter and during summer.

Table 4.2 Mean concentration (± s.d.) of crude protein (CP), acid detergent fibre (ADF) and neutral detergent fibre (NDF) in the kikuyu foggage during winter

	CP		NDF		ADF	
	G/kg DM					
DATE	Leaf	Stem	Leaf	Stem	Leaf	Stem
18-05-99	112 ± 16.0	98 ± 17.4	712 ± 29.0	688 ± 30.3	341 ± 11.6	329 ± 16.9
08-06-99	70 ± 17.3	64 ± 28.9	751 ± 15.7	724 ± 45.7	361± 5.2	370 ± 61.4
22-06-99	61 ± 13.6	59 ± 19.9	784 ± 22.9	758 ± 60.6	383 ± 29.4	371 ± 51.8
06-07-99	56 ± 9.8	52 ± 9.2	772 ± 6.3	767 ± 36.4	391 ± 13.7	391 ± 25.1

* Differences within within rows and elements not statistically significant

Table 4.3 Mean concentration (± s.d.) of macro elements in kikuyu foggage during winter

	Macro elements													
	P		Ca		Ca:P		Mg		K		K:Ca + Mg		Na	
	g/kg DM													
DATE	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
18-05-99	2.4^{a} ± 0.5	3.0^{a} ± 0.8	3.9^{a} ± 0.8	1.9^{b} ± 0.7	1.7^{a} ± 0.68	0.7^{b} ± 0.42	2.4^{a} ± 0.5	2.7^{a} ± 0.6	17.7^{a} ± 3.8	23.0^{a} ± 6.5	2.95^{c} ± 1.01	5.43^{d} ± 2.44	0.2^{a} ± 0.1	0.2^{a} ± 0.1
08-06-99	2.1^{a} ± 0.6	2.3^{a} ± 1.2	3.1^{c} ± 0.6	2.2^{d} ± 0.9	1.6^{a} ± 0.07	1.6^{a} ± 1.84	2.3^{a} ± 0.2	2.4^{a} ± 0.4	12.1^{a} ± 3.6	12.6^{a} ± 7.8	2.29^{a} ± 0.74	3.16^{a} ± 2.56	0.2^{a} ± 0.1	0.5^{a} ± 0.4
22-06-99	1.8^{a} ± 0.7	2.2^{a} ± 0.9	3.2^{a} ± 0.6	1.8^{b} ± 0.2	2.2^{a} ± 1.13	0.9^{b} ± 0.43	2.0^{a} ± 0.4	2.2^{a} ± 0.5	10.1^{a} ± 3.3	12.8^{a} ± 5.6	1.93^{c} ± 0.72	3.22^{d} ± 1.36	0.2^{a} ± 0.1	0.4^{a} ± 0.5
06-07-99	1.9^{a} ± 0.7	2.5^{a} ± 0.8	3.4^{a} ± 0.3	1.9^{b} ± 0.3	2.0^{a} ± 0.57	0.8^{b} ± 0.31	2.0^{a} ± 0.1	2.1^{a} ± 0.3	14.9^{a} ± 5.5	21.1^{a} ± 7.2	2.77^{a} ± 0.93	5.36^{b} ± 2.18	0.2^{a} ± 0.1	0.2^{a} ± 0.1

^{a,b} Means within rows and elements with different superscripts indicate differences between leaf and stem ($P < 0.05$)

^{c,d} Means within rows and elements with different superscripts indicate marginal differences between leaf and stem ($P < 0.1$)

Table 4.4 Mean concentration (± s.d.) of micro elements in kikuyu foggage during winter

	Micro elements							
	Zn		Mn		Cu		Se	
	Mg/kg DM						ng/g DM	
DATE	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
18-05-99	163.0 ± 21.35	164.2 ± 21.64	121.4 ± 62.59	122.2 ± 62.79	10.4 ± 0.10	10.5 ± 0.09	30.8 ± 16.8	31.0 ± 16.9
08-06-99	158.4 ± 60.09	158.8 ± 59.36	128.4 ± 57.28	128.7 ± 56.78	7.4 ± 2.90	7.4 ± 2.94	25.3 ± 13.2	25.5 ± 13.4
22-06-99	114.2 ± 32.11	113.9 ± 32 02	123.6 ± 43.20	123.4 ± 43.69	6.5 ± 2.39	6.5 ± 2.36	25.5 ± 7.8	25.4 ± 7.8
06-07-99	164.0 ± 37.46	164.4 ± 37.39	123.0 ± 45.82	123.1 ± 45.65	6.4 ± 2.38	6.4 ± 2.40	21.3 ± 4.5	21.3 ± 4.6

Differences within rows and elements not statistically significant

Table 4.5 Suggested mineral requirements for ruminants

Required Elements	Beef Cattle[a]		Lactating Dairy Cows[b]		Sheep[c]		Goats [d,f]	
	Growing Finishing	Early Lactation	Suggested Value	Range	Suggested Value	Range	Suggested Value	Range
Macroelements								
Calcium (g/kg)	1.90-7.30	2.20-3.80	--	4.30-7.70	--	2.00-8.20	--	--
Phosphorus (g/kg)	1.20-3.40	1.60-2.40	--	2.50-4.80	--	1.60-3.80	--	--
Magnesium (g/kg)	1.00	2.00	--	2.00-2.50	--	1.20-1.80	--	--
Potassium (g/kg)	6.00	7.00	--	9.00-10.0	--	5.00-8.00	--	5.00-8.00
Sodium (g/kg)	0.60-0.80	1.00	1.80	--	--	0.90-1.80	--	--
Microelements								
Copper (mg/kg)	10.0	10.0	10.0	--	--	7-11	--	--
Manganese (mg/kg)	20.0	40.0	40.0	--	--	20-40	>5.5	--
Selenium (mg/kg)	0.10	0.10	0.3	--	0.1-0.2	--	--	--
Zinc (mg/kg)	30.0	30.0	40.0	--	--	20-33	>10.0	--
Toxic elements[e]								
Copper (mg/kg)	100	100	80		8-25		?	
Selenium (mg/kg)	5	5	5		>2.0		?	
Zinc (mg/kg)	500	500	500		1000		1000	

The listing of a range recognizes that requirements for most minerals are affected by a variety of dietary and animal factors.

For some classes of animals, no suggested value is available or appropriate because of diverse physiological function.

[a]NRC (1996)

[b]NRC (1989)

[c]NRC (1985)

[d]NRC (1981)

[e]NRC (1980)

[f]Mineral requirements for goats have not been studied in detail. Lactating dairy goats have requirements similar to lactating dairy cattle. Other goats have mineral requirements more similar to sheep (Haenlein, 1980)

(McDowell, 1997)

Table 4.6 A comparison of the chemical composition of kikuyu in Natal

Mineral and Chemical Components	Green Dugmore (1998) (g/kg DM)	Green Miles *et al.*(1995) (g/kg DM)	Foggage Rautenbach (this trial) (g/kg DM)		
	October to May at Cedara	October to May at Cedara	May to July at Dundee		
		(Mean of 3 camps and seasons)	Leaf	Stem	Mean
Ca (g/kg)	2.40	2.80	3.40	1.90	2.70
P (g/kg)	3.30	3.40	2.00	2.50	2.30
K (g/kg)	3.60	36.5	13.7	17.4	15.6
Mg (g/kg)	3.00	3.00	2.20	2.40	2.30
Na (g/kg)	0.30	0.40	0.20	0.30	0.30
Ca:P	0.76	8.10	18.6	10.2	14.4
K/(Ca+Mg)	2.90	25.1	24.8	43.0	33.9
CP (g/kg)	200	-	74.6	68.1	71.4
ADF (g/kg)	350	-	369	365	367
NDF (g/kg)	650	-	755	735	745

4.2.1 GREEN:DRY and STEM:LEAF

Pasture management, forage yield and climate influence the species of forage predominating and also changing the leaf:stem ratio radically, thereby having a direct bearing on the mineral content of the sward. Barnes & Dempsey (1993) conducted grazing trials with sheep at Ermelo during the period 1986 – 1988 on well-established Kikuyu pasture. The results for the determinations of the proportions of leaf and stem indicated that there were no important changes in the quality of the foggage on offer in the paddocks which were stocked at successive times in the winter (Barnes & Dempsey, 1993). Marais (1990) reported as kikuyu matures the DM yield increases, but the leaf:stem ratio decreases, thereby probably reducing the nutritional value of the sward. In the study by Barnes & Dempsey (1993) the leaf to stem ratio ranged from 5.45 to 3.8 between the first and last collection. In the present study the leaf to stem ratio was from 1.83 to 1.33 between the first and last collection. The green to dry material ratio changed from 3.0 to 0.04 on a DM basis between the first and the last collection during phase 1 of the trial. The results for determinations of the proportions of leaf to stem indicated a much lower leaf to stem ratio in this study than in that of Barnes & Dempsey (1993). In both studies limestone ammonium nitrate (LAN) was applied during February (100 kg N/ha) and rested until late May, when foggage grazing began. But, in Barnes & Dempsey (1993) study single super-phosphate was broadcast at the rate of 40 kg P/ha at the start of each season and, as a precautionary measure prompted by the results of soil analysis, potassium chloride and calcitic limestone were broadcast at rates of 100 and 3000 kg/ha at the start of the season. According to Zimmer (2000) the yield of a crop depends on efficient crop growth, i.e. roots, stalks and leaves. But in order for the plant to produce as much as its genetic potential allows, the environmental conditions in which it grows should be optimal. If any environmental factor is not ideal, it becomes a limiting factor. In this study foggage leaf production and therefore foggage quality may have been limited due to limiting factors in the soil.

4.2.2 CALCIUM (Ca)

When the kikuyu Ca concentrations reported in this study are compared with animal requirements, it is evident that Ca was frequently deficient in terms of the requirements of lactating dairy cows, with kikuyu Ca concentrations just reaching the minimum requirement threshold for beef cattle and sheep (Table 4.3 and 4.5). Calcium concentrations were significantly ($P \leq 0.05$) higher in the leaf than stem of kikuyu which could have an influence on Ca intake of selective versus bulk grazers (Table 4.3). In the study of Miles *et al.* (1995) on macromineral levels in kikuyu grass at various times of the year, they focussed on the period October to May where their Ca concentrations in May were 3.30-3.80 g/kg compared to our 2.90 g/kg (3.90 g/kg leaf Ca to 1.9 g/kg stem Ca).

There were no significant increase or decrease in Ca concentration (leaf and stem) from May to July (Table 4.3). Calcium deficiencies in kikuyu pastures are aggravated not only by the fact that the bulk of pasture production is in the midsummer months when Ca levels are generally at their lowest, but also by the tendency for much of the Ca in kikuyu to form insoluble complexes with oxalate in which form Ca is essentially unavailable for absorption by animals (Miles *et al.,* 1995).

The effect of the nitrogen content of kikuyu grass on the oxalate and calcium content of leaf and stem material was investigated by Marais (1990). The grass contained equal portions of soluble and insoluble oxalate. According to Marais (1990) leaf material contains more than three times as much total oxalate than stem tissue. Therefore higher leaf calcium concentrations than stem concentrations do not mean more Ca available to the animal from leaves than stems. A high nitrogen content is associated with a high insoluble oxalate content of the sward (Marais, 1990). The calcium content of both leaf and stem material was extremely low. Results from Marais (1990) suggested that approximately 95% of the calcium could be bound as calcium oxalate and would probably not be available to ruminants. The bioavailability of calcium in the herbage decreases with an increase in nitrogen content of the grass (Marais, 1990). The nitrogen content of the kikuyu in this study is low (53.8-105.3 g/kg). Therefore the influence of nitrogen on the bioavailibility of Ca will not be considered very important.

4.2.3 PHOSPHORUS (P)

For grazing livestock, P is the mineral most likely to be deficient (McDowell, 1996). Kikuyu is highly responsive to applied P during its establishment phase of growth (Miles, 1998). This is particularly the case on virgin soils, where liberal additions of P promote rapid pasture establishment. However, once established, kikuyu is highly efficient in terms of its ability to utilize soil P reserves (Miles, 1998).

On clay soils, a P test of 10 mg/L is adequate for optimum growth, while on loam and sand the test value should be at least 18 mg/L (Miles, 1998). Concentrations of the P in the herbage are usually low in spring/early summer, and very high in January-February. A possible explanation for this is that the lower soil temperatures early in the season restrict root uptake of this nutrient. The practical implication of this finding is that where P is to be applied to established kikuyu pastures, the fertilizer should be topdressed in the late winter/early spring, rather than in mid- or late summer.

There are differences of opinion as to P requirements of beef cattle. Phosphorus requirements recommended by the NRC may be too high for grazing beef cattle. From Utah, no differences in average weight gains (0.45 kg per day), feed efficiency or appetite were observed between Hereford heifers fed for 2 years on a diet containing 1.40 g/kg P (66% of NRC recommendation) and comparable heifers receiving the same diet supplemented with monosodium phosphate to provide a total of 3.60 g/kg P (Call *et al.,* 1978). After eight months on a 0.90 g/kg P diet, however, some appetite reduction and decreased bone density were observed (Call *et al.,* 1978). On the contrary, studies from Florida demonstrated that 1.20-1.30 g P/kg was inadequate for growing Angus heifers in a 525-772 day experiment (Williams *et al.,* 1991a,b). Animals receiving the low P diet had lower gains (205 vs. 257 kg), exhibited pica and had bone demineralization (Williams *et al.,* 1991a,b). When phosphorus concentrations reported (2.00-2.70 g/kg P), are compared with animal requirements in Table 4.5 (1.70-15.3 g P/kg for beef cattle, 2.00-8.20 g P/kg for sheep and 5.30 g P/kg for dairy cows), it is evident that P concentrations were marginal for beef cattle and sheep but below minimum values for dairy cattle.

Mean foggage P concentrations ranged from 1.75 g/kg to 2.43 g/kg in the leaves and from 2.20 g/kg to 2.97 g/kg in the stems (Table 4.3). Significant ($P \leq 0.05$) within season variation in P concentrations occurred, the overriding trend being a maximum during May and decreasing towards July (Table 4.3). The July 1997 phosphorus values were between 1.60 g/kg and 2.80 g/kg for the whole plant and compare well with our values.

4.2.4 Ca:P

The tendency for an interaction between Ca and P, in terms of their absorption by animals, has led to emphasis on the ratio of Ca to P in feeds and forages. If little or no gain is expected from weaners in winter, the Ca and P concentrations in the foggage should be adequate. However, if even slight weight gains were required, supplementation of Ca and P would be necessary when the foggage is dry.

Miles *et al.* (1995) reported P concentrations in kikuyu in midsummer months adequate for ruminants but spring and autumn concentrations that were possibly marginal with respect to animal requirements (as was the case in the present study). The Ca:P ratio in feeds is frequently referred to in assessing the adequacy of these minerals for ruminants. It remains the view of many animal nutritionists that this ratio should not be below 1:1. According to Miles *et al.* (1995) kikuyu is a most unusual forage in this respect that it contains more P than Ca. In this study, however, this was not the case as all the mean (stem and leaf) values were above 1:1, except for the mean stem Ca:P ratios for the period 21.06.99 to 05.07.99 (Table 4.3).

According to Miles *et al.* (1995), Ca:P ratios were well below 1:1 over the December to the March peak growth period, and it is noteworthy that values as low as 0.41:1 to 0.5:1 occurred.

Therefore, although Ca:P ratios of below 1:1 occured during the growing season, we found that Ca:P ratios of above 1:1 occured during the winter period (because of very low P levels). As with the Miles *et al.* (1995) study, we found no significant seasonal variations in Ca:P ratio, although P concentrations decreased significantly (Table 4.3).

4.2.5 CRUDE PROTEIN

The composition of pasture DM is very variable; for example, the CP concentration may range from as little as 30 g/kg DM in very mature herbage to over 300 g/kg DM in young, heavily-fertilized grass (Dugmore, 1998). In this study (phase 1) CP content ranged from 56 g/kg to 112 g/kg DM in the leaves and from 52 g/kg to 98 g/kg DM in the stems. These CP values compared well with values obtained from a previous analysis on the study area during July 1997: 52 g/kg to 111.3 g/kg DM for the whole plant. The CP content of the Smutsfinger hay in phase 2 of this study was from 34.70 g/kg to 45.02 g/kg DM in the leaves and from 12.62 g/kg to 23.15 g/kg DM in the stems.

The CP concentration of old established kikuyu pasture at Cedara, fertilized with 210 kg N/ha split into three dressings over the season (herbage), range from 160 to 240 g/kg of the dry matter, with a CP degradability of 0.75 (herbage)(Dugmore, 1998). Van Ryssen *et al.* (1976) found CP concentrations of 233 g/kg during December, 222 g/kg during January and 147 g/kg during March on kikuyu pastures at Cedara over two seasons (herbage). According to Van der Merwe (1998) these levels are largely affected by the amount of nitrogen fertilizer applied. High CP concentrations (250 to 300 g/kg of herbage DM) are frequently recorded on highly nitrogen fertilized kikuyu pastures (herbage)(Van der Merwe, 1998). The fertilizer N requirements of kikuyu are related to environmental (moisture, length of growing season) conditions, and also to the level of production desired.

According to Miles (1998), for optimum production, annual N fertilizer requirements are in the range of 300 to 500 kg N/ha. In our study LAN application was 400 kg/ha (100 kg N/ha) after animal withdrawal in January 1999. The kikuyu pastures at Dundee in our study had CP values of 52.0 to 112.3 g/kg DM (foggage). According to Van der Merwe (1998) an interesting characteristic of kikuyu is that it has the ability to maintain its protein content, after nitrogen application, as the plant matures. In the present study however the CP concentrations decreased significantly during 18.05.99 to 08.06.99 ($P \leq 0.0055$) but not from 08.06.99 to 21.06.99 ($P \leq 0.059$) and 21.06.99 to 05.07.99 ($P > 0.2555$). Stems and leaves CP percentages did not vary significantly.

Dugmore *et al.* (1991) reported that the CP concentrations in the fistula-selected samples of steers grazing kikuyu were higher than the mean of the available herbage at low levels of herbage protein. In contrast, at high levels of herbage CP (>140 g/kg DM), the CP concentrations of the selected samples were lower than the mean of the herbage available.

Dugmore *et al.* (1986) indicated that CP levels in kikuyu were negatively related to the digestibility of CF, ADF and NDF fractions in the herbage. Therefore, as the CP levels increase, the decrease in the abovementioned fractions will reduce the digestible organic matter content of the kikuyu. In our study CP levels were not high. Therefore, reduction in digestible organic matter content would not apply. Crude protein is further subdivided into true protein and non-protein nitrogen. The non-protein nitrogen levels of kikuyu on Cedara are high and account for 20 to 30% of the CP (Brendon, 1980).

The non-protein nitrogen content increases during the growing season, with a peak concentration during autumn. According to Van der Merwe (1998), the nitrate concentration, which forms part of the non-protein nitrogen fraction, also reaches peak levels during autumn. Dugmore *et al.* (1986) indicated that kikuyu with CP levels of 200 g/kg or greater contain nitrate levels which are potentially toxic to livestock. Since we did not found CP levels higher than 120 g/kg, toxic nitrate levels may not be a problem in kikuyu foggage.

4.2.6 NEUTRAL DETERGENT FIBRE (NDF) & ACID DETERGENT FIBRE (ADF)

During phase 1 of this study the NDF, which consist mainly of lignin, cellulose and hemicellulose, and can be regarded as a measure of the plant cell wall material (McDonald *et al.*, 1988), ranged from 712 g/kg to 772 g/kg DM in the leaves and from 688 g/kg to 767 g/kg DM in the stems. The July 1997 values (on this study area) for the whole plant ranged from 699.4 g/kg to 793.5 g/kg DM. The Smutsfinger hay values were from 761.2 g/kg to 800.9 g/kg DM in the leaves and from 851.1 g/kg to 883.9 g/kg DM in the stems. The high fibre concentration of the kikuyu foggage is not unexpected, considering that the herbage was four to six months old, frosted and weathered during the winter. De Villiers *et al.* (2002) reported that NDF values of selected samples, although not significant, indicated that body weight losses will occur when the NDF concentration is above 810 g/kg DM. Meissner *et al.* (1991), however, concluded that the metabolisable energy intake on forages with NDF concentrations exceeding 550 g/kg DM may be insufficient to sustain satisfactory animal production. They attributed this to slow fermentation and long ruminal retention times. The question could be asked: What is "satisfactory animal performance", where, in the study of De Villiers *et al.* (2002) it was the sustaining of dry ewes to maintain their body weight or have a slight increase in weight? Cowan (2000) considered the high NDF concentrations (550 to 800 g/kg DM) of tropical grasses to be a major factor limiting production. In this study animals gained weight on kikuyu that had NDF concentrations of not more than 784 g/kg DM, whilst animals lost weight on Smutsfinger hay where NDF concentrations were above 810 g/kg DM.

The ADF represents essentially the crude lignin and cellulose fractions of plant material but also includes silica (McDonald *et al.*, 1988). The determination of ADF is particularly useful for forages as there is a good statistical correlation between it and digestibility. Dugmore *et al.* (1986) found a positive correlation between the fibre fraction in kikuyu and it's digestible organic matter content. Dugmore *et al.* (1991) found a similar trend where steers selected for higher ADF concentration than the average available in kikuyu pastures. De Villiers *et al.* (2002) found that in oesophageal selected samples the negative correlation between live weight change and ADF concentration (390 g/kg DM) was significant ($P < 0.05$). During phase 1 of this study the ADF ranged from 341 g/kg to 391 g/kg DM in the leaves and from 329 g/kg to 391 g/kg DM in the stems. The ADF values for July 1997 (on this study area) were from 375.1 g/kg to 464.7 g/kg DM. For phase 2 of the trial the values were from 486.8 g/kg to 511.7 g/kg DM for the leaves and from 554.6 g/kg to 602.9 g/kg DM for the stems.

The structural carbohydrate (fibre) fractions of old established kikuyu pastures at Cedara compromise approximately 350 ADF g/kg DM and 650 NDF g/kg DM (Dugmore, 1998).

The Cedara studies were done during the growing season. In this study, however, ADF concentrations of 328.5 to 391.0 g/kg DM and NDF concentrations of 688.5 to 784.4 g/kg DM were found, where stem and leaf concentrations did not vary significantly ($P \leq 0.05$). ADF concentrations did not vary significantly during sampling period, but NDF did vary significantly during the period 18.05.99 to 08.06.99 (P = 0.0208) and 08.06.99 (P = 0.0017), but not during the period 21.06.99 to 05.07.99 (P=0.8184). As herbage matures, the proportion of leaf to stem decreases. In this study we recorded a decrease in mean leaf:stem ratio of 1.83 on 18.05.99 to 1.40 on 05.07.99. This leaf:stem ratio decrease is associated with an increase in the structural cell wall constituents (NDF and ADF) and a decrease in the ratio of cell contents to cell wall constituents (Holmes & Wilson, 1984; Jones & Wilson, 1987). Plant cell walls, consisting mainly of structural carbohydrates such as cellulose and hemicellulose, form an important source of energy for the ruminant. The digestibility of these polysaccharides and the amount of energy provided to the animal depend largely on the degree of lignification of the tissue and the hemicellulose:cellulose ratio of the cell wall (McDonald *et.al.*, 1988).

A relatively small amount of lignin can render a large amount of cell wall carbohydrate indigestible. By screening kikuyu plants for a reduced lignin content it should be possible to improve the digestibility.

Dugmore (1998) reported very low non-structural carbohydrate in kikuyu, ranging from 300 to 800 g/kg of the DM. Good responses are therefore expected from supplementation with starch or other forms of highly available carbohydrate in the rumen. Kikuyu has relatively high ether extract (fat/oil) contents for a roughage at 28 g/kg of the DM (Dugmore, 1998). We recorded low fat content values of 10.6 to 15.1 g/kg on the Dundee kikuyu foggage during July 1997. The non-protein nitrogen content of kikuyu ranges from 200 to 300 g/kg of the CP fraction, not unusually high for high protein forage (Dugmore, 1998).

Metabolizable energy concentration (MJ ME/kg DM) of kikuyu at Cedara has been determined by *in vivo* digestion trials to be 9.3 MJ in the spring, 9.0 MJ in summer and 8.8 MJ in the autumn (Dugmore, 1998). On Cedara, these *in vivo* digestion trials have shown that high N levels in kikuyu have a negative impact on intake and digestibility, especially with very young material. Selection studies on kikuyu, using oesophageal fistulated steers, indicated that there was selection against high N (>150 g/kg CP) in the herbage.

4.2.7 MAGNESIUM (Mg)

The magnesium in fresh herbage is relatively unavailable to livestock (Miles *et al.,* 1995). In ruminants the major site of Mg absorption is the reticulo-rumen, while the large intestine may play a significant role in both the horse and ruminant. The absorption rate is relatively low, between 5 and 30%. Low absorption may be due to a number of factors:

- High K levels, particularly in young grass, greatly reduce the availability of Mg to animals because of a higher negative electrical potential in rumen fluid compared to blood.
- In the presence of high levels of ammonium ions and phosphate, an insoluble ammonium-phosphate-magnesium complex is formed which is almost unabsorbable.
- Phytic acid is known to interfere with magnesium availability.
- Low fibre content in ruminant feeds due to a rapid passage rate from the rumen.
- High rumen pH, mainly from feeds high in soluble protein.

These factors lead to the hypothesis that hypomagnesaemic tetany on lush pasture results from high levels of potassium and nitrogen fertilization. Because fibre content is low, the rapid passage of pasture material from the rumen will reduce the opportunity for effective Mg absorption (Miles *et al.*, 1995).

Endogenous Mg is excreted in the faeces and Mg in excess of requirements is excreted primarily via the urine. If Mg is in excess the excretion of calcium in the urine is increased and if calcium intake is high, Mg excretion will be increased. Milk is the main route of Mg loss in the dairy cow (Miles *et al.*, 1995). In healthy animals the control of Mg absorption and renal excretion, as mechanisms of regulating blood plasma levels, appear to be efficient. Magnesium is primarily withdrawn from the bone but apparently not at a sufficient rate to maintain blood Mg levels.

The K:Ca+Mg ratio has, over the years, been widely used as an indicator of the tetany potential of herbage, with values greater than 2.2 being linked to an increased incidence of tetany in grazing animals (Grunes *et al.,* 1989). The occurrence of hypomagnesaemia is associated with a series of other factors, such as climatic. Typically a Mg shortage causes grass tetany, however, grass tetany is not commonly seen on kikuyu (Dugmore, 1998), and relatively unheard of in KwaZulu-Natal (Miles *et al.,* 1995) despite the fact that the K:Ca+Mg ratio was, according to Miles *et al.* (1995), often much higher than the threshold ratio of 2.2 (particularly in midsummer). As indicated by the data presented in Table 4.3 we found mean stem ratios of 3.16 to 5.43 and mean leaf ratios of 1.93 to 2.95, with a whole grass mean (leaf and stem) of 2.73 to 4.19, therefore higher than the threshold of 2.2. Dairy cows at Cedara have responded to magnesium supplementation through improved fertility, i.e. fewer services to conception and shorter inter-calving periods (Dugmore, 1998).

Therefore, although grass tetany is not commonly seen on kikuyu the possibility of subclinical tetany impact on animals grazing kikuyu lush pastures would seem to warrant attention. The possibility for grass tetany on foggage is not really a factor because the conditions are dry, fibre content are high and passage of material from the rumen are not as high as in lush pasture. Mean (leaf and stem) Mg concentrations are above minimum levels for beef-, dairy cattle and sheep, but because K levels greatly reduce the availability of Mg, kikuyu may not reach minimum Mg levels (Table 4.5).

4.2.8 POTASSIUM (K)

In this study mean (leaf and stem) K concentrations range between 11.4 to 20.3 g/kg DM, which are well in excess of animal requirements, as is frequently the case with pastures (Miles *et al.* 1995). A K concentration in the vicinity of 5.0 to 8.0 g/kg is considered adequate for ruminants (NRC 1985; NRC 1988), although the requirement may be somewhat higher than this under conditions of heat stress (McDowell *et al.,* 1983). Miles *et al.* (1995) indicated that K concentrations of up to 50.0 g/kg were recorded in investigations during the October to May. In this study K concentrations of up to 28.6 g/kg occured during the period May to July. The NRC (1988) reported a maximum tolerable K concentration in the diets of dairy cows and sheep of 30.0 g/kg.

Increasing the level of dietary K from 7.0 to 30.0 g/kg linearly decreased energy and weight gains in lambs (NRC 1985). Nitrogen and K appeared to be excreted in a constant ratio in the urine. As this ratio is the same as in muscle, the suggestion is that tissue nitrogen and K are released together from metabolized tissue. This, furthermore, implies that protein and K should be supplemented in a specific ratio. According to Miles *et al.* (1995) a close relationship existed between herbage N and K concentrations, with the correlation co-efficient between levels of these nutrients in all camps and over both spring and summer having the r value of 0.70 (significant at $P \leq 0.01$). This indicates that high N fertilization rates promote luxury uptake of K. Clearly, judicious use of N fertilizer, together with regular soil testing so as to ensure that soil K is maintained at realistic levels, are important management considerations for kikuyu pastures. This recommended minimum K soil test for kikuyu is 140 mg/L, which allows for the uneven re-distribution of K through excretal returns (Miles, 1998). Potassium is readily absorbed as K ion, primarily from the small intestine. The level of K in the body is largely controlled by the effects of aldosterone upon kidney excretion. Factors influencing the rate of K excretion include the ratio of K and sodium in the distal tubule of the kidney, the capacity of the tubular cells to reabsorb sodium, and the amounts of sodium and hydrogen available for exchange with K (Miles, 1998).

Most kikuyu pastures on livestock farms contain adequate, or often, excessive reserves of P and K in their topsoil, with N supply being the growth determining factor from a soil fertility point of view. Although the topsoils of permanent pastures such as kikuyu contain huge reserves of N in the soil organic matter, this N is not available for the utilization by plants. Plant roots take up N in the form of ammonium or nitrate. An important consideration in the context of nutrient management is that while nutrients such as P, K, Ca and Mg are "held" by the soil and therefore their levels in the soil may be "build-up", because of the significant potential for gaseous and leaching losses of plant-available N, it is not possible to store plant-available reserves of the N in the soil (Miles *et al.*, 1995).

3.2.9 SODIUM (Na)

The lack of Na in kikuyu, a natrophobic plant that accumulates its sodium in the roots and not the leaves, require correction in the diet. A Na:K ratio exceeding 15:1 in the salivary fluid is desirable (Dugmore, 1998). Low levels of Na are implicated with bloat, due to the buffering effect of sodium in the rumen. Dairy cattle at Cedara have exhibited signs of a salt deficiency, namely the licking of urine. Consequently the salt content of the mineral supplements for use on kikuyu has been increased by 10% at Cedara (Dugmore, 1998). The recommended Na requirement for grazing ruminants is 0.4 to 1.8 g/kg DM (McDowell *et al.,* 1983). The higher level applies to lactating dairy cows that are particularly susceptible to Na deficiency due to the large amounts of Na secreted in milk (Miles *et al.,* 1995). In this study low mean (leaf and stem) Na levels of 0.20-0.30 g/kg were found while stem Na concentrations of 0.20-0.50 g/kg were not significantly higher than leaf Na concentrations of 0.20 g/kg (Table 4.3). The higher Na stem levels could be due to kikuyu's natrophobic characteristics. The ingestion of a plant that is relatively poor in Na but high in K (like the kikuyu in this study) will cause an increase in the amount of Na excreted via the urine and Na deficiency may result also following excess body fluid loss precipitated by excess sweating, diarrhoea, vomiting, diuresis, and inadequate adrenal response. Sodium concentrations in kikuyu are, therefore, largely inadequate in terms of animal requirements, and it is imperative that animals grazing kikuyu pastures have salt available to them at all times (Table 4.5).

4.2.10 ZINC (Zn)

The major portion of the body Zn is deeply deposited in the bone and therefore not readily retrievable. Free Zn is actively absorbed, largely from the duodenum, but also in the small intestine and the abomasum. Absorption appears to be under feedback control, which means that, more will be absorbed when Zn is deficient and less when Zn is adequate (Miles *et al*. 1995).

The kikuyu in this study had adequate Zn concentrations (114.1 to 164.2 mg/kg) considering that suggested mineral requirements for ruminants are 10 to 40 mg/kg (Table 4.5). Zinc toxicity's levels are above 500 mg/kg for beef and dairy cattle and above 1000 mg/kg for sheep and goats (Table 4.5). Zinc levels did not vary significantly during the study period except for the period 21.06.99 to 05.07.99 ($P = 0.0060$) (Table 4.4). Animals have a limited capacity for storing Zn in a form that can be mobilized rapidly, and therefore need a regular supply.

Zinc interacts with other elements such as Ca, Cu, Fe, Se and Mn. Of particular interest are the interactions of Zn with Cu and S. The major site of antagonism between Zn and Cu is the intestine. A high Zn intake induces the synthesis of the protein complex metallothionein. Because Cu apparently displaces Zn from metallothionein (the complex has a higher binding affinity for Cu relative to Zn), Cu may become trapped in the mucosal cells, thereby reducing its utilization. By supplementing with more Cu both the Zn toxicosis and the retarded uptake of Cu can be alleviated. These mechanisms, however, are apparently not very effective in sheep. Sheep have a limited capacity to synthesize metallothionein, which may account for the marked susceptibility of this species to Cu toxicosis (Miles *et al*., 1995). Excess sulphur in ruminant diets is both detrimental and wasteful (converted to sulphides in the rumen), unless sufficient soluble nitrogen and energy are present. If these are low, excess sulphur may depress Zn digestibility (and very often copper and molybdenum). Cattle, sheep, and most other mammals exhibit considerable tolerance to high intakes of Zn. The influence is rather through aggravating borderline deficiencies of minerals such as iron and copper (Miles *et al.*, 1995).

4.2.11 MANGANESE (Mn)

Dietary Mn is poorly absorbed, only about one percent (Miles *et al.,* 1995), but absorption and excretion apparently depend upon formation of natural chelates, primarily with bile salts. Variable excretion rather than variable absorption regulates the Mn content in the tissues. The possibility of Mn deficiency on veld or pasture is dependent on soil factors, plant species, stage of maturity, yield, pasture management, climate and soil pH. A Mn deficiency frequently occurs where heavy applications of alkaline fertilizers have been applied over a prolonged period of time. In the Bredasdorp area of the Southern Cape, for example, ewe fertility increased dramatically upon injection of Mn chelated compounds (Miles *et al.*, 1995). Manganese is one of the least toxic trace minerals. Toxicity will only result after prolonged excessive or very high levels of Mn. Kikuyu Mn levels of 99.71 to 128.53 mg/kg were found in our study, therefore well in excess of animal requirements of 20 to 40 mg/kg (Table 4.4 and 4.5). Manganese levels did not vary significantly over the study period except for the period 21.06.99 to 05.07.99 ($P = 0.0577$) (Table 4.4).

4.2.12 COPPER (Cu)

A Cu deficiency is known to exist in many parts of the world. A total of 34 tropical and subtropical countries in Asia, Latin America and Africa (including South Africa) have reported deficiencies more than any other mineral, with the exception of phosphorus (McDowell, 1984). In South Africa, the western and south-western to south eastern coastal regions are notorious for Cu deficiency. Copper concentration differences within grass and legume species can be high. A study on the Cu concentrations in 17 grass species grown together on a sandy loam soil ranged from 4.5 to 21.1 mg/kg DM (Underwood & Suttle, 1999). Much smaller but significant differences between species in west Kenya after adjustment for soil effects, kikuyu having the highest and *C. gayana* (Rhodes grass) the lowest concentration (Underwood & Suttle, 1999). However, when available copper concentrations were predicted, the lusher kikuyu lost much of its advantage, due mostly to the influence of sulphur (Underwood & Suttle, 1999). Copper is unevenly distributed in temperate grasses, the leaves containing 35% higher concentrations than stems. There is thus a tendency for values in the whole plant to decline during the growing season (Underwood & Suttle, 1999). Kikuyu foggage in this study had no significant variation between leaf and stem Cu concentrations. The Cu levels in this study ranged from 6.40 to 10.42 mg/kg DM (Table 4.4). The suggested mineral requirements, where level of production is not considered, are above 10 mg/kg for beef and dairy cattle (Table 4.5) and 7-11 mg/kg for sheep (Table 4.5). Therefore marginal to deficient Cu levels existed in kikuyu. Copper levels decreased significantly (P=0.0121) from 08.05.99 to 08.06.99 but thereafter Cu values did not alter significantly (Table 4.4).

Anaemia generally occurs in all species, and to a variable extent, poor growth, bone disorders, depigmentation of hair, fur, wool, or feathers, demyelination of the spinal cord, myocardial fibrosis, diarrhoea and scouring. Other symptoms are more species specific. According to McDowell (1984) Cu deficiency on pasture may result because of low soil Cu content, calcareous soils with high pH, well-leached sandy soils, and soils containing very high levels of molybdenum (Mo). Underwood & Suttle (1999) however reported that forage Cu is not influenced by soil pH, but the position of Mo is quite different. Molybdenum exerts its limiting effects on Cu retention in the animal only in the presence of S (McDowell, 1984). The highest herbage Mo concentrations occur on alkaline soils and on soils high in organic matter; the latter give rise to high sulphur levels in herbage (Underwood & Suttle, 1999). On granitic soils, liming can significantly raise Mo levels, markedly decreasing the all important Cu:Mo ratio of herbage (Underwood & Suttle, 1999). In this study no analysis was done on Mo or S concentrations in kikuyu foggage. Therefore no reference to the effect of Cu:Mo ratio and sulphur on Cu retention in the animal can be made.

4.2.13 SELENIUM (Se)

Mean foggage Se concentrations ranged from 21.3 ng/g to 30.8 ng/g DM in the leaves and from 21.3 ng/g to 31.0 ng/g in the stems (Table 3.38). There was no significant variation between leaf and stem Se concentrations. The only significant within season variation occurred during the period 21.06.99 to 05.07.99 ($P \leq 0.0306$).

Mineral composition of zinc, copper and selenium in Smutsfinger hay are approximately in the same range as kikuyu foggage values, except for Manganese values, that are very high and Sodium values that are very low in Smutsfinger compared to kikuyu.
The major clinical sign of Se deficiency is nutritional muscular dystrophy, popularly known as "white muscle disease". This disease occurs mainly in young calves and lambs (McDowell, 1984). The condition in older animals on pasture is less severe, although it may cause a progressive loss in condition and diarrhoea (McDowell, 1984). The affected animal appears unthrifty, therefore the term "illthrift", and reproductive ability may be impaired. In the mare, for example, Se deficiency has been associated with uterine infections, repeat breeding, early embryonic deaths and abortion (McDowell, 1984).

In cows the high incidence of retained placentas is characteristic of Se deficiencies. Selenium deficient areas are widespread in the world. In subtropical and tropical countries of Latin America, Africa and Asia, at least 20 have reported deficiency symptoms (McDowell, 1984). In South Africa deficiencies have been confirmed in the Cape coastal areas and parts of the Orange Free State and Natal. An excess of Se has been reported for the area surrounding Beaufort West (McDowell, 1984). The Se status of the kikuyu in this study (in KwaZulu-Natal) was deficient in terms of all animal requirements; 21 to 31 ng/g DM (Table 4.4) to the animal requirement of 0.1 to 0.3 mg/kg DM (100 to 300 ng/g DM) (Table 4.5). Selenium levels did not vary significantly during the study period except for the period 21.06.99 to 05.07.99 (P=0.0306) (Table 4.4).

4.3 RUMEN DEGRADABILITY OF DRY MATTER

Dry matter degradability results are presented in Table 3.40 and illustrated in Figure 3.16, 3.17, 3.18, 3.19 and 3.20. The DM degradability decreased marginally significantly between period 1 and 2 ($P < 0.1$). The average DM degradability over time was 65.77% (18-05-99), 54.53% (08-06-99), 54.99% (22-06-99) and 54.99% (06-07-99). The average DM degradability in the different camps over time were 52.45% (camp 1), 63.72% (camp 2), 48.22% (camp 3), 62.56% (camp 4) and 62.36% (camp 5). Therefore the DM degradability of kikuyu foggage decrease significantly from May to June but stay the same from June to July. The DM degradability decreased therefore with time.

The determination of ADF is particularly useful for forages as there is a good statistical correlation between it and digestibility (McDonald *et al.,* 1988). In this study however the ADF concentrations did not vary significantly during the sampling period although the DM degradability decreased marginally significantly between period 1 and 2.

CHAPTER FIVE

CONCLUSION

The primary objective of this thesis was to investigate the response of beef weaners grazing kikuyu foggage to different levels of P supplementation during the winter months and the effect of supplementation on weight gain or loss during the transition from winter to summer. A further objective of the trial was to obtain detailed information on the mineral composition of kikuyu leaves and stems during winter. The greatest evidence to support P supplementation was that serum Pi levels below 1.29 mmol/L or 0.65 mmol/L are said to be indicative of an adequate dietary P (Ternouth, 2001). The slow onset of the effects of a low P diet (Bortolussi *et al.*, 1996), has led to the extended study period (phase 2) on Smutsfinger hay (transition from winter to summer). Furthermore P supplementation may increase weight gains during winter if energy and protein or some other nutrient are not a first limiting factor. Kikuyu foggage composition of the leaves and stems would give an indication of any limiting factors.

Analysis concluded that serum Pi levels of the sample animals remained above 1.29 mmol/L in all the groups throughout the trial (phase 1 and 2), implying that the dietary P in all the treatments were adequate. During phase 1 the kikuyu P concentrations were above minimum animal requirements (> 1.2 g/kg) for growing steers but during phase 2 Smutsfinger hay P concentrations were well below animal minimum requirements. The average trend during phase 1 of the trial was that animals had an average Pi level gain. During phase 2, however, Pi levels dropped more in the sample animals of group 1 (8 g P/day) than in animals of group 5 (0 g P/day)(Table 3.10). This could be explained by the low levels of kikuyu and Smutsfinger N that will increase Pi (Ternouth, 2001). Animals from group 1 (8 g P/day) gained an average of 8 kg LW during the trial but group 5 (0 g P/day) gained an average of only 2 kg LW (Table 3.9). The average weight gain during the trail were the highest for 8 g P/day supplementation. Therefore 8 g P/day supplementation increased weight gains the most during winter if energy and protein are not first limiting.

An important consideration in the current study is that if pastures received P and N and not only N as in this study, lower P supplementation or no supplementation could be required on kikuyu foggage. Under normal farming practices NPK (non trace element fertilizer) are applied, but on kikuyu pastures trace element deficiencies can be corrected by soil trace element fertilization.

In terms of animal requirements kikuyu foggage composition indicated that CP, Na, Cu, Se and stem Ca:P ratio could be limiting factors. The CP concentrations decreased with time to reach levels of < 60 g/kg DM in the dry foggage (56 g/kg to 112 g/kg DM in the leaves and from 52 g/kg to 98 g/kg DM in the stems of kikuyu during phase 1), indicating that supplementation of CP would be required by animals grazing the kikuyu foggage in mid-winter. The CP content of the Smutsfinger hay in phase 2 of this study were between 34.70 g/kg and 45.02 g/kg DM in the leaves and between 12.62 g/kg and 23.15 g/kg DM in the stems. Crude protein levels, however, are largely affected by the amount of nitrogen fertilizer applied and could explain higher CP values in other studies. The decrease in CP over time in this study could be explained by the fibre increase of kikuyu over time. In this study there were exceptionally high NDF values. The other studies were not done as extensively over the winter period as this study and not for leaves and stems separately, therefore more research are required. The high fibre concentration of the kikuyu foggage is not unexpected, considering that the herbage was four to six months old, frosted and weathered during the winter. As expected, the DM degradability of kikuyu foggage decreased over time and decreased significantly from May to June but stayed the same from June to July. As kikuyu matures the DM yield increased, but the leaf:stem ratio decreased, thereby probably reducing the nutritional value of the sward. The green to dry material ratio changed from 3.0 to 0.04 on a DM basis between the first and the last collection during phase 1 of the trial.

Another important practical implication realised from the current research is that if little or no gain is expected from weaners in winter, the Ca and P concentrations in the foggage should be adequate. However, if even slight weight gains were required, supplementation of Ca and P would be necessary when the foggage is dry. We could therefore speculate as to whether trace element fertilization on kikuyu would eliminate the necessity to supplement Ca and P. However we should take into consideration that as plants mature mineral contents declines due to a natural dilution process and translocation of nutrients to the root system. Calcium concentrations were significantly ($P \leq 0.05$) higher in the leaf than in the stem of kikuyu which could have an influence on Ca intake of selected versus bulk grazers. There were no significant increase or decrease in Ca concentration (leaf and stem) from May to July. Significant ($P \leq 0.05$) within season variation in P concentrations occurred, the overriding trend being a maximum during May and decreasing towards July. The prohibitively high K levels of the kikuyu foggage in this study are likely to induce Mg deficiencies in grazing ruminants. We found higher K:Ca+Mg ratio than in other studies. These results however were for only one season and only on one farm and could be different in other regions and with different fertilization programs and soil types. The lack of Na in kikuyu, a natrophobic plant that accumulates its sodium in the roots and not the leaves, require correction in the diet. The kikuyu in this study had adequate Zn and Mn concentrations for growing beef cattle but marginal to deficient Cu levels and deficient Se levels.

The inverse ratio of Ca:P for which kikuyu herbage are notorious, are not the case in our study. Sufficient mineral supplementation to ruminants pastured on kikuyu is of cardinal importance in ensuring animal health and productivity, and that seasonal differences in the mineral supplementation program should occur. Therefore one should have a different mineral and protein supplementation program for kikuyu foggage and herbage. Smutsfinger hay needs to be supplemented in all minerals except Mg, Mn and K. Smutsfinger hay are deficient in CP and have high NDF and ADF values.

From the results of the current study, together with the limited information on kikuyu foggage and foggage leaves and stems, future research is essential over a longer period and in different regions of South Africa. Important factors which should be taken into account in future work, highlighted by the experiment reported, are as follows. Soil samples should be taken before commence of study. Results from kikuyu foggage (leaves and stems) for different regions could be compared. Animal P supplementation on kikuyu pastures are not necessary because pastures could be fertilized with P fertilizers, therefore P supplementation on natural grazing are more relevant. Extreme accuracy should be achieved with collection techniques, if reliable results are to be obtained. Care should also be taken to ensure that experimental groups are sufficiently large to allow for adequate precision in order to draw valid conclusions.

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APPENDIX 1

Serum inorganic P (Pi) levels (mmol/L) of sample animals during phase 1 of trial.

GROUP	ANIMAL NO.	18.05.99 mmol/L	08.06.99 mmol/L	22.06.99 mmol/L	05.07.99 mmol/L	20.07.99 mmol/L	TOTAL (Ave. gain/ Loss) Mmol/L
8 g P/day	99	1.77	2.21	2.21	2.09	2.13	0.36
8 g P/day	593	2.29	2.88	3.11	2.56	3.02	0.73
8 g P/day	150	2.95	2.81	2.65	3.40	3.05	0.10
8 g P/day	90	2.74	2.56	3.31	2.59	3.19	0.45
8 g P/day	52	2.01	2.68	2.60	2.44	2.44	0.43
6 g P/day	122	2.96	2.73	3.23	3.06	2.95	(0.01)
6 g P/day	50	2.18	2.62	2.15	2.47	2.54	0.36
6 g P/day	36	3.54	3.44	3.00	3.20	2.84	(0.70)
6 g P/day	73	2.58	2.55	1.42	2.65	2.54	(0.04)
6 g P/day	85	1.41	2.91	2.68	3.15	3.25	(1.84)
4 g P/day	169	2.06	3.21	2.04	2.88	2.37	0.31
4 g P/day	91	2.14	2.92	2.45	2.32	2.85	0.71
4 g P/day	132	2.24	3.00	2.32	2.83	2.39	0.15
4 g P/day	46	1.99	2.50	2.01	2.23	2.30	0.31
4 g P/day	14	2.66	2.68	2.93	2.63	2.79	0.13
2 g P/day	196	2.19	3.15	3.12	3.16	2.99	0.80
2 g P/day	181	2.51	2.59	2.66	2.85	2.76	0.25
2 g P/day	87	1.83	2.21	2.40	2.38	2.66	0.83
2 g P/day	109	2.05	2.09	2.24	2.52	2.17	0.12
2 g P/day	60	2.22	2.38	2.34	2.56	2.59	0.37
0 g P/day	44	2.28	2.55	2.31	3.17	2.75	0.47
0 g P/day	138	2.01	2.74	2.94	3.83	2.52	0.51
0 g P/day	97	2.32	2.57	3.04	2.43	2.74	0.42
0 g P/day	29	2.25	2.07	3.25	3.45	3.05	0.80
0 g P/day	49	2.86	2.32	2.47	2.43	2.29	(0.57)

APPENDIX 2

Serum inorganic P (Pi) levels (mmol/L) of sample animals during phase 2 of trail.

GROUP	ANIMAL NO.	05-08-99 mmol/L	19-08-99 mmol/L	03-09-99 mmol/L	16-09-99 mmol/L	TOTAL (Ave. gain/ Loss) mmol/L
8 g P/day	99	3.30	2.04	1.96	2.22	(1.08)
8 g P/day	593	2.66	2.45	2.42	2.56	(0.04)
8 g P/day	150	3.53	2.35	2.76	2.60	(0.93)
8 g P/day	90	2.89	4.28	2.54	2.47	(0.42)
8 g P/day	52	2.54	2.21	2.41	2.31	(0.23)
6 g P/day	122	2.69	2.42	2.33	2.45	(0.24)
6 g P/day	50	2.35	2.13	2.26	2.10	(0.25)
6 g P/day	36	3.27	3.02	3.05	3.36	0.09
6 g P/day	73	2.40	2.52	2.70	2.33	(0.07)
6 g P/day	85	3.21	2.64	2.21	2.64	(0.57)
4 g P/day	169	2.62	2.64	2.66	2.33	(0.29)
4 g P/day	91	2.65	2.21	2.49	2.41	(0.24)
4 g P/day	132	2.42	2.46	2.49	2.60	0.18
4 g P/day	46	2.42	2.51	2.40	1.96	(0.46)
4 g P/day	14	2.20	2.36	2.69	2.44	0.24
2 g P/day	196	2.96	2.57	2.43	2.73	(0.23)
2 g P/day	181	2.89	2.77	2.60	2.37	(0.49)
2 g P/day	87	5.50	1.82	2.31	2.40	(3.10)
2 g P/day	109	2.42	2.48	1.90	-	(0.58)
2 g P/day	60	2.27	1.85	2.07	2.16	(0.11)
0 g P/day	44	2.51	1.86	2.20	2.17	(0.34)
0 g P/day	138	2.73	2.37	2.55	2.45	(0.28)
0 g P/day	97	1.71	2.28	2.45	2.23	0.52
0 g P/day	29	2.85	5.71	3.08	2.42	(0.43)
0 g P/day	49	2.20	1.82	1.34	2.23	0.03